Teachers and Teaching

Strategies, Innovations and Problem Solving

Gerald F. Ollington
Editor

NOVA

TEACHERS AND TEACHING STRATEGIES:
INNOVATIONS AND PROBLEM SOLVING

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GERALD F. OLLINGTON
EDITOR

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CONTENTS

Preface		**vii**
Chapter 1	Applications of Intellectual Development Theory to Science and Engineering Education *Ella L. Ingram and Craig E. Nelson*	**1**
Chapter 2	Teachers' Judgment from a European Psychosocial Perspective *M.C. Matteucci, F. Carugati, P. Selleri, E. Mazzoni and C. Tomasetto*	**31**
Chapter 3	A Problem-based Approach to Training Elementary Teachers to Plan Science Lessons *Lynn D. Newton and Douglas P. Newton*	**55**
Chapter 4	An Emphasis on Inquiry and Inscription Notebooks: Professional Development for Middle School and High School Biology Teachers *Claudia T. Melear and Eddie Lunsford*	**75**
Chapter 5	Facilitating Science Teachers' Understanding of the Nature of Science *Mansoor Niaz*	**89**
Chapter 6	The Impact of in-Service Education and Training on Classroom Interaction in Primary and Secondary Schools in Kenya: A Case Study of the School-based Teacher Development and Strengthening of Mathematics and Sciences in Secondary Education *Daniel N. Sifuna and Nobuhide Sawamura*	**101**
Chapter 7	Classroom Discourse: Contrastive and Consensus Conversations *Noel Enyedy, Sarah Wischnia and Megan Franke*	**133**
Chapter 8	Developing Critical Thinking Is Like a Journey *Peter J. Taylor*	**155**
Chapter 9	Inquiry: Time Well Invested *Eddie Lunsford and Claudia T. Melear*	**171**

Chapter 10 Intensive Second Language Instruction for International Teaching Assistants: How Much and What Kind Is Effective? **187**
Dale T. Griffee, Greta Gorsuch, David Britton and Caleb Clardy

Chapter 11 How to Teach Dynamic Thinking with Concept Maps **207**
Natalia Derbentseva, Frank Safayeni and Alberto J. Cañas

Chapter 12 Competency-based Assessment in a Medical School: A Natural Transition to Graduate Medical Education **229**
John E. Tetzlaff, Elaine F. Dannefer and Andrew J. Fishleder

Chapter 13 Beliefs of Classroom Environment and Student Empowerment: A Comparative Analysis of Pre-service and Entry Level Teachers **245**
Joe D. Nichols, Phyllis Agness and Dorace Smith

Chapter 14 Interactionistic Perspective on Student Teacher Development During Problem-based Teaching Practice **257**
Raimo Kaasila and Anneli Lauriala

Chapter 15 To Identify What I Do Not Know and What I Already Know: A Self Journey to the Realm of Metacognition **283**
Hava Greensfeld

Chapter 16 Traces and Indicators: Fundamentals for Regulating Learning Activities **323**
Jean-Charles Marty, Thibault Carron and Jean-Mathias Heraud

Chapter 17 Professional Learning and Technology to Support School Reform **351**
Ron Owston

Chapter 18 Collaborative Knowledge Construction During Structured Tasks in an Online Course at Higher Education Context **359**
Maarit Arvaja and Raija Hämäläinen

Chapter 19 Challenges of Multidisciplinary and Innovative Learning **377**
Jouni Hautala, Mauri Kantola and Juha Kettunen

Index **391**

PREFACE

If the future of any society can be pinpointed, it is with the teachers who help form the citizens of tomorrow. Sometimes their impact is equal to the parents and sometimes surpasses it by not a small measure. This new book tackles teaching Strategies, Innovations and Problem Solving as the focal points in teaching.

Chapter 1 - Students' approaches to the nature of knowledge (known as intellectual development, epistemological development, or cognitive development) have significant impacts on their approach to learning and on their ability to learn throughout and beyond college. College students generally matriculate, and often graduate, with a dualistic (i.e., right or wrong) view of knowledge that is typically incompatible with the paradigms of their chosen field of study. For biology majors faced with addressing evolution in multiple courses and ultimately as the central framework of their studies, their intellectual development may have a profound influence on their understanding of evolution. In this chapter, the authors report the results of their investigations on the relationships among evolutionary content knowledge, acceptance of evolution, course achievement, and intellectual development (using Perry's framework) within upper-level evolution courses. They provide examples of the application of Perry's scheme to controversial content to illustrate different intellectual approaches used by students to cognitively manage this content. Based on prior research and their own experience, they expected to find a positive relationship between intellectual development and achievement or acceptance of evolution in their course, meaning that students with relatively unsophisticated views of knowledge would earn on average lower grades than students with more complex views. They observed levels of intellectual development that were consistent with our expectations for college students, reflecting Perry's dualism or multiplicity stages. Contrary to their expectations, the authors found no association between intellectual development (or its change) and either evolutionary content knowledge or acceptance of evolution, and intellectual development level was not correlated to final grade. These results together suggest that learning evolution in the course was not limited by the perspective a student had on the nature of knowledge. They attribute this lack of association between intellectual development and achievement to the pedagogical philosophy and established practices of the course, to expose students to Perry's model of intellectual development and to encourage students to practice cognition at the contextual relativism stage during various in-class exercises. These practices are described in modest detail. The findings are used to discuss and illustrate applications of intellectual development theory to support students in their current level of intellectual development. The authors also

discuss mechanisms to facilitate the intellectual development of students in science and engineering courses.

Chapter 2 - The role that school evaluation, diplomas, degrees, educational and career counseling, and the selection and promotion of individuals play in our societies is of such importance that it would be unwise to ignore the mechanisms that form the basis of different types of judgment. The starting point of judgment production is the production of inferences based on information, which implies several steps. The European approach emphasizes that school judgment should be conceived as a psychology of everyday life, where dynamics are rather similar both at school and in everyday activities. The main approaches that could be integrated, in order to obtain a better understanding of the construction process of teachers' school judgment are three: social representations, the socio-cognitive approach to judgment production, and the theoretical grid of levels of analysis. According to the latter approach, context could be analyzed at the interindividual, situational, cultural and ideological level. The most important contribution of this analytical distinction refers to the possibility of articulating these levels as sources of possible influence of a variable at a given level on other variables at another level. The approach formulated by Doise provides the framework for presenting a research review on different levels of contextual effects on teachers' judgments. In particular, this chapter will explore research contributions which show that: 1) culturally shared social representations of intelligence in terms of innate gift might influence teachers' judgments of their pupils; 2) teachers' evaluations are affected by social norms and causal explanations of pupils' failure vs. success; 3) pupils' academic performance normally takes place in complex social contexts (typically classrooms) whose features affect individuals' cognitive functioning (e.g., presence of others, visibility, social comparison, self-categorization processes and may either improve or disrupt such performance, depending on students' past history of success vs. failure in similar evaluative tasks. Finally, the "key theme" of evaluation in virtual contexts (ICT) will be investigated by exploring the role of technical artifacts as a special kind of contextual determinants of learners' web actions. The "state of the art" of evaluation and new technologies will then be discussed, with a particular focus on which activities can be tracked and evaluated, in relation to the current development of web–tools. While exploring the several contextual factors that are likely to influence education and the production of teachers' judgment, this chapter will deal with some implications, which refer to practical aspects of teachers' activity.

Chapter 3 - Pre-service teacher training can be short and hurried. It is often difficult to find time to develop the range of knowledge and skills the authors believe students should have in order to teach effectively. Attempts to cram students with what they need are understandable but risk producing superficial, unconnected learning. In the end, such learning is often worthless when it comes to putting it into practice. Recognising this problem in one of the authors courses, they came to accept that a quart will not go into a pint pot. Instead of trying the impossible, they set out to equip their student-teachers with skills which would enable them to teach effectively even when the particular science topic had not been covered in detail on the course. The skill they focused on was lesson planning in science, developed through a problem-based approach. This study describes the background, the problems and the outcomes, some of which were not quite as anticipated. It concludes with practical advice for those seeking a solution to the quart into a pint pot problem when training teachers.

Chapter 4 - The problem of how to make science instruction in schools more authentic has been the subject of much debate. National reform recommendations, as well as a number

of research studies, stress the need for science classrooms that more closely match the domain of the professional scientist. This chapter, a report of a qualitative research study, examines the experiences and outcomes of a group of practicing science teachers, from central Appalachian schools, who were engaged in a professional development workshop. Two organizing themes, guided inquiry and representation of scientific thought and knowledge by way of inscription, characterized the program. Participants were engaged in a number of guided inquiry activities. They were asked to link these activities to their home states' curriculum standards and to consider how they could incorporate such activities in their own classrooms. Further, participants made inscriptional-type entries in their laboratory notebooks throughout the duration of the workshop. Participants indicated that the workshop provided them with helpful experiences toward implementation of standards-based instruction they could use in their own classrooms. A survey indicated that students had, indeed, incorporated many of the workshop's activities into their teaching. Further, the authors found that students tended to transform basic and concrete inscriptional representations of their work (such as narrative statements, diagrams, etc.) into more complex ones (such as tables or graphs) when they dealt with data from long-term inquiry activities, as opposed to short-term activities or simple observations. They hope that the activities and outcomes described in this chapter will be useful to both science teachers and science education teachers at all levels of education.

Chapter 5 - Recent research in science education has recognized the importance of understanding science within a framework that emphasizes the dynamics of scientific research that involves controversies, conflicts and rivalries among scientists. This framework has facilitated a fair degree of consensus in the research community with respect to the following essential aspects of nature of science: scientific theories are tentative, observations are theory-ladden, objectivity in science originates from a social process of competitive validation through peer review, science is not characterized by its objectivity but rather its progressive character (explanatory power), there is no universal step-by-step scientific method. This study reviews research based on classroom strategies that can facilitate high school and university chemistry teachers' understanding of nature of science. All teachers participated in two Master's level degree courses based on 34 readings related to history, philosophy and epistemology of science (with special reference to controversial episodes) and required 118 hours of course work (formal presentations, question-answer sessions, written exams and critical essays). Based on the results obtained this study facilitated the following progressive transitions in teachers' understanding of nature of science: a) Problematic nature of the scientific method, objectivity and the empirical nature of science; b) Kuhn's 'normal science' manifests itself in the science curriculum through the scientific method and wields considerable influence; c) Progress in science does not appeal to objectivity in an absolute sense, as creativity, presuppositions and speculations also play a crucial role; d) In order to facilitate an understanding of nature of science we need to change not only the curricula and textbooks but also emphasize the epistemological formation of teachers.

Chapter 6 - The aim and purpose of the Classroom Interaction Study was to assess or measure the success or impact of the School-based Teacher Development (SbTD) and Strengthening of Mathematics and Sciences in Secondary Education (SMASSE) In-service Education and Training (IN-SET) programmes against envisaged outcomes (success indicators) in the projects with regard teacher pupil/student interactions within the classroom setting. It also gave teachers the opportunity to give perceptions of what they considered to have what they considered to have been the achievements of the two programmes. The

classroom observation approach aimed at describing what teachers and pupils' did in the classroom or the teacher-pupil interaction. The observations focused on three main areas, namely; the frequency with which instructional materials were used, how the teacher utilised class time and the amount and form of interaction observed between the teacher and pupils/students.

From the observations, there seem to be a number of features of classroom behaviour in the teaching of sciences and mathematics. Teachers generally spent much of their class time presenting factual information, followed by asking pupils individually or in chorus to recall the factual information in a question and answer exchange. Students were rarely asked to explain a process or the interrelation between two or more events, and the teacher rarely probed to see what elements of the material or process the pupils did not understand. This interrogatory style was an evaluative exercise, not one that sought to increase pupils understanding.

Chapter 7 - Researchers claim that classroom conversations are necessary for supporting the development of understanding and creating a sense of participating in the discipline, yet we know there is more to supporting productive talk than simply having a conversation with students. Different types of conversations potentially contribute differently to the development of student understanding and identity. The authors have been investigating the strengths and limitations of two such conversations: contrastive and consensus conversations. Within a contrastive conversation students have the opportunity to make their own thinking explicit and then compare and contrast their strategies to the thinking of others. Consensus conversations ask students and the teacher to begin to put ideas on the table for consideration by the whole group—much like a contrastive conversation—but then go on to leverage the classroom community as a group to build a temporary, unified agreement about what makes the most sense for the class to adopt and use. Here, they detail both types of conversation, their affordances and challenges, and investigate the conditions under which a teacher may want to orchestrate a contrastive or a consensus conversation.

Chapter 8 - This chapter presents five passages in a pedagogical journey that has led from teaching undergraduate science-in-society courses to running a graduate program in critical thinking and reflective practice for teachers and other mid-career professionals. These passages expose conceptual and practical struggles in learning to decenter pedagogy and to provide space and support for students' journeys while they develop as critical thinkers. The key challenge that the author highlights is to help people make knowledge and practice from insights and experience that they are not prepared, at first, to acknowledge. In a self-exemplifying style, each passage raises some questions for further inquiry or discussion. The aim is to stimulate readers to grapple with issues they were not aware they faced and to generate questions beyond those that the author presents.

Chapter 9 - Many recent reform recommendations on science teaching have emphasized the need for incorporation of scientific inquiry as a routine part of science instruction. Inquiry is a difficult skill to master for both the science teacher and the science student. Many science teachers, new to teaching by inquiry, are disappointed in their students' abilities to design and carry out sound experiments. Often, they abandon teaching by inquiry for that reason. This chapter is a report of a qualitative study of the skills displayed by a group of graduate students [n=10] in Science Education, all of whom were preservice teachers, as they engaged in long-term inquiry activities with living organisms. The participants' initial experimental designs were dismal, lacking in the essential features associated with quality scientific inquiry. With

the passage of time and with mentoring by course instructors, the students became adept at designing and carrying out sound scientific inquiries. The authors argue that development of inquiry skills, in particular the ability to design and carry out a sound scientific experiment, is a skill that must be developed over time. If time is invested in such an endeavor, the results are often very rewarding. They hope that the information presented in this chapter will help science teachers and science educators realize that time invested in well thought out inquiry activities will help their students to master critical science skills.

Chapter 10 - Second language instructional programs in academic settings take many forms in terms of length and intensity. Whether a program is intensive (four or more hours per day, five days per week) or conventional (one hour three or four days per week) may be determined by programmatic needs. Instructional formats may also be shaped by assumptions about the nature of the content being learned. A second language, for example, may be seen as a body of content to be mastered, rather than something requiring extensive opportunities for input, practice, and use. Learners may be seen as needing only to learn *about* language with the result that contact hours set aside for instruction are seen as reducible. Time on task needed for input, practice, and use of these features of language may be given short shrift. Empirical investigations are needed to learn how much instruction in terms of length and intensity is effective in developing second language learning. The current study explores this issue in the context of a three-week intensive English as a second language program for newly arrived international teaching assistants (ITAs) at a research university in the southwest U.S. The current six-hour-per-day, five-days-per-week late-summer program was intended to improve ITAs' pronunciation (word stress) and intelligibility (discourse competence), and classroom communication skills (compensation of communicative code using visuals, repetitions, etc.). Using a sample of $N = 18$ ITAs, a statistical model was developed to test whether a third week of intensive instruction in word stress, discourse competence, compensation skills, and an overall rating significantly and meaningfully improved ITAs' skills in those areas in a teaching simulation task. Results suggested that a third week of intensive instruction contributed to significantly and meaningfully higher scores in the four areas of ITAs' classroom communication.

Second language instructional programs in academic settings take many forms in terms of length and intensity (Kaufman and Brownworth, 2006). Whether a program is intensive (five or more hours of language instruction per day) or more conventional (one hour five times a week or ninety minutes twice a week) may be determined by programmatic needs (availability of classroom space or funding, or length of time allowed by a given academic semester or term). Instructional formats may also be shaped by commonly held, perhaps undiscussed, assumptions about the nature of the content (language) being learned, and the place of that content in perception of student needs. A second language, for example, may be seen as a body of content to be mastered, rather than something requiring extensive opportunities for input, practice, and use. Learners with specialized needs, such as upper intermediate and advanced learners who must improve their pronunciation (word stress) and intelligibility (discourse competence) for professional purposes, may be seen as needing only to learn *about* pronunciation and intelligibility for future use, with the result that contact hours set aside for instruction are seen as reducible. Time on task needed for input, practice, and use of these features of language may be given short shrift. Empirical investigations are needed on how much instruction (with attendant practice and use opportunities) in terms of

length and intensity is effective in developing second language learning as measured by current assessments of language use.

The current study explores this issue in the context of a three week intensive English as a second language program for newly arrived international teaching assistants (ITAs) at a U.S. university. ITAs are Chinese, Korean, Indian, etc. graduate students who will be supported as instructors in undergraduate physics, math, chemistry, etc. classes in their subject area, in their second language (English). The current six-hours-per-day, five-days-per-week late-summer program portrayed in this report is intended to improve ITAs' pronunciation (word stress) and intelligibility (discourse competence), and classroom communication skills (compensation of communicative code using visuals, repetitions, etc.) prior to the start of the fall academic semester. For programmatic reasons, a shorter, one- or two-week intensive program was suggested, which raised concern as to whether ITAs would improve as much as needed in the shorter suggested time frame. Fortunately, assessments of ITAs' performance were done throughout the workshop, which allowed investigation of their improvement at various points. The purpose of this report is to demonstrate the use of a statistical model which estimated 18 ITAs' improvement on a similar measure at two different points in the workshop (the 8^{th} and the 16^{th} days), and to discuss the results in light of the duration, intensity, and type of instruction and learner practice known to have taken place prior to each measurement. An additional purpose was to help those who run such intensive programs make reasoned efforts to maintain or increase the number of contact hours needed for second language improvement.

Applied linguistics is in many respects an interdisciplinary field, drawing from research traditions in psychology and education (in additional to theoretical linguistics). Thus the following literature review explores relevant research from these fields, particularly to forge connections between current (if unexamined) models of intensive ITA preparation programs and key related psychological and educational concepts such as duration (length) and intensity (frequency of instruction or practice). The authors see two other concepts, time on task and practice, as related to duration and intensity, in that time on task and practice refer to what happens in classrooms for particular amounts of time within a program (duration) and in spaced or massed conditions on a given day of classes (intensity).

Chapter 11 - Concept Map (CMap) is a graphical knowledge representation system, which has received growing popularity as a teaching and evaluation tool. In CMaps knowledge is represented by linking concepts to one another and specifying the nature of their relationship on the link. A pair of concepts connected with a linking phrase is called proposition.

In general, knowledge is organized by relating different concepts to one another. The authors argue that there are two types of conceptual relationships: static and dynamic. The static relationship organizes knowledge by grouping similar items under the same concept and noting the belongingness of the concept to a more abstract construct as a super-ordinate or identifying its own sub-categories. For example, category "chair" is a part of a super-ordinate category "furniture" and may have sub-categories of "lawn chair" and "dining room chair." In addition, static meaningful relationships could be based on intersecting two constructs from different domains. For example, "design" and "chair" may be intersected by noting that "chair" requires "design." Organization of knowledge based on static relationships often results in hierarchical arrangement of concepts, which is very typical of most Concept Maps.

On the other hand, the dynamic relationships reflect how change in one concept affects another concept. The emphasis is on showing the functional interdependency between concepts. For example, “increase in the amount of gasoline consumption” results in “increase in the level of carbon dioxide in the environment.” The dynamic relationships have played an important role in the advancement of physical sciences. For example, Newton invented calculus as a representation system for dynamic relationships. Similarly, the authors argue that Concept Maps need the capability for representing dynamic relationships.

However, CMap, in its traditional form, primarily encourages static thinking. In this chapter the authors, on one hand, bring attention to this tendency and, on the other hand, discuss the strategies teachers can use to encourage dynamic thinking with Concept Maps. These strategies include:

- imposing a cyclic map structure instead of hierarchical arrangement of concepts,
- quantifying the root concept of the map instead of a static category, and
- reformulating the focus question of the map from “what” to “how.”

The authors discuss theoretical issues and empirical evidence in support of the proposed strategies.

Chapter 12 - Performance evaluation in traditional graduate medical education has been based on observation of clinical care and classroom teaching. With the movement to create greater accountability for graduate medical education (GME), there is pressure to measure outcomes by moving toward assessment of competency. With the advent of the Accreditation Council for Graduate Medical Education’s Outcome Project, GME programs across the country have shifted to a competency-based model for assessing resident performance. This system has enhanced the quality of feedback to residents and provided better means for program directors to identify areas of resident performance deficiency. At the same time, however, the majority of medical schools have maintained a traditional approach to assessment with the passing of comprehensive examinations and “honors’ on clinical rotations as measures of student achievement. The added value of new assessment approaches in graduate medical education suggests that medical educators should consider broadening the use of competency-based assessment in undergraduate medical education. This paper describes the design and implementation of a portfolio-based competency assessment system at the Cleveland Clinic Lerner College of Medicine. This model of assessment provides a natural transition to competency-based assessment during residency training, and a framework for tracking and enhancing student performance across multiple core professional competencies.

During the last decade, the Accreditation Council for Graduate Medical Education (ACGME), under the leadership of David Leach, M.D., initiated a philosophical shift in approach to the assessment of resident performance. A comprehensive review of GME was undertaken with the intent to define specific competencies that could be applied to all residents. The result was published in February of 1999 as the ACGME Outcome Project (www.acgme.org/Outcome). Full text definitions for these competencies were published in September 1999 with expectation of a 10 year, three-phase implementation timeline. Mastery of 6 Core Competencies (Table 1) was established as a standard for all residents in training

and all residency programs reviewed after July 1, 2003 were obligated to demonstrate curricular objectives and new assessment processes focused on these competencies.

This chapter describes the design and implementation of a portfolio-based competency assessment system at the Cleveland Clinic Lerner College of Medicine and addresses the portfolio approach and implementation challenges more generally. The authors conclude that this model of assessment provides a natural transition from medical school into competency-based assessment during residency training, and a framework for tracking and enhancing student performance across multiple core professional competencies.

Chapter 13 - This project explored the possibility of establishing a classroom model of motivation. One-hundred-forty-four current elementary and secondary teachers with one or two years of teaching experience and 116 university pre-service teacher education students completed a 40-item Likert-type questionnaire that focused on four classroom dimensions of affirmation, rejection, student empowerment, and teacher control. The results of this project suggested that early career teachers and university student pre-service teachers varied on their reported desire for teacher empowerment versus student empowerment in the classroom, and on their desire to provide a positive classroom environment as opposed to one that may encourage a classroom atmosphere of rejection. Implications for future research and the need for creating affirming, empowering, motivational classroom environments are discussed.

Chapter 14 - The paper deals with the implementation of problem-centred teaching by four 2nd year pre-service teachers doing their Subject Didactics Practicum (SD 2) in one primary school classroom (grade 3) at the University of Lapland, in northern Finland. The authors focus here mainly on student teachers' experiences of mathematics teaching. The aim of problem centred mathematics teaching is to assist pupils to acquire new mathematical content through problem-solving, and help them understand how the new knowledge is connected to their former mathematical content knowledge.

In this article the authors focus on how participating student teachers' former beliefs, experiences and goals influence, and are in dialogue with the situational demands of the classroom which involve a new approach to teaching and learning mathematics: problem-based approach. The data gathering is based on the portfolios and interviews of four student teachers doing their practice teaching in the same classroom. The interview and field notes of cooperative class teachers and supervising lecturers are used as complementary data to check the credibility of the results.

The results are presented in the form of student teachers' developmental profiles. Due to different former beliefs and experiences, the students' initial orientation to a new situation and their strategic adjustments to it varied a lot. The article sets out different concrete examples of how the students put problem solving into practice. On the whole, the participants' view of teaching and learning mathematics became more many-sided and versatile. In the case of three students, the changes in their views of mathematics teaching and learning were clearly reflected in their teaching practices, while in the case of one student the changes in action were meagre, and he did not seem to have internalised the new approach**.** The results suggest the importance of paying attention to students' mathematical biography when aiming at changes in their pedagogical views and practices.

Chapter 15 - One of the most important descriptive models for adult learning processes, known as Experiential Learning, is that of Kolb (Kolb, 1981, 1984). The learning process according to Kolb occurs within a simple cycle, starting with a new "concrete experience" followed by reflective thinking on the part of the active learner. This study presents a model

for the reflective learner which does not fall into line with Kolb's proposed model. This alternative model has been built following action research using the self-study approach tracking the experiential learning process of the lecturer (referred to as facilitator in the study) of an experimental course for fostering thinking at a college of education.

Analysis of the significant events occurring at each stage of the action research and of the factors that set the learning process in motion showed it to be a developmental process composed of four interdependent components: Knowledge of content (metacognition), pedagogical knowledge, knowledge of methodological research and personal metacognitive thinking skills. This study, which relates to essential aspects of the concept of metacognition, and includes recommendations for constructivist instruction focused on the development of the learners' metacognitive thinking, indicates the power of action research as a professional development tool for teacher educators. The research findings presenting the developmental process of a facilitator in an academic institution give new meaning to the concept of metacognitive thinking within an educational context. Through these research findings the authors receive insights into the complexity of the learning process which demands activation of metacognitive thinking. Contrary to Kolb’s model, this occurs not only after “concrete experience”. The application of the model presented in this chapter while implementing metacognitive thinking at different stages of the learning process will improve the thinking performances of the students in higher education. The chapter analyzes the developmental processes experienced by a lecturer in the sciences, and will be of interest to teachers in general, as well as science teachers who wish to integrate the instruction of higher order thinking skills into science topics.

Chapter 16 - The work reported here takes place in the educational domain. Learning with Computer Based Learning Environments changes habits, especially for teachers. In this paper, the authors want to demonstrate through examples how traces and indicators are fundamental for regulating activities. Providing teachers with feedback (via observation) on the on going activity is thus central to the awareness of what is going on in the classroom, in order to react in an appropriate way and to adapt to a given pedagogical scenario.

In the first part, the paper focuses on the description of different ways and means to get information about the learning activities. It is based on traces left by users in their collaborative activities. The information existing in these traces is rich but the quantity of traces is huge and very often incomplete. Furthermore, the information is not always at the right level of abstraction. That is why the authors explain the observation process, the benefits due to a multi-source approach and the need for visualisation linked to the traces.

In the second part, the authors deal with the classification of the different kinds of possible actions to regulate the activity. They also introduce indicators, deduced from what has been observed, reflecting particular contexts. The combination of contexts and reactions allow us to define specific regulation rules of the pedagogical activity.

In the third part, concepts are illustrated into a game based learning environment focused on a graphical representation of a course: a pedagogical dungeon equipped with the capacity for collaboration in certain activities. This environment currently used in the authors’ University offers both observation and regulation process facilities. Finally, the feedback about these experiments is discussed at the end of the paper.

Chapter 17 - Research suggests that teacher expertise is one of the most influential factors affecting student achievement, and that continuous, on-the-job professional learning is the most effective strategy for teachers to develop this expertise. School reform efforts that ignore

these research findings are unlikely to succeed. In this chapter, the author discusses the importance of teacher learning in sustaining innovative classroom use of technology and provide a framework for supporting ongoing teacher professional learning. The framework, called PD*LEARN, is built upon established principles of effective teacher professional learning.

Chapter 18 - This chapter presents a study that explored how two different tasks developed for supporting student groups' collaborative activities in a web-based learning environment enhanced students' collaboration during web-based discussion. Furthermore, the aim was to study what challenges were faced during online interaction from the perspective of collaborative learning. The subjects of the study consisted of two small groups of teacher education students studying the pedagogy of pre-school and primary education in a web-based learning environment. The students' web-based discussion was analyzed in terms of communicative functions and contextual resources. The results of the study indicate that the educational value of the students' discussions was not very high. Neither of the groups used such functions as argumentation and counter argumentation in their discussion. The knowledge was more cumulatively shared and constructed than critically evaluated. Whereas Group 1 relied more on theoretical and practical background material, Group 2 relied more on their own experiences as resources in their knowledge sharing and construction. There were both changes in the participatory roles as well as in content-based roles between the tasks. Participation in Task 2 was more equally distributed in both groups compared to Task 1. It also seemed that in Task 2 both of the groups were engaged in content-based activity, whereas in Task 1 the discussion of Group 2 did not focus on sharing and constructing knowledge but on organizing and commenting on the process of working on the document to be written. Thus, the discussion forum was not fully successful as a context for problem-solving and knowledge construction as was intended. The study demonstrates that the teacher cannot be easily replaced by even the most advanced technology or pedagogical pre-structuring. Despite the pre-structuring of the tasks the students would have needed the teacher's support in engaging them to participate more equally, in deepening their discussion and in guiding them to use the resources as was intended – that is, in supporting collaborative knowledge construction.

Chapter 19 - The purpose of this chapter is to explore how higher education institutions can promote the synergic and multidisciplinary learning to increase their innovativeness and the external impact on the region. The organization of the Turku University of Applied Sciences was developed to support the multidisciplinary and innovative activities. The organizational change is described in the chapter using the Balanced Scorecard approach, which was used to communicate the strategic objectives and support the implementation of the new multidisciplinary organization. The Balanced Scorecard approach is not only a tool for the communication and implementation of the strategic plans, but it can also be used to consistently define the objectives of the organizational change. The empirical results of the study show that the multidisciplinary faculties can be successfully formed to create innovative research and development.

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Chapter 1

APPLICATIONS OF INTELLECTUAL DEVELOPMENT THEORY TO SCIENCE AND ENGINEERING EDUCATION

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ABSTRACT

Students' approaches to the nature of knowledge (known as intellectual development, epistemological development, or cognitive development) have significant impacts on their approach to learning and on their ability to learn throughout and beyond college. College students generally matriculate, and often graduate, with a dualistic (i.e., right or wrong) view of knowledge that is typically incompatible with the paradigms of their chosen field of study. For biology majors faced with addressing evolution in multiple courses and ultimately as the central framework of their studies, their intellectual development may have a profound influence on their understanding of evolution. In this chapter, we report the results of our investigations on the relationships among evolutionary content knowledge, acceptance of evolution, course achievement, and intellectual development (using Perry's framework) within upper-level evolution courses. We provide examples of the application of Perry's scheme to controversial content to illustrate different intellectual approaches used by students to cognitively manage this content. Based on prior research and our own experience, we expected to find a positive relationship between intellectual development and achievement or acceptance of evolution in our course, meaning that students with relatively unsophisticated views of knowledge would earn on average lower grades than students with more complex views. We observed levels of intellectual development that were consistent with our

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expectations for college students, reflecting Perry's dualism or multiplicity stages. Contrary to our expectations, we found no association between intellectual development (or its change) and either evolutionary content knowledge or acceptance of evolution, and intellectual development level was not correlated to final grade. These results together suggest that learning evolution in our course was not limited by the perspective a student had on the nature of knowledge. We attribute this lack of association between intellectual development and achievement to the pedagogical philosophy and established practices of the course, to expose students to Perry's model of intellectual development and to encourage students to practice cognition at the contextual relativism stage during various in-class exercises. These practices are described in modest detail. Our findings are used to discuss and illustrate applications of intellectual development theory to support students in their current level of intellectual development. We also discuss mechanisms to facilitate the intellectual development of students in science and engineering courses.

INTRODUCTION

College is a difficult time in the intellectual development of an individual. College students are confronted with challenges on all fronts, and cognitive, personality, social, and epistemological development are occurring rapidly (King and Kitchner, 1994; Baxter Magolda, 2001; Wise, Lee, Litzinger, Marra, and Palmer, 2004). Students' approaches to these challenges have especially powerful effects on their abilities to master complex critical thinking, writing, and problem solving tasks (Perry, 1970; King and Kitchner, 1994; Baxter Magolda, 2001). College students generally matriculate, and often graduate, with views of knowledge that are either "dualistic" (right or wrong) or "multiplistic" (any answer is just as good as any other) (Mentkowski, 1988; King and Kitchner, 1994) and can be deeply incompatible with the paradigms of their chosen field of study. This assertion is supported by studies across disciplines and types of institutions (e.g. Belenky, Clinchy, Goldberger, and Tarule, 1986; Baxter Magolda, 2001). For example, most engineering students enter the engineering curriculum with a multiplistic view of knowledge (Palmer, Marra, Wise, and Litzinger, 2000; Marra, Palmer, and Litzinger, 2000; Wise et al., 2004), an approach to knowledge that practicing engineers know to be insufficient to accomplish appropriate work – excellent bridge design is decidedly not based on the unsupported opinion of the designer. Given this inherent mismatch between the novice and the expert, not just in knowledge but in approaches to knowledge, a major task of the college experience is developing the approach to knowledge reflective of the profession. Such fundamental changes in cognition are frightening and hard, such that students can self-select out of certain fields depending on their initial dispositions to knowledge (Tobias, 1993).

Perry's (1970) model of intellectual development describes the patterns of thought expected for matriculated students. Several theorists have followed up on Perry's original insights (partial review in Hofer and Pintrich, 1997), usually by modifying the terminology suggested for the qualitatively different approaches used by students, or applying the framework to different groups of students. Here we use a slightly different version of the terms Perry suggested (substituting "contextual relativism" for the sometimes misleading "relativism" for the third major approach). According to Perry's scheme, and supported by much evidence (e.g. Belenky et al., 1986; King and Kitchner, 1994; Baxter Magolda, 2001; Hart, Rickards, and Mentkowski, 1995; see the partial review in Hofer and Pintrich, 1997 and

Rappaport's (2006) accessible descriptions), many students enter college with dualistic thinking patterns, accepting knowledge as either correct or incorrect. Students exhibiting this thinking pattern view their role as passive receivers of knowledge from an all-knowing authority. To the dualistic student, knowledge consists of facts that are meant to be memorized. As development proceeds, students begin to accept a multiplistic view of knowledge, where several alternate answers to a problem can coexist and choosing among them is a matter of arbitrary personal preference. Any given authority's view is seen as only one of many possible opinions, and all opinions are seen as equally valid. Personal experience, personally interpreted, is seen as having the preeminent role in the individual coming to know how the world works, regardless of whether that experience can be generalized. This disposition toward knowledge gradually proceeds toward the understanding that knowledge is context-based. In this, the highest level of intellectual development found commonly among undergraduates, students demonstrating "contextual relativism" compare alternative ideas (hypotheses, designs, historical interpretations, etc.) using appropriate criteria (such as the results of experimental manipulations) to distinguish stronger or more valid ideas from weaker ones. In essence, students learn that all opinions are not equal and that examining the validity of an opinion often depends on applying appropriate criteria in the evaluation. Furthermore, students now can see themselves as generators of knowledge, becoming participants in their field by creating new analyses, contributing research, sharing their learning, and generally participating in the community of scholars. The fourth major position, commitment within relativism, is rarely observed among undergraduates. Here, when making commitments, individuals understand both criteria and consequences, and feel prepared to defend their commitments to others. Despite it rarity as an outcome, this level of intellectual development would be the ideal outcome for liberal, disciplinary, and professional education.

Evolution makes for an intriguing context in which to study the influences on and correlates of intellectual development. The theoretical framework of evolution is exceptionally well-supported by biological and geological lines of evidence and is almost universally accepted within the scientific community (National Academy of Sciences [NAS], 2008; NAS, 1998; e.g. Proceedings of the National Academy of Sciences special issue of May 2007). Yet evolution, particularly instruction in evolution, is highly controversial in the United States, a fact that is attributed often to "politicization of science in the name of religion" (Miller, Scott, and Okamoto, 2006). Nelson (2007) has argued that ineffective undergraduate science education must be seen as a second major contributing factor. This controversy is generally framed as a discussion about scientific evidence, as proposed most recently by the intelligent design movement and notably illustrated in the Kitzmiller v. Dover Area School District trial of 2005 and the Kansas Board of Education actions of 1999 and 2005. Students whose families or religious institutions question evolution will often feel cognitive dissonance when encountering forcefully presented evolutionary content in college, especially since most undergraduates are intellectually in either a dualistic right-or-wrong world or in a multiplistic one in which decisions are seen as arbitrary personal choices. As perceived by these students, the controversy around evolution centers on "facts" or unsupported opinions, rather than on scientific evidence and argumentation, and in this case the "facts" or "opinions" proffered by scientists are disputed in the public arena (although not in the scientific arena). The most publicized aspects of the evolution debate in the United States are highly dichotomized, with the majority of argumentation focused on the evidence

supporting evolution. To a dualistic student, this debate may be confusing – either the evolutionists are right or the creationists are right. The side a student takes may be a function of which party serves as the ultimate authority in their world-view (i.e., scientists or religious leaders [or God, if the student accepts the Bible as the actual word of God]). In a multiplistic approach, students would regard all opinions on this controversy as simply personal opinions, even when individuals, such as scientists, present strong evidence and clear argumentation in favor of certain positions. In our junior and senior level evolution courses, we often encountered students who accepted both creationism and evolution, usually in what is called a theistic evolution pattern (summarized as God provided the raw materials and the initial input of living beings, then oversaw the world as natural processes resulted in the diversity of life), a framework consistent with the teachings of Catholicism, many Protestant denominations, and liberal Judaism (e.g. Zimmerman's 2006 Clergy Letter Project and Matsumura's 1995 Voices for Evolution) and advocated by a number of influential scientists (for example, Gould's non-overlapping magisteria, 1997; see also Ayala, 2007). Some students seem to regard this issue as just one personal choice among several. As long as the advocacy centers on personal choice rather than rational consideration of the positions, this approach likely comes from the perspective of multiplicity. Contextual relativism regarding evolution would be demonstrated by students who are exploring or have explored alternative stances in order to understand more fully the reasons (evidence accompanied by scientific and theological implications) why some sophisticated people accept each position. Commitment in contextual relativism might be demonstrated by students who accept how evolution is by far the better explanation based on scientific criteria alone, yet ultimately reject evolution as an explanation for the origin of life or even for the diversity of life because the underlying consequences or risks of accepting evolution in the face of their own religious beliefs are too terrible. Alternatively, such a student might profess very strong religious belief, but accept that a conservative religious perspective is inadequate for understanding scientific processes. The latter approach to the age of the earth was well illustrated by St. Augustine's arguments some 1600 years ago in his "On the Literal Truth of Genesis":

> Usually even a non-Christian knows something about the earth, the heavens, and the other elements of this world, about the motion and orbit of the stars … and this knowledge he holds to as being certain from reason and experience. Now it is a disgraceful and dangerous thing for an infidel to hear a Christian, presumably giving the meaning of Holy Scripture, talking nonsense on these topics; and we should take all means to prevent such an embarrassing situation, in which people show up vast ignorance in a Christian and laugh it to scorn. ... how are they going to believe those books in matters concerning the resurrection of the dead, the hope of eternal life, and the kingdom of heaven, when they think their pages are full of falsehoods on facts which they themselves have learnt from experience and the light of reason? (415/1982, pp. 42-3).

Given that students can have such different approaches to the evolution content in their courses, there is strong motivation, then, for examining how evolution acceptance and learning relates to the intellectual development of college students.

The proposition that intellectual development influences students' approaches to challenging ideas is strongly supported by research regarding both scientific and non-scientific topics. Kardash and Scholes (1996) studied the relationship between students' intellectual development and their approaches to a task requiring synthesis of contrasting

passages. This study focused on the causative relationship between HIV and AIDS as a controversial topic (at the time of their study, the relationship was still considered tentative and public understanding was low for the scientific issues). Students with strongly held beliefs in the certainty of knowledge (consistent with Perry's dualism level and measured prior to the synthesis task) were far more likely to write conclusions that did not reflect the tentativeness of the data presented in the passages. This outcome was strongly expected, given that students with dualistic perspectives understand knowledge as right or wrong – there aren't two sides to even a controversial issue, only the right side. These researchers also confirmed a result well known to instructors of challenging ideas: Students with strongly held initial beliefs were much more likely to completely ignore the tentativeness presented in the passages and instead generate conclusions strongly consistent with their prior beliefs. This behavior, termed "biased assimilation" by Lord, Ross, and Lepper (1979), is seen in numerous settings – for example, studies of capital punishment (Lord et al., 1979), evaluations of politics and presidential candidate debates (Munro, Ditto, Lockhart, Fagerlin, Gready, and Peterson, 2002), and the biological bases of homosexuality (Boysen and Vogel, 2007), among others. Every thriving academic discipline has its debates, a truism understood by its practitioners to lead to advancement of the field. For students entering a field, such debates bring cognitive dissonance.

As an extended example from a controversial science perspective, we explain here how Perry's positions play out when considering nuclear power as a method of generating electricity. Nuclear power is "carbon neutral" but not "pollutant neutral". Nuclear power is vastly safer to the average individual than coal mining, but failures in nuclear power generation are decidedly more disastrous to the nearby region than a single mining incident (compare Chernobyl to the Crandall Canyon mine cave-in in Utah). Thus, controversy exists about the utility, safety, benefits, and detriments of nuclear power generation. Dualists will view the question of nuclear power generation in black-or-white terms – nuclear power is either really safe or it should be completely banned. The choice one makes is based on the decisions of that person's authorities. Someone out there knows which one is right and that person should decide and we should adopt that position. The non-expert individual has no role in consideration of the alternatives and should not expect to understand the reasons for the decision. For the dualistic individual, there is no debate, as the answer is clear. In contrast, a person who views knowledge as multiplistic would rely on personal feeling in taking a stand, understanding that people have different viewpoints, and would advocate getting along during conflict. Everyone's perspective would be seen equally valid: A physicist's position holds no more weight than a pop singer's opinion. Such an individual recognizes that multiple opinions exist and that no one authority has total possession of truth. When and if these multiple opinions come to be compared and the reasoning and evidence underlying different positions are discovered and understood, the individual comes to contextual relativism. Here we understand that nuclear power is advocated by the current United States government on economic grounds (less dependence on foreign oil, lower cost per MWh), national security grounds (reduced trade with potentially hostile nations), and environmental grounds (nuclear power generation is essentially carbon neutral in comparison to fossil fuel use), among other reasons. At the same time, nuclear power is opposed by some environmentalists on safety grounds (nuclear power plant failures of some sort have occurred twice per decade since the first power generating systems were established) and pollution grounds (the United States does not have a good mechanism for storing the hazardous waste produced). The individual

approaching such a controversy from the framework of contextual relativism understands that there is valuable learning to be had in the reasoning and appropriately supported positions of others. Once this realization and understanding occurs, the individual could reasonably make a commitment to nuclear power by examining consequences of the positions and his or her internal value system, essentially performing a moral cost-benefit analysis on top of an analysis of the various benefits and negative consequences and their probabilities. Such an individual may hold the environment very dear and be greatly concerned by safety issues and the waste generated by nuclear power generation. This person could come to accept nuclear power generation in certain contexts – for some submarines, but not urban areas; for energy production if projected carbon dioxide levels reach critical levels, but not until then. Discourse becomes an exercise in weighing benefits and negative consequences and their probabilities in specific contexts, not in back-and-forth arguing about facts.

With this example of intellectual development applied to a controversial subject, it is clear that students' intellectual development has significant impact on their learning as undergraduates and on their ability to learn and function in society beyond college. The relationship between students' stages of intellectual development and their achievement has been examined in numerous settings, with the general finding that intellectual development is a good predictor of academic performance. Lawson and Johnson (2002) reported a strong association between achievement and neo-Piagetian intellectual development of non-major biology students. Students identified as using hypothetico-deductive reasoning earned twelve percentage points more on the course's final examination than did students identified as using descriptive reasoning (see also Johnson and Lawson, 1998). Similarly, achievement (measured as course grade) was strongly related to Piagetian developmental level among introductory statistics and computer science students (Hudak and Anderson, 1990). In this study, 84% of students at the formal operations level (characterized by hypothetical and abstract reasoning) earned 80% or higher in statistics, while 75% of students demonstrating concrete operations in their thinking failed to demonstrate mastery at the 80% level. Although these neo-Piagetian classifications are different than those underlying the Perry scheme, the pattern remains clear: Students with more sophisticated cognition achieve more. Results using measures of the Perry scheme are similar. Zhang and Watkins (2001) reported a small but statistically significant positive association between intellectual development and academic achievement measured as cumulative GPA for introductory psychology students. In excellent work on freshman and sophomore students from both a junior college and a traditional university, Schommer (1990) demonstrated that performance on both mastery and comprehension tasks was negatively influenced by acceptance of all-or-none learning perspectives – a typical dualistic approach. Similar patterns have been reported for samples of high school students: Epistemological belief regarding the nature of knowledge predicted GPA, explaining 10% of variance in GPA among students (Schommer, 1993). In general, advanced intellectual development promotes achievement.

From these reports and our own experiences, we hypothesized that intellectual development would strongly influence the educational outcomes for students faced with personally and intellectually challenging material. We therefore predicted for students in a senior level course in evolution that is required of biology majors that:

1) intellectual development would be positively related both to evolutionary knowledge and to acceptance of evolution,

2) students with more advanced intellectual development would be more likely to change in their acceptance of evolution, given a better understanding of the nature and construction of knowledge, and
3) students with more advanced intellectual development would average higher grades in the course, as a result of being better able to integrate seemingly unrelated patterns, to construct meaning from their own previous and new learning, and to understand how personal and scientific perspectives can co-exist.

As a result of our study design, we were also able to examine short-term changes in student intellectual development, and also ask whether our course influenced evolutionary knowledge and acceptance.

1981 PILOT STUDY

An unpublished 1981 study provides critical background to our investigation and can be seen as a pilot study for ours. One of us (Nelson) read Perry's work in the early 1970's and found it very helpful in more explicitly formulating what critical thinking would mean in an advanced biology course such as evolution (Nelson, 1989; 1999). By 1981, he was teaching "Evolution and Ecology", then the most advanced course required for biology majors and taken predominantly by seniors. Building on Perry, he greatly increased his emphases on the nature of science and on the uncertainty inherent in most scientific knowledge, expecting that this focus would help students move out of dualism by developing a deeper understanding of science as a process of critical thinking. He also had begun providing study guides both for all readings and for the lectures that included all of the questions that might be on the exams (a total of 100 to 300 essay questions as a pool for each exam). He assumed that level of intellectual development would be decoupled from exam grades by using a question pool where the answers were literally in the books or in the lectures, with minimal or no interpretation required. He anticipated that these would be accessible even to dualists. In terms of course format, approximately one-third of the total number of class periods was devoted to full period discussions. The students typically read an article for each discussion and prepared a three page worksheet that asked them to select the authors' main points and evaluate the strength of the support offered for each. The students were also required to explain and justify in terms of consequences and tradeoffs whether each main point should be accepted until shown to be probably false, or rejected until shown to be probably true. The worksheets were graded largely on preparation effort with gradually increasing standards for adequacy implemented through the semester. Nelson assumed that emphasizing effort in preparation rather than full comprehension would make it easier for less sophisticated students to complete these worksheets but that the preparation and discussion in doing so would strongly encourage intellectual development.

These assumptions were evaluated by comparing the course grades to scores on the Measure of Intellectual Development (MID), given as a pre- and post-test. The MID is an instrument that assesses intellectual development based on the Perry model (Perry, 1970; Knefelkamp, 1974; Mentkowski, Moeser, and Strait, 1983; Moore, 1988), and is comprised of essays probing students dispositions toward the nature of knowledge, source of authority,

and participation in learning. The essays were not available to the instructor until the following semester and were scored subsequently by the Center for the Study of Intellectual Development in Olympia, Washington, thus precluding any effects from the assessment on grading or on interactions with students. The numerical assessment of intellectual development is described in more detail below. The MID scores ranged from 2.33 (a score indicating dualistic thinking) to 4.33 (indicating late multiplicity) on the pre-test. On the post-test, scores ranged from 2.33 to 4.67, with a mean increase for the class of 0.21 (just under one-third of a level). Contrary to Nelson's expectations, there was a strong association between the MID pre-test score and final course grade. The seven students with MID scores below the pre-test mode each earned a below average final grade. Seven of eight students above the pre-test mode earned above average grades (including 5 A+ grades; i.e. 3.9-4.0 on a 4.0 scale). The 21 students with MID scores at the mode (for this group, 3.33 meaning early multiplicity) were intermediate, with eight having earned below average grades and thirteen having earned above average grades (including 6 A+). The same pattern held, but was usually weaker, on each main task in the course. The seven students below the MID pre-test mode usually earned below average grades for the discussions, for the worksheets, and for each of the individual exams of the course, while the eight above the mode usually earned higher than average grades. A similar pattern held for the MID post-test: All five students with MID scores below 3.00 (indicating intellectual development below early multiplicity) earned a below average grade while only four of eleven with relatively high MID scores (late multiplicity and above) did so. Thus, neither the exam grades nor the discussion grades were successfully decoupled from the students' initial modes of thinking as assessed by the MID. Neither was the course uniformly successful in promoting development: MID scores decreased from the pre-test to the post-test for four students, stayed the same for thirteen students, advanced by one-third of a stage for ten students, and advanced by a greater amount for seven students.

Further analysis of these data revealed that grades on most of the questions on the final exam showed no relationship to the MID post-test score. However, for one question there was a strong relationship between student MID score and the points earned. Of the ten students with MID scores below the class mode who attempted the latter question, six earned zeros and four earned ten points (full credit), In contrast, of the sixteen students with MID scores at the class mode or higher, only four earned no points, while one earned five points and eleven earned ten points. The difference between zero and ten on this question produced about a letter grade difference for the final exam. The question was: From a female bird's point-of-view, when is it preferable to mate with a male who already has at least one other mate, rather than choosing a male with no current mates? (Answer: When there are more remaining resources available in the mated male's territory than in that of the best unmated male's territory). The answer summarized material made explicit in the text, and the questions were available ahead of time. Discussion with students in subsequent semesters showed that some students thought this question was picky because the answer was so dependent on context whereas others thought it was fascinating for the same reason. This basic dichotomy illustrates the thinking perspectives of dualism or multiplicity and contextual relativism. Even when the answers were readily available in the text, many students with multiplicity frameworks were unable to produce an exam response demonstrating contextual relativism.

Nelson drew two working conclusions from this study. It was clear that simply because an answer to a study question was stated in a single sentence in the book did not make it

equally accessible to different groups of students. Further, it was clear that more support was needed if students were to master the more complex aspects of his courses. The current study assesses a course that was taught using several techniques that were adopted with that goal in mind.

POST-1981 TEACHING CHANGES

Nelson wanted to teach in way in which the most important ideas of the course could be mastered, to the greatest extent possible, by all of the students. That is, he wanted to provide the scaffolding that would make these concepts accessible across as much of the range of MID scores as possible while keeping or even increasing the extent to which the ideas were intellectually challenging. He made several changes after the 1981 data were analyzed and the results were assimilated (Nelson, 1986; Nelson 2000). Among the more extensive were:

a) Structured discussion was used more frequently and intensively in lecture. These discussions often centered on a multiple-choice question to deepen understanding of the concepts or their applications, even though the question would require a short essay on the exam. For example, after briefly explaining the idea of a "fair test", he had the students answer the following question: "Scientists think that a fair test is one that: a) could have shown any of the alternatives to be either probably correct or probably wrong. b) is based on a line of data or reasoning independent of those on which each of the alternatives are based. c) yields a lot of data. d) contradicts popular ideas. e) supports their own preferred answers. f) None of the above, all of the above, or only two of the above. Explain for each." (The answers are both a and b and, therefore, only f.) After each student had had a couple of minutes to choose the answers and note the reasons, they were asked to compare answers with their neighbors. After the answers were debriefed in whole group, the students were told that a possible essay question for the exam would be "Explain the idea of a fair test in science."
b) The study questions given for the readings were made more explicit while often being made more challenging. The increased structure focused on the more difficult questions and made it much easier for students who were only partially understanding the answers to identify when they were missing pieces, and to study together more profitably. Two examples of questions given for Gould's Book of Life (2001) illustrate this.

    1) **"What is the "worst and most harmful of all our conventional mistakes about the history of our planet"? (p. 10) How does the usual treatment of invertebrates in fossil iconographies contribute to this mistake? Gould laments that we are still awaiting the "real revolution" in our concepts and iconographies of fossil history. What change does he call for here? (p. 21) How does this change relate to the "worst and most harmful of all our conventional mistakes about the history of our planet" discussed earlier? (Hints: The mistake involves the misperception of a goal. How so? The revolution involves our view of processes. Include

contingency in your answer.)" The students knew that hints would not be included if this question were used on the exam. The double stars indicated that the question was among the more likely for use on the exam, an appropriate choice since the question synthesized key ideas across sections. Note that both the ideas of a social context for scientific ideas and the idea of historical contingency rather than deterministic outcomes for evolution seemed to be challenging for many students, making the explicitness of the question and hints appropriate.

2) **"Compare the hypotheses that the sedimentary record of the earth was deposited gradually over hundreds of millions of years versus rapidly in layers one on top of the other during a one year, global flood. Frame your answer in terms of the central scientific criterion of explaining features and differences. Include at least five of the following considerations (i.e. five from a through f in your discussion). For each of the five, explain how at least one rich fossil deposit that we analyzed in this book illustrates your main points and for each of the five answers explain: Would this aspect of the record be easy or hard to explain with flood geology? How so? a) The span of time over which individual sites were formed, as indicated by the geological evidence. b) The extent to which the associated sediments and the associated fossils make ecological sense. c) The reasons the fossils in many rich fossil deposits are so well preserved. d) The extent to which similar fossils are found together. e) The differences among the kinds of fossils found in fairly similar ecological conditions at different times. f) The extent to which the distribution of many deposits makes geographic and ecological sense when placed on a map of continental positions at the time as reconstructed from paleomagnetic evidence." The set of readings and questions that led up to this summary question were introduced with a statement of the key problem: "One important thing that this book does is allow us to compare the hypotheses that the sedimentary record of the earth was deposited fairly gradually over hundreds of millions of years versus rapidly in layers one on top of the other during a one year-long global flood. Key aspects of the flood scenario are that only a few fossils (at most) would have been formed during the several hundred years before Noah, and consequently all of the sedimentary rocks in the geological column had to be formed during the flood, with most of the organisms somehow suspended until the layers below them could be deposited. Thus, none of the fossil deposits could represent lakes, river flood-plains, or deserts. The central question is, thus, whether the geological patterns we find are compatible with this scenario. Put differently, the question is whether normal geology or flood geology better explains the features we find (remember that explanation is the central task of science)."

c) The focus on critical thinking was made much more explicit. It became clear that the students needed to understand science as process of critical thinking in which alternative ideas are compared using explicit criteria, resulting in one idea being more probable, better supported by the evidence, or other wise stronger. The above comparison of mainline versus flood geology illustrates this approach. In other cases more general criteria or procedures were developed. For example, in discussing the

results of experiments in lectures or in the readings, students were repeatedly asked why each treatment was used (i.e., what potentially confounding variable each addressed). More generally, great emphasis was placed on the idea that science is process of comparing ideas and that scientists accept ideas only when they are better than the scientifically accessible alternatives on specified criteria. A number of comparisons utilized many of the same criteria; thus, standard geology is better than flood geology, an old age of the Earth is better than a young age, and evolution is better than young-earth or fixed species creationism. In each case, they are better not just because they win one fair test but because they win a series of such fair tests that are independent of each other and (in these cases) do not come out second best on even one fair test. Many students seemed to not understand the power of making comparisons using appropriate criteria until they were asked to apply this approach to topics outside the course. Thus, for an extended discussion, students were asked to fill out a worksheet before class that asked, in part: "a) Explain the two criteria: *fair tests* and *multiple independent tests*. b) State what basic task each criterion could used for *outside of science.* c) State a specific non-scientific question or comparison to which these two criteria could be applied. Examples can be from any non-scientific area including incidents that might cause jealousy, sports, consumer goods, mechanics, business decisions, crimes, mystery novels, issues with parents, etc. d) Explain at least two alternative possible answers to the question. And, e) explain at least two potential fair tests and indicate which conclusion would be supported by what results from each." In sum, by instituting these more explicit, extensive, and relevant exercises in the course, Nelson intended to support student learning regardless of intellectual development, and promote students' ability to demonstrate that learning on course assessments.

d) Extensive comparisons were made between standard evolutionary science and young-earth creationism (Nelson, 2000 lists 21 such comparisons). In addition, three major kinds of creationism were compared: Quick or young-earth creationism, progressive (old Earth with fixed kinds) creationism, and gradual creationism (also known as theistic evolution). It was also pointed out that different religious groups tended to advance different views (details in Nelson, 2000).

Further, Nelson emphasized that public controversies involving science usually rest on different views of consequences and, hence, the parties can rationally disagree on how strong the evidence must be to justify a particular conclusion. He then introduced a key metaphor: "Consider, for example, an intact but quite rusty hand-grenade. With it on the table between us and a munitions expert at our side, we agree that it is so rusty that the chances of it exploding if we pull the pin are slim--decidedly less than 1 in 10,000. Shall we pull the pin? The most probable hypothesis, by far, is that the grenade will not explode. When presented with this thought experiment, however, most people conclude that we should not pull the pin. Why not? Because, if the most probable hypothesis is wrong and the grenade does go off, the results are likely to be 'inconvenient,' especially for those testing the hypothesis. It is important, too, that a demonstration that the grenade is too rusty to explode has negligible benefits. Thus, it is totally rational to reject even a very probable hypothesis when the benefits of acceptance, were it true, are small and the consequences of being wrong are large." This is, of course, exactly the view of evolution taken by young earth creationists. The payoffs are

seen to be small and acceptance is seen as increasing the risk of damnation or of other severe religious consequences. Thus, if one would not pull the pin, then one should not accept evolution, unless a different view (than the religious view) of consequences and payoffs is generated. In an attempt to counter this young-earth view of tradeoffs, Nelson emphasized the applied benefits of evolution though various aspects including Darwinian medicine and also noted the differences in risks emphasized by different theologians (see for an example the quote above from Augustine). Students were given a series of questions to prepare for discussion that included:

1) "Many fundamentalists have emphasized the religious risks that flow from interpreting Genesis and science to be in conflict with each other. Briefly summarize these risks (see Rusty Hand Grenade, above). Saint Augustine emphasized a counterbalancing religious risk from interpreting the Bible so that it conflicts with clear empirical knowledge. Briefly summarize this risk. How would this help explain the fact that most United States Christian denominations do NOT reject evolution?"
2) "To avoid the false dichotomy of Atheistic-Science versus Christian-Creation it is useful to consider a range of positions. Compare and contrast the ideas of Non-Theistic Evolution, Gradual Creation (Theistic Evolution), Progressive Creation and Quick (Young-Earth) Creation. For each, suggest a view of consequences that leads rationally to accepting it rather than any of the other three positions."

In sum, the goal of these modifications was to promote learning and demonstrations of learning by all students, and especially by those students whose conceptual and developmental frameworks seemed most likely to negatively influence the learning and acceptance of evolution.

METHODS FOR THE CURRENT STUDY

Study Population

Our study group was comprised of mostly junior and senior biology majors enrolled in a single evolution course at a large Midwestern university. The course was the final required course for the biology major, and so most students already had completed the majority of their degree requirements, including genetics and molecular biology. In previous semesters, students who enrolled in the course described themselves as slightly or moderately religious, primarily practicing versions of Christianity, but Judaism and Islam were also represented. Initially, 139 students enrolled in the course and completed at least one of the pre-test instruments (described below). Final course grades were recorded for 119 students, and 107 students completed at least one post-test instrument. Complete matches for all pre-test instruments, all post-test instruments, and final course grade were possible for 86 students. There were no statistically significant differences in the responses of the students for whom matches could be made and all other responses collected (data not shown). Therefore, we analyzed only the data collected from these 86 students. A student's final grade in the course

was based on learning group participation and grades from three exams, occasional quizzes, and learning group worksheets.

The content of our evolution course followed three main themes: The history of life, evolutionary patterns, and evolutionary processes. The course content was integrated with lessons on the nature of knowledge and strategies involved in critical thinking. Course meetings consisted of twice-weekly combined lecture and discussion sessions and once-weekly learning group periods. During learning groups, students engaged in various critical thinking exercises, like comparing hominoid skulls, simulating population genetics dynamics, evaluating different religious and scientific conceptions of the evolution/creation controversy, and constructing phylogenies from molecular sequences (examples of these activities and many more are available from the Evolution and Nature of Science Institutes; see http://www.indiana.edu/~ensiweb/). One 75-minute course session was devoted to introducing Perry's scheme of intellectual development (including discussion with required reading and preparation of a three page worksheet). Additional course details are given above as post-1981 modifications and by Nelson (1999; 2000; 2007).

Data Collection

Approval for research on human subjects was obtained prior to data collection. We used final grade in the course as our measure of achievement. We administered three instruments to students enrolled in our upper-level evolution course, with each instrument administered as a pre-test on the first day of the course and as a post-test during the final week of the course. First, students completed a survey that assessed acceptance of evolution (hereafter, "acceptance"), the Evolution Attitudes Survey. This instrument has been used informally on thousands of students (B. Alters, personal communication) and in one previous published report (Ingram and Nelson, 2006). Survey items included "Over billions of years all plants and animals on earth (including humans) descended (evolved) from a common ancestor (e.g. a one-celled organism)" and "There is fossil evidence supporting that animals, including humans, did not evolve" (see Ingram and Nelson, 2006 for the complete survey). Student responses on the twelve item survey were scored on a five-point Likert scale, with complete acceptance of evolution represented by a total score of 60 (i.e. 12 items times five points each) and complete rejection of evolution by a total score of 12 (i.e. 12 items times one point each). Second, we administered the Concept Inventory of Natural Selection (CINS – Anderson, Fisher, and Norman, 2002) as a measure of basic evolutionary content knowledge. This instrument assesses students' understanding of a major mechanism of evolution via a 20-item multiple choice exam, with each item having a single correct answer and distractors that model common alternative conceptions. Gain scores (Hake, 1998) were calculated for each individual student for the CINS and the acceptance survey, since these instruments have an upper limit (i.e., a perfect score is possible). Finally, we administered the Measure of Intellectual Development (provided and scored by the Center for the Study of Intellectual Development). The instrument consisted of two essay questions, one administered as a pre-test, and the other as a post-test (Appendix A). Data returned from the scoring of this instrument are approximately continuous numerical descriptors of Perry positions, with the scale proceeding from 2 (full dualism) through 5 (contextual relativism). Numerical ratings 3 and 4 correspond to early and late multiplicity, differentiated by what the student understands

the fundamental learning task to be – either learning how to find the right solutions to solvable problems (early multiplicity) or prevaricating in the face of problems with multiple solutions or that are unsolvable (late multiplicity). Scores given as X.33 or X.67 (such as 2.33 or 3.67) indicate students in transition between positions.

Example MID Responses

Since the MID results are so central to our study, we provide a few examples of student responses to illustrate the developmental differences it assesses. In our pilot study, the best classes cited by the students who scored comparatively high on the MID pre-test essays were rarely science courses, even though the students were taking a senior-level course for biology majors. In this vein, an extensive study of seniors at several institutions found that lower level science courses tended to be viewed as stultifying by both those who were completing a major in science and by those who had planned to major in science initially but had then shifted to another major (Seymour and Hewitt, 1997). Although the instrument asked for the "best" course the student had taken, the advanced essays often discussed the most interesting course. Emphases included interactions, larger syntheses and personal outcomes. A couple of examples suffice to demonstrate these patterns.

> "The most interesting class I have taken, [a great books course in the Honors Division], was the least structured of any class I know on campus… It incorporated discussion groups and weekly lectures, discussions being in three hr. blocks once a week, lectures one and a half hours approx. once a week. Its downfall was the incompleteness with which each period and individual was studied; its strength, of far greater importance, was its stimulation of individual thinking and ideas. Grading was based on four essays that were meant to integrate the ideas discussed. Of particular interest is the fact that the course was inter-departmental, hence philosophy was discussed with its historical and aesthetic background as well as [with] literature and art. This de-compartmentalization is in the right direction for the philosophy of education." (MID 4.33)
>
> "I took a course [a topic in philosophy]… I was a biology major who wanted to see if I could learn something from philosophy to help me with theoretical questions in biology. The teacher was great! The course was hard but we were not penalized in any way. I worked as hard as I could and I got encouragement, great feedback (always couched in positive terms), respect for my ideas even though they were not well-formulated or mainstream, a competent teacher and scholar with whom to engage in dialogue, and great class discussions since the teacher knew how to foster discussions… I was accepted among these people as a legitimate and valuable class member even though I had never done philosophy before. Other features:…The teacher connected with me on the first day…The teacher did not hesitate to tell me when my ideas were exciting and interesting. The teacher knew how to help me focus on what I was trying to pull out of the vagueness of creative thought." (MID 4.0)

The best classes cited by the students who scored comparatively low on the MID essays were usually science courses. The substance of the descriptions was radically different, with a focus on efficient transfer of knowledge from authority to student. A couple of examples again suffice.

> "General Biology. Dr. [X] was the professor and had tapes of every lecture available for listening and review. He was very organized, and made the topic interesting. He moved from point to point smoothly, tying it all together. He was always very clear and precise. He always wore a suit and tie, which, in a sense, made you respect that he took time to get ready for class. … He was available for consultation frequently, and always explained questions more thoroughly than needed. (This made you feel smart rather than stupid.) " (MID 2.33)
>
> "The best class I've taken in college is [endocrinology]. I did not do well but I found the lecture to be highly interesting and the text interesting as well. My professor for this course was Dr. [X]. I found him to be a very good teacher. This was due to his well-organized lectures, his ability to write his thoughts on the board, which made it much easier for me to take notes, and his desire to help the student when problems arose. The atmosphere of the class was relaxed and he was always willing to answer questions during his lectures. I found his tests to be tough but fair. My grade does not appear high but I felt that I had learned a great deal concerning the subject matter." (MID 2.67)

These examples illustrate the diagnostic capability of the MID. Furthermore, they reveal the fundamentally different perspectives that students with contrasting intellectual development levels have. These examples also support our basic premise that students with lower levels of intellectual development were expected to have lower achievement in courses focused on the integration of seemingly unrelated patterns, the construction of meaning from their own learning, and the understanding of how personal and scientific perspectives can co-exist.

Statistical Analyses

Normality of the data was tested by the Anderson-Darling normality test. The data resulting from our study were non-normal (Table 1), in most cases due to a strong skew towards maximum values (i.e. the means were much closer to the maximum than the minimum except for the MID). Because of this finding, we first performed statistical analyses on all variables using appropriate nonparametric statistical tests. Subsequent parametric testing resulted in identical outcomes. We report only the results of parametric tests for easier interpretation. The linear association among measures was tested by Pearson's correlation, while change over the semester by students was tested by paired t-tests. χ^2 was used to test whether the course had a disproportionately positive effect on student knowledge, acceptance of evolution and intellectual development (explained more fully below). Our criterion for statistical significance was $p < 0.05$.

RESULTS

Student knowledge of natural selection, acceptance of evolution, and levels of intellectual development level all increased over the course of a single semester (as measured by the means; Table 1). Student knowledge and evolutionary acceptance both increased by more than 10%, while gains in intellectual development were more modest (content knowledge: $t = 3.95$, $p < 0.001$; acceptance: $t = 8.89$, $p < 0.001$; intellectual development: $t = 3.07$, $p = 0.001$; $df = 86$ for all comparisons, with all tests one-tailed consistent with our expectation of

increases over the semester). More than 40% of the students demonstrated greater intellectual development on the post-course assessment. For the knowledge score, the significant increase in demonstrated knowledge occurred despite the limitation on the amount of change possible for students initially earning very high knowledge scores (e.g., 18, 19, or 20 on the natural selection pre-test). The high initial scores demonstrate a high level of residual mastery from earlier learning. The positive effect of the course on these three measures was confirmed by analyzing the patterns of change among students whose responses differed between the two administrations of the instruments. We tested the hypothesis that the course had no effect on changes in knowledge of natural selection, acceptance or intellectual development, leading to the prediction that a student whose responses changed over the semester would have been equally likely to have a greater score as a lower score on these measures. We used a χ^2 test to compare changes in student scores against the expectation that 50% of students who changed increased their scores and 50% decreased their scores (each test had $df = 1$). We found that for students whose acceptance, knowledge or intellectual development changed over the semester, that change was strongly in the positive direction (knowledge: $\chi^2 = 11.52$, $p < 0.001$, of 73 students with different scores, 51 increased their score; acceptance: $\chi^2 = 49.95$, $p < 0.001$, of 82 students with different scores, 73 increased their score; intellectual development: $\chi^2 = 8.96$, $p < 0.005$, of 54 students with different scores, 38 increased their score). These results provide strong support for the assertion that the class in total influenced knowledge, acceptance, and intellectual development. Incidentally, they also strongly suggest that the students were taking the instruments seriously and trying to do well.

Measures of student knowledge, acceptance, and intellectual development were related to each other modestly, if at all. At the beginning of the course, prior to advanced instruction in evolution, students' knowledge of natural selection and their acceptance of evolution were statistically significantly correlated, although the strength of this relationship was modest ($r = 0.293$, $p = 0.006$), possibly because of the highly skewed natural selection scores. On the pre-tests, neither acceptance of evolution nor knowledge of natural selection was even modestly correlated with intellectual development (respectively, $r = -0.097$, $p = 0.376$ and $r = -0.065$, $p = 0.551$). After one semester of instruction, there was no longer a statistically significant association between knowledge of natural selection and acceptance of evolution ($r = 0.166$, $p = 0.126$). Again, we found no significant association of either content knowledge or acceptance with intellectual development (respectively, $r = 0.012$, $p = 0.914$ and $r = -0.027$, $p = 0.807$). In short, intellectual development was not related to either content knowledge or acceptance when those measures were assessed simultaneously.

We did not find support for our prediction that students with greater intellectual development would find learning or changing personal attitudes easier. The initial level of intellectual development demonstrated by students was not associated with the absolute change in content knowledge or acceptance of evolution (respectively, $r = -0.009$, $p = 0.935$; $r = 0.027$, $p = 0.808$), nor with the relative gain as measured by the gain scores (again respectively, $r = -0.052$, $p = 0.639$; $r = -0.011$, $p = 0.919$). Furthermore, there was no statistically significant association between the absolute amount of change occurring in intellectual development and absolute change in either content knowledge or acceptance of evolution (respectively, $r = -0.006$, $p = 0.954$; $r = 0.090$, $p = 0.412$). Finally, we found no relationship between the end-of-course intellectual development and change in either content knowledge or acceptance of evolution, measured either as absolute gain or relative gain (absolute knowledge gain $r = 0.005$, $p = 0.966$; absolute acceptance gain $r = 0.149$, $p =$

0.175; relative knowledge gain r = -0.009, p = 0.934; relative acceptance gain r = -0.037, p = 0.742). Although students' intellectual development, acceptance and knowledge all increased, change in intellectual development was not associated with acceptance or knowledge.

Students' intellectual development was unrelated to achievement in the course, regardless of when development was assessed. We found no statistical correlation between intellectual development and final grade in the course (pre-course: r = 0.068, p = 0.533; post-course: r = 0.013, p = 0.902; absolute change: r = -0.046, p = 0.677). Despite the absence of a statistical association between these two factors, we did observe two interesting patterns. First, the 16 students who made the lowest intellectual development score on the pre-course assessment (2.33 indicating mostly dualistic thinking) earned final grades throughout the range found in the class (in distinct contrast to the findings of the 1981 pilot). In contrast, of the eight students who made the three highest initial intellectual development scores, seven earned average or better in the course. Second, the four students earning the lowest intellectual development score after the class (2.33, as for the pre-test) all earned a below average grade in the course. We also note that the student earning the lowest grade in the course (consistent with her or his very low the pre- and post-course CINS scores) demonstrated the greatest change in intellectual development; this student's acceptance score also increased from 51 to 58. Achievement was significantly but modestly related to both pre-course and post-course knowledge of natural selection scores (respectively, r = 0.321, p = 0.002; r = 0.353, p = 0.001), as would be expected since demonstrating knowledge of natural selection on unrelated course assessments was part of the final course grade and since the pre-course knowledge score were so high. Students' acceptance of evolution at the end of the course also was modestly related to achievement in the course (r = 0.2099, p = 0.049).

DISCUSSION

Intellectual development did not have a statistically significant influence on the educational outcomes (knowledge or achievement) of students enrolled in our upper-level, biology majors evolution course. This outcome of our study probably should be seen as unexpected, based on our own understandings of the nature of evolutionary science as well as by the results of much prior work cited above, including our own pilot study.

By definition, evolutionary biology is an integrative endeavor, with developments in the field relying heavily on a sophisticated understanding of the processes of science, inductive reasoning, and the nature of scientific knowledge. This complexity is reflected in the course material and textbook. As a basic illustration of this fact, consider that the conclusion that evolution by natural selection is the best explanation for the unity and diversity of life is strongly supported by concurrent analyses of suites of fossils, molecular data including amino acid and nucleotide sequences, and evaluation of the structure and function of extant anatomical features, among many other possible lines of evidence. Understanding even a single element of this complex picture requires the recognition that multiple possible interpretations exist, but that one interpretation can be overwhelmingly the most likely.

Thus, given the content area of our course, the most likely outcome was a strong positive correlation between intellectual development and achievement. That this outcome did not occur here, but did occur in our 1981 pilot study, suggests that Nelson's post-1981

modifications succeeded in supporting mastery of complex materials by a broader range of students. Nelson had revised his teaching in hopes of increasing the extent to which students at lower MID levels could master conceptually advanced material and, hence, reduce the association between MID scores and achievement, a goal that was apparently achieved. However, as noted above, students who earned a high pre-test MID score had a disproportionate chance of earning a high grade and the four students who had the lowest post-test MID scores all earned below average course grades; in other words, the intended decoupling was not fully successful.

The results of this study and the larger mean change found in our pilot study confirmed that measurable change in intellectual development can occur over one semester. Although these changes are small relative to our aspirations, they are larger than those often reported in the literature for a single semester. Indeed, Hofer and Pintrich (1997) noted that changes in intellectual development do not necessarily occur in college. The amount of change we report for one semester is comparable to the findings of a longitudinal study of a liberal arts program over two years: Hart et al. (1995) reported a change of 0.21 (from a mean of 2.94 to 3.15 on the MID) over two years of the college experience, beginning with freshmen, and a total change of 0.46 (to 3.40) at graduation (using the same assessment tool as we used). In comparison, our students scored slightly lower overall on the MID assessment, even given their junior and senior status; however, the senior students in our pilot study were more typical. The intellectual development starting point of our juniors and seniors was lower than expected for reasons that are not clear. Barnard (2001) found that students enrolled in a learning community scored the same on the pre- and post-test MID essays as our students, although in her study, again the students were entering their college experience (they were also measured over one semester). Swick, Simpson, and Van Susteren (1991) reported that 78% of entering first year medical students scored 3.0 or below on the MID, a finding of particular note given that many of our biology majors intended to pursue medical studies. Similarly, the intellectual development of third-year education students was determined to be solidly in Perry's multiplicity stage, and that assessment did not change after five months for a control group (Hill, 2000). Among engineering students, intellectual development of first-year students was 3.27 by the MID (Pavelich and Moore, 1996; Wise et al., 2004). Wise et al. (2004) found little change by the junior year, with the same cohort of students scoring on average 3.33. However, these two studies are notable in that both research teams found seniors to be firmly in the late multiplicity stage, measuring on average 4.28 and 4.21 by the MID (respectively Pavelich and Moore, 1996; Wise et al., 2004). In summary, the level of intellectual development we report here from our main and pilot studies is in line with the intellectual development levels observed by others. Additionally, our one-semester changes were at the upper end of these other reports. Given the strength of these patterns and the relatively small amount of change accomplished by various interventions, other mechanisms of promoting or encouraging intellectual development must be sought if we are to accomplish the goals of liberal and professional education (but see Mentkowski and Associates, 1999).

It is important to contrast our results following extensive pedagogical modification to the more common finding of a strong effect of intellectual development on academic achievement, namely the positive relationship between these characters. At the lower levels of intellectual development, where achievement is hindered, this effect can prevail even with material that might appear engaging and intrinsically encouraging of academic development, as was our experience with evolution. For example, Kardash and Scholes (1996) found that

students who accepted certainty of knowledge wrote conclusions reflecting certainty regarding a deliberately tentative passage on HIV as the causative agent of AIDS. Thus, students who viewed knowledge as dualistic tended to evaluate complex material in a dualistic way. Kardash and Scholes (1996) also found that a student's strength of belief regarding the relationship between HIV and AIDS was inversely related to the degree of certainty reflected in their written conclusions, what can be viewed as an achievement task. In contrast, we found no relationship between intellectual development and acceptance of evolution. Furthermore, in our intentionally supportive course, achievement was independent of demonstrated intellectual development measured either prior to or following the course, as we intended.

Although we had successfully supported the students in being able to produce complex answers in the specific contexts that they had studied, the various strategies we implemented through the semester did not foster generalized intellectual development to the extent we expected, although the change in intellectual development of our students was notable in comparison to several other studies. Perry recognized that students can practice higher levels of cognition in limited situations, only much later generalizing this disposition. In our case, students appeared to respond appropriately to tasks that required answers that were stated in the form of contextual relativism in the context of our evolution course. But when intellectual development was evaluated more globally (using the non-course specific essay prompts of the MID given in Appendix A), higher levels of thinking were not apparent.

By directly addressing Perry's model in class and using activities designed to elicit complex decision making processes, we had hoped to facilitate the development of students' reasoning and understanding of their own cognition. Such activities involved the simple approach of both the instructor and students thinking aloud through the questions presented in the activities and to student questions. This basic idea is consistent also with the recommendations of Belenky et al. (1986), who stated "So long as teachers hide the imperfect processes of their thinking, allowing their students to glimpse only the polished products, students will remain convinced that only Einstein – or a professor – could think up a theory" (p. 215). More generally, they found that many students are "hidden multiplists" who can present complex thinking when required but who persist in believing that choice among intellectual alternatives is fundamentally a matter of personal preference with little or no regard to evidence and argumentation. Such a response would allow complex thinking in the context of course without a parallel manifestation on the MID. It may also be pertinent that the MID post-test (Appendix A) asked the student to describe the learning environment that the student would choose as ideal. It would not seem unreasonable for the students' view of ideal support to lag somewhat behind their own best current thinking.

In our study, the overall approach of supporting complex thinking explicitly and implicitly likely increased intellectual development above what would be normally expected over a single semester during college or given some other experimental intervention. However, intellectual development did not differentially affect changes in achievement, knowledge of evolution, or acceptance of evolution. We view these results in two positive lights. First, our results support the assertion that our pedagogical strategies do result in increases in acceptance of evolution and knowledge of evolution, and likely contribute in some part to increases in intellectual development, since all of these measures increased over the course of the semester. Other research has demonstrated that students with greater levels of intellectual development are more successful in college and in outside endeavors (e.g. Hart

et al., 1995), so simply promoting intellectual development is a positive outcome that is expected to be helpful to the students in future activities. Second, since levels of students' intellectual development did not strongly influence achievement in our course, as has been reported in other research, we can claim that we eliminated negative bias toward less intellectually advanced students. In other words, students' performance in our course was apparently a better reflection of learning and effort, as opposed to reflecting underlying intellectual traits that either promote or hinder understanding. We intended to decouple intellectual development and achievement by using supportive interventions, and this decoupling was successful. For these reasons, we can now view our efforts to facilitate intellectual development as promoting life skills, rather than simply having the immediate effect of altering perspectives on acceptance or rejection of evolution.

We also emphasize that the minimum acceptance score for acceptance of evolution increased from 17 to 26 (Table 1). This increase parallels Verhey's (2006) finding that an intellectually complex approach (discussions comparing evolution and intelligent design) fostered increased acceptance of evolution by a large fraction of students who began the course with low acceptance values. In his study, very few students made such shifts when taught with an intellectually simpler, evolution only, approach.

Under frameworks other than intellectual development, one might actually expect less rather than more acceptance of evolution from approaches such as Verhey's and that used in this chapter. Individuals experiencing new, conflicting, or otherwise challenging material who might normally be multiplistic or relativistic often initially rely on dualism to begin to conceptualize the problem. Perry (1970) documented such "regression to dualism" under academic stress. For a more current example, upon being diagnosed with cancer, most patients report a preference for immediately receiving facts regarding prognosis, treatment, expected lifespan, and the like (Schofield, Butow, Thompson, Tattersall, Beeney, and Dunn, 2001), generally acting as a passive recipient of information with the doctor being the authority. A strong preference for supplemental information is desired by most individuals, as is discussing the diagnosis with a counselor some time after the initial diagnosis (Schofield et al., 2001), as outcome we view as consistent with reclaiming a relativistic viewpoint. Similarly, people who are expert and relativistic in one field often resort to basic dualism when charged with learning in unrelated fields (Tobias and Hake, 1988; Tobias and Abel, 1990; Tobias, 1993). Students in our course could reasonably have avoided major conceptual conflict with evolution previous in their academic careers. Indeed, several such comments were received throughout the years that we taught advanced evolution. Upon having their dominant paradigm challenged, these students might have regressed to lower stages of thinking on the Perry scale. If so, then our focus on critical analysis and examining criteria allowed some such students to "overcome" their situation-specific multiplistic thinking and demonstrate adequate achievement. Taken together, these findings support our assertion that any bias in either direction resulting from an inherent relationship between intellectual development and achievement (as suggested by studies reviewed in the introduction) was reduced in our course, such that individuals with widely differing intellectual development levels could and did achieve similar course outcomes.

Table 1.

		Minimum value	Maximum value	Mean	Standard deviation	Anderson-Darling A^{2a}	p^b	paired t	p^c
Acceptance survey[d]	pre-test	17	60	44.63	8.099	1.04	0.010	8.89	<0.001
	post-test	26	60	49.54	7.443	0.97	0.014		
CINS	pre-test	8	20	14.79	3.410	1.72	<0.005	3.95	<0.001
	post-test	7	20	16.14	3.211	2.07	<0.005		
MID	pre-test	2.33	3.67	2.78	0.323	3.59	<0.005	3.07	0.001
	post-test	2.33	3.67	2.91	0.286	6.09	<0.005		
Final grade		47.18	101.75	83.28	10.166	1.25	<0.005		

[a]goodness-of-fit test against a normal distribution
[b]p for Anderson-Darling A^2
[c]one-tailed hypothesis of paired t-test contrasting pre-course value to post-course value
[d]n = 86 for all cells

EDUCATIONAL IMPLICATIONS

For the specific case of evolution, excellent work suggests alternate strategies for positively influencing content knowledge while simultaneously promoting an understanding of the nature of science. We view an appropriate understanding of the scientific endeavor as being equivalent to at least Perry's contextual relativism, in that scientists routinely propose arguments that succeed or fail in different frameworks. Nelson (2000, 2007) recommends and describes three strategies for addressing the nature of science: Discussing creationist misconceptions without explicitly identifying them as such, structuring a course with the nature of science as the central theme, and melding these two to illustrate the failure of creationism as science. Research supporting these recommendations is becoming more common (Verhey, 2005; Scharmann, Smith, James, and Jensen, 2005; others cited in Nelson, 2007).

Direct experiences in the profession are another mechanism for facilitating or fostering intellectual development of students (Wise et al., 2004; Pavelich and Moore, 1996). For engineers, this experience is design; for scientists, research. When students encounter the poorly structured problems of reality, they can make tremendous strides in their conceptions of knowledge and who makes meaning. In both engineering and science undergraduate education, these experiences typically occur near or during the final year of study. In a qualitative analysis of a small group of senior engineering students, Marra and Palmer (2004) found that most students rated as having high Perry levels described co-op or internship experiences as key in providing "intellectual challenge". Similar research found that students who completed a first-year design course had Perry ratings significantly higher than those who did not participate, even after controlling for GPA and SAT scores (Marra et al., 2000). Although these researchers are careful to note that this difference in intellectual development cannot necessarily be directly attributed to the design experience itself, they propose that the project- and team-based environment fosters "natural progression towards more complex thinking". Similarly, our observations of students completing formal summer Research Experiences for Undergraduates (REUs) support the assertion that students' intellectual development advances following practice in the profession. These observations fit with the findings of research in which student participants in REUs self-report, and are similarly evaluated by advising faculty, as having significantly increased processes of science capabilities, such as formulating hypotheses, evaluating evidence, professional communication and the like (Hunter, Laursen, and Seymour, 2007; Kardash, 2000; Lopatto, 2004; Seymour, Hunter, Laursen, and Deantoni, 2004). We view understanding the nature of science to be implicitly related to intellectual development, so presumably REUs promote intellectual development in concert with scientific skills. These findings comprise a strong argument for encouraging students to engage in direct experience of the profession. To our knowledge, no published work examines the outcomes of REUs specifically with respect to intellectual development, although one of us has initiated such a project in the context of environmental research. More such work is needed to better help educators understand how, over what time period, and in what scenarios intellectual development changes, specifically in relation to the education enrichments found to be so influential to professional development.

Structured activities in which students are faced with "poorly structured" problems are good ways of challenging students' intellectual development. Such activities are well-

designed, but are capable of leading toward multiple possible answers. Consider a simple assignment in a basic anatomy and physiology class: "Rank the body systems in order of their importance to reproduction" (Ingram, Lehman, Love, and Polacek, 2004; see http://www.indiana.edu/~hhmi/docs/Reproduction-All.pdf). Answers from different teams are likely to be significantly different (e.g., the circulatory system is the most important to one team, while the nervous system is the most important to another team, with circulation ranking last). Each ranked list can be confirmed as an appropriate ranking in a whole-class summary, highlighting the ways in which each list captures important information. A student holding dualistic perspectives will likely be somewhat frustrated, asking "Which ranking is correct?" to which a reasonable response might be "In this case, we have multiple correct answers – what other types of problems might result in this same outcome?". A student demonstrating multiplicity might ask "How do you know which ranking is better?" to which a reasonable response is "We'd probably need to look at the criteria each team used to generate their list before we answered that question – shall we compare criteria?". The main idea here is to provide the scenarios in which students can practice new ways of thinking at their own pace. The ultimate poorly structured problems are those mentioned previously, namely scenarios leading to knowledge generation in the field. Such experiences can be supported in the individual classroom setting through carefully constructed assignments. For example, a history of education course assignment might involve students acquiring primary documents related to a particular aspect and time period in the institution's history, perhaps development of the science departments during the World Wars. When this material can be combined with the course material to discover common patterns, students can come to view themselves as participating in the community of scholars from whom and with whom they learn.

One of us (Ingram, Nelson is retired) preferentially uses material generated through undergraduate research in all courses, to demonstrate how "students just like you" are contributing to our knowledge of science. In biology, some appropriate research topics are menstrual synchrony (McClintock, 1971), choosiness based on relationship longevity (Woodward and Richards, 2005), and prevalence of vancomycin-resistant staph on paper money (Bhalakia, 2005). Although in this scenario, students themselves aren't responsible for new knowledge, this simple strategy demonstrates that possibility.

Basic recommendations besides those reviewed here are readily available. For example, Wankat and Oreovicz's (1993) book "Teaching Engineering" is posted in PDF chapters (see References for the link); Chapter 14 deals specifically with models of intellectual development and contains summaries of previous work on strategies for promoting intellectual development. The most notable recommendation of Wankat and Oreovicz is the practice-theory-practice model of instruction, developed by Knefelkamp to specifically address intellectual development. In this model, students are introduced to a concept through some concrete experience, then the instructor presents theory or the conceptual framework that explains the experience. Finally, students solidify knowledge through additional practice and extension (paraphrased from Wankat and Oreovicz, 1993).

An example from ecology illustrates this model of instruction as applied by one of us (Ingram). The conceptual issue is population regulation (or absence thereof); more specifically, logistic growth and subsequent predator-prey population size fluctuations. In an introductory ecology course, students are introduced to the EcoBeaker simulation system and its Isle Royale module (SimBiotic Software, 2003) and are encouraged to explore population size variation under a wide range of initial conditions. The basic scenario is: Limited space

(the island) and resource availability (plants representing food), a moose population (herbivores), and, occasionally, the presence of wolves (carnivores). In the simulation, students can manipulate the initial population size of the plant population, the plant population growth rate, the moose growth rate, and other key variables. Students are presented with a series of basic questions. For example, what happens to the moose population over time? Under what conditions will the moose population size be relatively high or relatively low? How does a sudden change in the resource supply influence the moose population? (The answers are respectively, the population grows when resources are plentiful, they overshoot the resource supply, have a population decline, and eventually population size stabilizes; when the plant population has a high rate of reproduction or low rate; and, the moose population tracks resource supply, sometimes overshooting, sometimes not). This portion of the exercise allows students to operate within their levels of intellectual development – there is generally a correct answer (understandable to all students including dualists) and multiple solutions in terms of initial conditions exist (early multiplicity). We then introduce the formal conceptual and mathematical framework of carrying capacity and logistic growth, building on previous explorations of exponential growth and explaining how the simulation system is iterating these equations in the background. These formal models support the dualistic student by demonstrating that facts regarding this interaction exist, and support the multiplistic student by demonstrating that reasonable predictions can be made to discover new "truths" (perhaps the outcome of introducing an invasive plant species to a state park). Students then return to the simulation to confirm that the equations introduced have biological meaning and systematically manipulate the system to discover the limits of the equations in predicting outcomes. A final challenge is added – and the final practice step introduced – when wolves as predators on the moose appear on the island. In this simulation module, the wolf introduction at first seems to cause random fluctuation in the moose population. Eventually a cyclical pattern can emerge, but such a pattern is highly dependent on the initial conditions; population crashes occur regularly. This last modification within the module illustrates that ecologists are reasonably able to predict the outcomes of simple systems and within a set of known constraints, a piece of learning likely to be very useful for the dualist student. To multiplistic students, this last modification illustrates that ecologists have strategies for solving problems that can be applied in various settings. An activity such as this one could build further, with this last modification serving as the initial practice step for a second cycle. The role of the instructor is critical in such learning cycles, as the instructor maximizes learning and potential for intellectual development by constantly assessing student positions, responding to questions accordingly, and providing meaningful nudges toward alternate ways of thinking. Culver (1987) extends this basic model to the course and curriculum levels, again working from Knefelkamp's foundation, with the recommendations of initially assessing student development levels, translating those development levels to criteria for choosing appropriate activities, then evaluating the extant materials for their fit with the first two aspects and modifying as needed. The premise of all of these recommendations begins with simply paying attention to the intellectual development of the students with whom one works.

A final example serves to illustrate the relative ease by which student intellectual development can be supported. In Perry's original work, he interviewed the same students over four years, completing a significant longitudinal study and revealing dramatic changes in intellectual development over the course of those four years. In contrast, subsequent work

performed as a cross-section study at a comparable institution found considerably less difference in intellectual development between the first and last years of college (Belenky et al. 1986). One possible explanation for this difference is that the simple intervention of questioning students during an extensive interview about how they think, where knowledge comes from, what roles teachers play in these issues, and how appropriate evaluation occurs influenced students to ponder these issues outside the interview and reformulate their understandings. Perry's interview strategy tacitly revealed the issues he felt important, and so student attention was focused on those issues. The lesson to an instructor here is that simply asking students systematically about these elements in ways that cause the students to reflect on aspects of their own intellectual development can have the positive outcomes both of informing the instructor about appropriate pedagogical strategies and of facilitating the development of the students.

CONCLUSION

In this chapter, we have introduced intellectual development as a framework for understanding students' dispositions to different learning tasks, particularly tasks that seem in conflict with their own learning expectations or with their worldview, political, religious, or moral stances. This framework provides instructors with additional information for supporting student learning and achievement. Student intellectual development clearly has important effects on the overall approach students take to their own learning, although their intellectual development is a characteristic likely unknown to them. The concluding message of this work is that student performance can be supported by relatively simple but thoughtful interventions, largely regardless of or in spite of student intellectual development. We suggest that careful attention to student intellectual development can profoundly influence both the students' classroom experiences and the instructor's experience. Instead of seeing the students as somehow inadequate, we can see them as deeply engaged with the most central of educational tasks: Moving from passive acceptance to self-authorship and intellectual and ethical responsibility.

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APPENDIX A. ESSAY PROMPTS FOR THE MEASURE OF INTELLECTUAL DEVELOPMENT

Essay A

Describe the best course you've experienced in your education. What made it positive for you? Feel free to go into as much detail as you think is necessary to give a clear idea of the course. For example, you might want to discuss areas such as the subject matter, class activities (readings, films, etc.), what the teacher was like, the atmosphere of the class, the evaluation procedures – whatever you think was most important in making this experience so positive for you. Please be as specific as possible in your response, describing as completely as you can why the issues you discuss stand out to you as important.

Essay AP

Describe a course that would represent the ideal learning experience for you. Please be as specific and concrete as possible about what this course would include; use as much detail as you think is necessary to present clearly this ideal situation. For example, you might want to discuss what the content or subject matter would be, what the teacher/s would be like, your responsibilities as a student, the evaluation procedures that would be used, and so on. Please explain why you feel the specific course aspects you discuss are "ideal" for you.

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Chapter 2

TEACHERS' JUDGMENT FROM A EUROPEAN PSYCHOSOCIAL PERSPECTIVE

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ABSTRACT

The role that school evaluation, diplomas, degrees, educational and career counseling, and the selection and promotion of individuals play in our societies is of such importance that it would be unwise to ignore the mechanisms that form the basis of different types of judgment. The starting point of judgment production is the production of inferences based on information, which implies several steps. The European approach emphasizes that school judgment should be conceived as a psychology of everyday life, where dynamics are rather similar both at school and in everyday activities (Monteil, 1989). The main approaches that could be integrated, in order to obtain a better understanding of the construction process of teachers' school judgment are three: social representations (Moscovici, 1976; Mugny & Carugati, 1985/1989), the socio-cognitive approach to judgment production (Dubois, 2003), and the theoretical grid of levels of analysis (Doise, 1982/1986). According to the latter approach, context could be analyzed at the interindividual, situational, cultural and ideological level. The most important contribution of this analytical distinction refers to the possibility of articulating these levels as sources of possible influence of a variable at a given level on other variables at another level. The approach formulated by Doise provides the framework for presenting a research review on different levels of contextual effects on teachers' judgments. In particular, this chapter will explore research contributions which show that: 1) culturally shared social representations of intelligence in terms of innate gift might influence teachers' judgments of their pupils (Carugati & Selleri, 2004); 2) teachers' evaluations are affected by social norms and causal explanations of pupils' failure vs. success. (Matteucci, 2007); 3) pupils' academic performance normally takes place in complex social contexts (typically classrooms) whose features affect individuals' cognitive functioning (e.g., presence of others, visibility, social comparison, self-categorization processes: Monteil & Huguet, 1999), and may either improve or disrupt such performance, depending on students' past history of success vs. failure in similar

evaluative tasks. Finally, the “key theme” of evaluation in virtual contexts (ICT) will be investigated by exploring the role of technical artifacts as a special kind of contextual determinants of learners' web actions. The “state of the art” of evaluation and new technologies will then be discussed, with a particular focus on which activities can be tracked and evaluated, in relation to the current development of web–tools. (Mazzoni, 2006). While exploring the several contextual factors that are likely to influence education and the production of teachers’ judgment, this chapter will deal with some implications, which refer to practical aspects of teachers’ activity.

INTRODUCTION

The role that school evaluation, diplomas, degrees, educational and career counseling, and the selection and promotion of individuals play in our societies is of such importance that it would be unwise to ignore the mechanisms that form the basis of different types of judgment.

If we were to define the concept of school evaluation and, to this purpose, we asked common people to describe their idea of what is a fair and impartial school evaluation, we would probably obtain quite a predictable response. Such a response would be likely to define evaluation as an operation that may quantify, as much precisely as possible, the level of achievement of a pupil or student as far as a given school performance is concerned. This means that evaluation is generally perceived as performance-focused, and independent of subjective factors related to a certain situation or to the relationship between teacher and pupil. What may be inferred is that the performance of pupils is usually not considered as something that may be influenced by elements other than those directly connected with the cognitive dimension or the knowledge acquired by learning. A deeper insight into this issue, however, would probably reveal that these observations not always prove to be right. They do not apply, for instance, in the case of children at their first school experiences, since they all deserve a reward when they strive to do their best. Moreover, the previous observations do not apply in the case of disadvantaged children, because they may obviously not be compared to other children (e.g., because of disabilities or because they do not speak the same language of their classmates). The objectivity of performance-based evaluation, therefore, seems to face a few challenges already on a non-specialist level of discussion. Numerous studies have actually identified multiple determinants involved in school evaluation, and have shown that evaluation is far from corresponding to a mere performance-based judgment, which is independent of context-related influences.

If we asked the same question to a teacher (i.e., to describe their ideas of what is a fair and impartial school evaluation), we would probably obtain a different response, which would focus, instead, on the variety of factors involved in evaluation. Thus, evaluation in this case would be defined as a complex operation, which takes into account elements related to several dimensions, such as the student’s possible improvement in the course of time, his or her achievement in relation to his or her potentialities, his or her background, the importance assigned to the subject, or also external events (e.g., familiar context, etc.).

In this chapter we will not deal with evaluation as a concept per se. Rather, we will discuss on the production of judgment, while considering that teacher judgment is the first

step within the process of evaluation and that, at the same time, it is at the basis of educational practices.

As a matter of fact, the starting point of judgment production is the production of inferences based on information, which occurs according to several steps. Kruglansky (1990) suggests that there are two paradigms as far as this research domain is concerned. The realistic paradigm focuses on the question of exactness of judgment, which is based on an external criterion, (i.e., external to the judge) which, in turn, is supposed to be objectively valid; the second paradigm, i.e., the phenomenal one, is particularly interested in the process of judgment production, or in its exactness, but it develops starting from the judge's internal point of view. In the case of the realistic/external paradigm the exactness of teachers' judgments of their pupils should be based on the external standardized test. Correlations between standard scores and teachers' judgments constitute the criterion of exactness**.**

The results obtained through this approach (Hoge & Coladarci, 1989) indicate differences related to specific school subjects, specific classes, specific teachers of the same class, and personality traits. The inconsistencies of these results, however, allow few probative conclusions (Bressoux & Pansu, 2003).

While observing the interplay of realistic and phenomenal paradigms (judgment exactness vs. process), several scholars documented the association between judgment (positive vs. negative) variation and pupils' individual characteristics. They noticed that given the same performance, judgment is influenced by several variables: physically attractive pupils are judged more intelligent, attentive, outgoing, according to the idea that 'what is beautiful is good and smart'. Other variables, i.e., school social behavior, previous information (previous school records), and ethnic and social origins, were shown as influencing teachers' judgment.

In other words, these variables seem to play the role of socio-cognitive anchoring points for teachers' judgments as far as the social values of their pupils are concerned, although they may function according to different levels of school systems, and individual idiosyncrasy of teachers. Phenomenal paradigm, therefore, seems to be more adequate, or at least less inadequate, to an in-depth study of judgment production in its complex and different levels of articulation.

School judgment manifests itself in several forms, such as informal remarks, i.e., praise, smiling, feed-back, or formal marks, i.e., school records, vocational guidance. In this sense, the prototype of school judgment, i.e., the mark, represents an objectified form of attributing a social value to students, and plays a major role in the negotiation of the didactic relation, and in the prediction of future school success vs. failure (Selleri, Carugati, & Scappini, 1995).

Moreover, school judgments could be theoretically conceived as the results of three levels (Gilly, 1990): everyday experience (school activities and behavior), teachers' social representations of students' characteristics and behavior within the context of school system (see also Mugny & Carugati, 1985/1989), general social norms (moral values), and norms related to the wider context of school systems (curriculum, general objectives).

Gilly's suggestion introduces the question of what theoretical status should be assigned to school judgment. The European approach emphasizes that school judgment (except for some specificities) should be conceived as a psychology of everyday life, where dynamics are quite similar both at school and in everyday activities (Monteil, 1989). In order to better understand the process of construction of teachers' school judgment, three main approaches could be integrated: social representations (Moscovici, 1976; Mugny & Carugati, 1985/1989), the

socio-cognitive approach to judgment production (Dubois, 2003), and the theoretical grid of levels of analysis (Doise, 1982/1986), which is aimed at organizing the content and the form of empirical research from the conceptual point of view.

This constitutes the theoretical framework of this chapter, which will provide a brief description of these approaches, and will present original empirical contributions.

The first paragraph will illustrate Doise's contribution by means of some examples borrowed from research in various fields of social psychology. The second one will present the results of a research program on social representations of intelligence and development, in order to focus on the originality of this specific European approach to everyday conceptions, and to compare it to the social cognition approach (Carugati & Selleri, 2004).

The third paragraph will offer a brief theoretical sketch of a socio-cognitive approach to judgment production, which has been adopted as framework for empirical research projects, in which the social norm of effort is related to the production of school judgment.

The fourth paragraph will describe further studies, which emphasize the role of contextual factors not only as a determinant of teachers' judgments, but also as a powerful constraint to students' performance in evaluative settings.

The final paragraph will introduce the issue of evaluation within e-learning activities. In this case, a parsimonious approach will be proposed. This consists in an empirical tool, which has been developed according to the theoretical framework of this chapter, and which is aimed at analyzing actual behavior of members of an e-learning activity.

The Conclusion paragraph will then present some general arguments and suggest possible implications for teachers' activities.

1. Levels of Explanation of Teaching-Learning Practices

It is well established that teaching-learning practices are contextually embedded. But when scholars attempt to conceptualize this topic, and to work on that from an empirical point of view, literature offers a huge amount of tools (e.g., Bronfenbrenner's person-in-context model and Bruner's cultural psychology). A key contribution is offered by Doise's European approach (1982/1986) in terms of four levels of explanation and analysis of experiments and social practices. According to this approach, context could be analyzed at the intra-individual, inter-individual, situational, and cultural/ideological level. Such an analytical distinction allowed to articulate these levels as sources of possible influences on each other. In order to inscribe the presentation of empirical research within a theoretical framework, a brief sketch of Doise's four levels will follow.

At the intra-individual level, research describes how individuals organize their perception, their evaluation of social milieu, and their behavior within this environment. In such approaches the interaction between individual and social environment is not dealt with directly, and only the mechanisms by which the individual organizes his/her experience are analyzed. Different approaches have been proposed: research on cognitive development within the Piagetian tradition; balance theory; cognitive dissonance and social categorization theories; attribution theory; and the general approach of social cognition are some cases in point (Fiske & Taylor, 1991). Other examples concerning adult ideas about child rearing or education and intelligence have been studying within the framework of beliefs systems,

everyday cognition, and lay conceptions (Carugati, 1990a, 1990b; Carugati & Selleri, 1998, 2004). As far as school judgments are concerned, as conceived in the framework of realistic and phenomenal paradigms (Kruglansky 1990), a considerable amount of research has produced evidence about the accuracy of teachers' judgment about pupils' performance on standardized tests. Through the correlations between judgments and scores, Hoge and Coladarci (1989), by means of a meta-analysis of 16 studies, show a variation between .28 and .92 (median .66), which reveals important differences related to specific school subjects, classes, and teachers of the same classes. In the same vein of intra-individual level, some scholars have introduced the notion of high bias vs. low bias teachers (Bressoux & Pansu, 2003).

A second level of analysis focuses on interpersonal processes as they occur within a given situation or event. At this level, the different social positions that partners occupy outside a specific event are not taken into consideration. The object of study is represented by the dynamic relations between partners at a given moment, in a given situation. Partners, moment, and situation, however, are seen as interchangeable factors. For instance, the communication network studied by one of Lewin's co-workers, i.e., Bavelas (1950), is an old paradigm that adopts this second analytical approach. Networks of this type have often been employed to show how the different communication systems, which may exist between people, allow a more or less efficient organization of the available information in a context of problem solving. Another pupil of Lewin, i.e., Kelley (1967) employs a theoretical model – attribution theory – which essentially belongs to the level of interpersonal relations as well. In order to explain how people attribute intention to one another, he suggested a model based on analysis of variance, which takes account of the consistency of other people's behavior in different situations. Examples of research on social interaction in individual development are to be found in, e.g., Carugati & Gilly, 1993; Doise & Mugny, 1997; and Perret-Clermont, 1979/1980. In their research paradigm, social interaction between children is studied as independent variable within the experimental design, in order to study its causal effects on specific content of cognitive development (i.e., Piaget's "concrete operations", i.e., length, weight, space, number, etc.).

A third level of analysis, which considers the effect of differences in the social position of interacting partners, has developed since mid '50s. In the first experiments about pre-existing status differences in persuasion between partners (Thibaut & Riecken, 1955), subjects were required to persuade two other subjects, which were involved in the same experiment, to donate blood to the Red Cross. These two other subjects were actually confederates: one was introduced as a person, whose status was higher than that of the target subject, whereas the other was presented as a person, whose status was lower than that of the target subject. Each time, such confederate subjects would let themselves be persuaded by the 'genuine' subjects, who completed a questionnaire about these companions, both at the beginning and at the end of the session. Results showed that subjects believed that the low-status partner had really been convinced by their arguments, whereas the high-status partner was seen as more autonomous and as acting independently, according to his/her personal decision.

All variations introduced into an experimental setting, however temporary or limited, could be affected by pre-existing dynamics and thus tell us something about their nature. Frequently, the effects of the variables taken into account in an experiment can only be studied in terms of changes in the pre-existing dynamic. At a theoretical level therefore, we should articulate third-level explanations (i.e., sociological ones) and second-level

explanations, which deal with the specific experimental situation. Another example is provided by a research on the effects of social comparison, and of the labeling of pupils of French compulsory school (14-16 year-olds) in terms of school success vs. failure in school performance (Huguet, Dumas, Monteil, Genestoux, 2001; Monteil, 1989). Pupils, whose performance in biology was differentiated according to two levels, were requested to attend a class of biology: half of them were warned that at the end of class they would be questioned about the class topics (visibility condition), whereas the other half received no such warning (anonymity condition). What resulted was that high-level pupils in the anonymity condition performed worse than their peers in visibility condition, whilst low-level pupils performed better in anonymity than their peers in the visibility condition. As for teachers' judgment, it was shown that judgments and school marks were more severe according to college reputation (high-level colleges: Bressoux & Pansu, 2003, p. 19).

The fourth level (cultural/ideological) refers to the well-established assumption that every society develops, shares, and tries to transmit to new generations its own ideologies, systems of beliefs, representations, values and norms, so that the established social order may be legitimated and maintained. An example of such a belief is that which holds that positive and negative sanctions are not distributed by chance. This is the main principle at the basis of Lerner's research (1971), which asserts a general belief in a 'just world'. His investigations manipulated situational variables: subjects took part in a learning experiment where electric shocks were inflicted on a student who made mistakes (defined as the 'victim').

This 'victim' might or might not receive a fee; he might or might not expect further suffering: these variables had an important effect on subjects' attitudes toward the victim. These attitudes were more depreciative in those cases in which the victim had to carry on suffering, or in which he received or did not receive fees. The basic explanation proposed by Lerner is that subjects themselves are profoundly convinced that the world they live in is just, and that people who suffer must deserve their fate. Recent literature on victimization is based on a similar assumption (Perez, Moscovici, & Chulvi, 2007). Milgram (1974) invoked the prestige of science in his attempt to interpret his results, i.e., the fact that subjects who were randomly recruited through newspaper advertisements were ready to torture others when the experimenter insisted that they did so: '*the idea of science and its acceptance as a legitimate social enterprise provide the overarching ideological justification for the experiment* '(p.142).

Institutions such as business, churches, governments, and educational systems provide a huge amount of legitimate realms of activities, each of which are justified by these values and needs of society. From the standpoint of everyday life, people (potentially) accept this legitimization because they exist as part of the world into which they are born, and in which they are raised. Berger and Luckmann (1966) have provided a convincing theoretical framework of the dynamics of legitimation in modern society, as a part of the social construction of reality and of socialization processes. Puzzling enough, these widespread beliefs lead to the justification for whatever happens to the people who inhabit in this part of thinking society. It is this conviction of universal applicability, which paradoxically lays the social foundation for social differentiation and discrimination.

2. TEACHERS' REPRESENTATIONS OF INTELLIGENCE AS A SOCIAL CONSTRUCTION

Elsewhere we have extensively presented arguments and empirical research in favor of the idea that a number of objects of research, which have stimulated studies for many decades, could be framed at the fourth level of analysis (Carugati, Selleri, & Scappini, 1994; Mugny & Carugati, 1985/1989). It may be argued that almost everybody agrees in placing a positive value on intelligence, which is seen as a social value of prime importance. We know that the term does not refer to any single concept or theory. Indeed, it can fairly be said that there are as many definitions of intelligence as there are scholars or school of thought claiming to define it scientifically. Intelligence lends itself to a great number of different approaches. Thus, we often take for granted a topic, which is still the subject of much discussion. Such a discussion is mainly focused on the nature of intelligence and its development. It is well-known that different fields of study do not come to an agreement as far as these two dimensions are concerned. In spite of this, however, the word "intelligence" is used very often, particularly in school contexts, and most of all when pupils' school results are poor, lacking, and far from expectations. When the school failure of some students of a given class is constant, teachers often evoke the lack of intelligence in order to provide a temporary explanation to this insufficient performance. This occurs especially when the distribution of school marks in that class shows a majority of high-performance students as against a minority of low-performance students. The idea that teachers have about the nature of intelligence, therefore, becomes a relevant starting point of their activity. As a matter of fact, the lack of intelligence can be defined, on the one hand, as a lack of a specific natural gift, which is differently distributed among people. In other words, it may be defined as a "*mysterious problem which science has been unable to solve"*(Mugny & Carugati, 1985/1989). On the other hand, however, this lack can be explained as a feature that is likely to be more or less developed by virtue of human and material resources that characterize the socio-cultural environment in which subjects are embedded. The difference between these two approaches is relevant: the first one sees intelligence as defined by nature, whereas the second one considers intelligence as part of a developmental process, in which it is nurture that plays a more significant role.

In light of a student's school failure (level 1), then, teachers are pushed to account for this fact, especially if the student is very young, because each school system (level 4) requires a systematic activity of evaluation. Moreover, the same school system obliges teachers (level 3) to make any possible effort to remove as much obstacles as possible from the learning process of students.

At this point, is it possible, and legitimate, to hypothesize a relationship between teacher's ideas and representation about the nature of intelligence (level 4), and their everyday school activity (level 2)? This point deserves more in-depth analyses.

Our theoretical reference is the theory of social representations, and particularly the culturally shared social representations of intelligence, i.e., a specific empirical approach which has been developed during the last 20 years (Carugati, 1990a,1990b; Carugati & Selleri, 2004; Carugati, Selleri, & Scappini, 1994; Mugny & Carugati, 1985/1989).

What does "social representations" actually mean? Drawing from a vast amount of research, which began with Serge Moscovici's masterpiece about psychoanalysis in French

culture (1976), it could be suggested that every representation tends to turn or transform an unfamiliar thing (for instance the scientific object like psychoanalysis, or the nature of intelligence) into something familiar. Consensual universes are universes where each of us wants to feel at home, sheltered from areas of disagreement and from incompatibility. We are confronted with the dynamics of familiarization of the strange whereby objects, individuals, and events are recognized and understood on the basis of prior encounters or models. As a result, memory tends to predominate over logic, the past over the present, the verdict over the trial.

The basic tension between the familiar and the unfamiliar is resolved in our everyday consensual universe in favor of the familiar. This is why conclusions have primacy over premises: before seeing and listening to someone, we make a judgment on him/her, we categorize him/her, and we form a mental image of him/her. Such mental categories are not merely cognitive abstractions, but are essentially social in character.

Furthermore, as it has been already shown (Carugati & Selleri, 2004**;** Mugny & Carugati, 1985/1989**)**, representations of intelligence are related to educational practices, which are supposed to be more or less effective in coping with difficulties in learning. As a matter of fact, the main result of the original research was that teachers who perceive intelligence as an inexplicable faculty organize their conceptions of intelligence in terms of gift, and thus are more confident in educational practices in terms of severe evaluation and competition.

A recent contribution (Carugati & Selleri, 2004), aimed at verifying the first results (Mugny & Carugati, 1985/1989) after 20 years, tested the hypothesis that the inexplicability of intelligence is the anchoring point in building up a representation of it in terms of a gift unequally distributed among pupils**.** In other terms, our attempt was that of confirming the previous results through a study on a sample of female teachers who work in Italian elementary schools, junior high schools, and high schools.

Drawing on the original questionnaire, we used a sample of items about intelligence and educational practices, which has been shown as the most representative of the organization of teachers' representations (cfr. Selleri, Carugati, & Scappini, 1995).

As for intelligence, we have verified the consistency of a theory of intelligence as a natural gift, associated with the idea of natural inequalities.

In order to operationalize the influence of inexplicability of intelligence, we used the following item as independent variable: "*The existence of differences of intelligence between individuals is a mysterious problem, which science has been unable to solve"*.

According to the frequencies of the above mentioned item, a new variable was produced, i.e., "Mystery", with two modalities: "negative mystery teachers" (1-2 frequencies: teachers who don't agree with the content of the item) and "positive mystery teachers" (4-5 frequencies: teachers who agree that intelligence is inexplicable). This new variable has been employed as independent variable for analyzing the influence it exerts on factors of intelligence and educational practices.

The socio-cognitive organization of teachers' representations fits almost perfectly in with previous results (Mugny & Carugati, 1985/1989): a core of representations of intelligence and educational practices still persists. The first apparent result is the pervasive influence of the subjective sense of inexplicability of intelligence on the way teachers are positioned: as for intelligence, the *positive mystery teachers* are more likely to agree with the idea of gift, conformism, severe assessment.

As far as educational practices are concerned, results show a similar sketch. The first elements that emerge as relevant within educational practices refer to the construction of an *environment, which is favorable to learning* (e.g., trust in pupils; dialogue between teacher and parents; feedback; and the creation of a positive atmosphere in class); the second ones are related to a type of activity, which may be defined as oriented towards the *promotion of awareness as far as the reasons of failure are concerned* (e.g., encouraging pupils with low performance to work in small groups, or also together with a class mate with higher school performance; teaching him / her to be more precise and hard-working; and stimulating him/her by means of frequent tests and consequent evaluations); the third is based on *social comparison* as a stimulus for improvement (e.g., promoting the pupil's competition with his/her classmates, promising him/her a reward in the case of better achievement, showing him/her that his/her school performance is lower than that of his/her classmates, assigning more homework).

3. SOCIAL NORMS INFLUENCING TEACHERS' JUDGMENT

The study of how teachers' social representations of intelligence influence educational practices is a good example of Doise's "ideological level". As a matter of fact, Doise (1982/1986, p.15) argues that every society and institution develops not only systems of beliefs, such as social representations, but also values and norms which legitimate and maintain the established order. Among the several institutions are those involved in the education system. We may therefore hypothesize that these norms and values influence teachers' judgments and their evaluations. The evaluation of achievement in school contexts may actually be considered as a kind of social judgment which is influenced by social and moral norms, since it is not merely an estimation of pupils' accomplishments. Two main theoretical approaches, i.e., the norm of internality (Beauvois & Dubois, 1988), and the attributional approach as conceptualized by Weiner (2006), have explored the social and moral determinants of teachers' judgment. In particular, these two theories base their analysis on the perceived causality of school failure or success, or on the causes that pupils indicate in order to explain achievement-related events. As a matter of fact, several studies prove that pupils and teachers, in their answers to questions asking for specific reasons of either successful or poor school results (e.g., *"Why did I fail the math test?"*, *"Why am I good at geography but not at mathematics?"* or, from the teachers' point of view, *"Why did this pupil obtain such a poor performance?"*), typically make use of internal vs. external causal attributions. Examples of internal attributions are those based on ability (i.e., cognitive abilities, aptitudes, skills or expertise), or on effort expenditure on schoolwork (i.e., commitment, dedication, diligence, etc.). Although other internal or external causes can be held to explain school results (e.g., external causes: task difficulty, help or hindrance of others; internal causes: personality, health, etc.), effort and ability supremacy as causes for success and failure have been proved on several occasions (Flammer & Schmid, 2003; Weiner, 1985).

Drawing on the notion of social norm as a prescriptive standard and an evaluation principle based on the social utility of observable events (behaviors and reinforcements), the social norm of internality has been defined as the "*social valuing of judgments that*

accentuate the causal weight of the actor in what he/she does (behaviors) and in what happens to him/her (outcomes and reinforcements), to the detriment of judgments that minimize that causal weight" (Dubois, 2003, p. 249). Within the framework of this theoretical perspective, pupils' internal/external causal explanations have been proved to affect teachers' judgments even in presence of other relevant information, e.g., parental socioeconomic status (SES) and pupils' achievement level (Dubois & Le Poultier, 1991). Indeed, pupils who express internal explanations (or who are supposed to use internal explanations), receive predictions about school success which are more favorable than those ascribed to pupils who provide external or "blended" (i.e., internal and external) explanations (for a review: Pansu, Bressoux, & Louche, 2003).

Thus, tenants of this approach maintain that it is the social norm of internality that represents one of the possible determinants of teachers' judgments, by virtue of the social utility that this type of explanation is associated with. Social utility is defined as the known suitability of the person to the options that characterize the social functioning of the system to which the collective belongs (Beauvois, 2003, p.251). As a result, pupils' internal explanations of certain events in school contexts may be considered as more useful, since they attribute the possible responsibilities of failure to students themselves, instead of attributing them to teachers or the school institution.

The attributional approach to social motivation (Weiner, 2006) has offered a significant contribution to the understanding of the role that causal explanations play in the formulation of teachers' judgment. Studies carried out within this approach have particularly emphasized the role of effort in influencing teachers' judgment (an internal cause, which the individual is able to control). As a matter of fact, several studies have revealed that, in achievement contexts, high effort is rewarded, whereas lack of effort is punished (for a review: Weiner, 2006). In particular, in case of school failure, teacher feedbacks are more positive – or less negative – towards those pupils who make effort, rather than towards those who do not make effort, and who obtain equivalent performances (Matteucci, 2007; Matteucci & Gosling, 2004).

Using a metaphor, Weiner (2006) compares life to a courtroom, where the person is a judge who must rationally interpret evidence and reach a decision regarding daily transgressions. In a similar manner, the classroom may be considered as a courtroom, and achievement evaluation as a sentence in which inferred ability and effort expenditure are the principal determinants. Experimental outcomes obtained over about thirty years, led Weiner to the view that performance evaluation is based on moral principles, which are shared and are typically linked to the school context.

Weiner (1995) argues that it is because of the «work ethic» deriving from the Protestant Ethic that effort is made in order to achieve excellence, as far as our Western culture is concerned. Thus, everyone should make an effort and work hard – in life as well as in school. The principle that derives is that pupils must put effort into learning, and try to perform as well as possible in school activities and exams. A student that fails because s/he does not make efforts in order to succeed is judged responsible for the negative outcome that s/he obtains and must therefore "respond" to others.

Both of these theories represent examples of Doise's approach to the "ideological level", since they illustrate how beliefs, values and norms of an institution, such as that of school, may influence a process that apparently develops only at the intra-individual or inter-individual level, i.e., teacher evaluative feedback.

Although they share a few common aspects, these two theories differ on some points. On the one hand, attribution theory as discussed by Weiner (2006) is founded on an analysis of folk explanations of causes related to certain outcomes. That is, his analysis begins with a specific outcome, and people are invited to explain end results or consequences rather than actions. On the other, the norm of internality theory deals both with outcomes and behaviors. This means that the causal explanations provided do not concern a specific outcome – as is the case of Weiner's research - but rather a series of hypothetical events presented by means of a questionnaire. Thus, the judgment that follows is not an evaluation or a feedback on an outcome, but it is typically a prognostic for future success/failure.

A further difference may be identified when it comes to the discussion of the norm or value that is considered to be at the basis of the results obtained. According to researchers focusing on the internality norm, the subjects' internal explanations deserve more value and appreciation. They are therefore more likely to encourage positive judgments, despite the performance level, because they are based on key constituents of individualism, which is a central theme in Western culture and society. Weiner suggests that causes attributed to succeeding or failing elicit judgments on responsibility which, together with negative emotions such as shame and anger, are likely to influence judgments. This process is guided by a sort of "ethic of work" that characterizes Western societies, and, on a more general level, by a moral judgment on responsibility related to negative events.

Today, the debate on these two theories, as far as the role of effort is concerned, is still open (Pansu & Jouffre, in press). Should it be considered as an internal cause, and thus as the vehicle of values as maintained by the theory of internality norm, or should it be seen as a cause that the individual may control, and that therefore elicits positive vs negative judgments, depending on the type of event to be explained (success vs failure)? Research is being carried out in order to provide further elements to be integrated into these two theories, and in order to obtain a clearer view on the fields of application. In one of our recent studies (Matteucci, Tomasetto, Selleri, & Carugati, in press), a sample of teachers was asked to judge target-pupils on the basis of some information, including their answers to an attributional questionnaire. Results show that two different judgments (evaluative and prognostic) made by teachers are more favorable in the case of internal-effort condition than in that of the other two conditions, i.e., internal-ability and external explanations. In spite of that, our results do not entirely confirm the theoretical scheme of Weiner on sanction connected to the pupil's lack of effort, because both positive (school success) and negative (school failure) events were included in the profile judged by teachers. However, it should be emphasized that teachers were here asked to express judgments on the basis of causal explanations provided by pupils in a pre-filled questionnaire, which did not concern a specific outcome, but a series of hypothetical events.

In other words, when teachers have to express a judgment on a specific negative event (i.e., school failure) which is explained in terms of lack vs presence of the pupil's effort, they deal with effort as a cause that plays a key role in determining responsibility, and thus the sanction or reward. Moreover, when they have to express a judgment, not on the basis of direct explanations referring to that event, but on the basis of explanations referring to various types of hypothetical events provided by a pupil through a questionnaire, and which may thus be associated to a general explanation and interpretation style of certain facts, the pupil's use of effort in causal explanations is appreciated, regardless of the fact that the event to be explained is a school success or failure.

A possible interpretation may be linked to one of the teachers' missions, i.e., children's socialization with moral and social rules (e.g., Wentzel & Looney, 2007). Besides transmitting knowledge, teachers also encourage children to develop a set of values and standards that are supposed to orient their behavior and define the goals they strive to achieve. As a result, it may be suggested that teachers should disapprove and punish those pupils that fail at school because of lack of effort. Conversely, they should praise those who demonstrate to be aware of the importance of effort in achieving a successful outcome, and who express this belief through their answers to the questionnaire.

Summing up, both of these theories confirm the idea that social norms and/or values – which characterize school contexts – affect teachers' judgment and, therefore, they are promoted by teachers themselves in the course of processes of socialization and by means of reprimand (i.e., negative evaluation) and reward (i.e., positive evaluation). In our opinion, a general promising interpretation about the role of norms in the production of judgments considers effort as a valued concept in school context. In other words, we would like to suggest the idea that effort should be considered as a specific norm which characterizes the school context, and thus intervenes in the production of school judgments.

4. Being Evaluated in the Classroom: Contextual Influences on Students' Performance

The role of contextual factors should be taken into account not only as a determinant of teachers' judgments, but also as a powerful constraint to students' performance in evaluative settings. In other terms, specific features of the school context may affect not only the way in which teachers evaluate students' performances, as we explained above, but also the way in which students themselves perform when being subject to evaluative activities at school.

We will now consider the physical environment in which school evaluation normally takes place: whether in the form of written tests or oral examinations, evaluation activities mainly occur in the classroom, and therefore the pupils/students to be evaluated are required to produce their performance in presence of a certain number of schoolmates. Although such a condition may appear trivial, it should not be overlooked that the effects of the mere presence of a coactor (even in absence of any kind of interaction with him/her) on individuals' cognitive functioning have been at the center of an overwhelming amount of research in experimental social psychology, which dates back from Zajonc's drive theory (Zajonc, 1965, 1980). More recently, the distraction-conflict theory (Baron, 1986; Muller, Atzeni, & Butera, 2004), moreover, has illustrated that when other people are present and share the same situation, part of the individual's attention is dedicated to the elaboration of the information related to the presence of such coactors – although this kind of information is irrelevant for the accomplishment of the task. Since complex tasks normally require individuals to spend as much cognitive resources as possible, in order to attain a satisfactory result, it may easily be argued that the distraction caused by the coactors' presence may interfere with individual cognitive performances. In particular, Baron (1986) contends that in such situations the limited amount of available resources is dedicated to the scrutiny of the most central elements of the task at hand, whereas all the peripheral cues are ignored.

As well as Zajonc's theory, also the distraction-conflict model postulates that the presence of others may either enhance or disrupt individuals' performance, depending on the features of the task at hand. As a matter of fact, the focalization of attention on the central cues may actually be more helpful in those tasks, in which central elements are essential for achieving the right solution. This is the case, for instance, when the teacher inserts a number of irrelevant distractors within the task, and the ability expected from the pupil is that of identifying, among the several distractors, the relevant information which may then lead to the correct solution. Thus, enhanced focalization on central elements may undoubtedly be considered useful to the pupil. Unfortunately, similar tasks are not so common in daily school practice (Huguet, Galvaing, Monteil, & Dumas, 1999). Rather, teachers often expect students to be able to integrate pieces of knowledge drawn from different sources, to provide critical interpretation of available information, to apply knowledge to new domains in a creative way, etc. Indeed, in all these cases the focalization effect induced by a coactor's presence is absolutely detrimental to the students' performance (Monteil & Huguet, 2001).

An extension of Baron's theory has been proposed in the last few years by Muller et al. (2004), which maintain that above and beyond the mere presence of others, the focalization effect is due to the pervasive human tendency to engage in social comparisons with other people. In fact, the other individuals which are simultaneously present in the evaluative context are not only persons who capture our attention with their physical presence, but are also the most easily available targets against which we can evaluate the adequacy of our own performances. In the view of Muller et al., the coactors' presence in the same contexts captures attention only when it is, or may become, threatening to the individual. According to the social comparison theory (Festinger, 1954; see also Guimond, 2006), a threat may arise any time an individual compares his/her own performance with that of a coactor who is, or may even potentially be, superior to him/her. Such a threat absorbs part of the individual's attentional resources, which, therefore, may not be employed for an effective task accomplishment. In line with this premise, Muller et al. (2004) found that, in a laboratory setting, participants' performances on a perceptual task were subject to a focalization effect either when the present coactor was declared to be more competent than them, or when no information was provided concerning the performance of the coactor. On the contrary, this did not occur when the participant was assured that the coactor was less competent than him/her. However, this latter condition is quite unlikely to occur in real school contexts, since almost no student (except for the highest achievers) may be completely confident that nobody else in the classroom will outperform him/her. By consequent, the mere presence of others is very likely to absorb attentional resources, and therefore to prevent individuals from performing at their best during the evaluative activity, particularly in those tasks which require decentration, open mindedness, and the ability to collect and integrate different pieces of information (Butera & Buchs, 2005).

All the above mentioned studies deal with the possible effects that the physical presence of other students in the same setting may exert on individuals' school performance. In all these cases, schoolmates act as a potential target of social comparison, and therefore as possible sources of comparison threat, at an inter-individual level (Level 2 in Doise's terms): the coactor becomes a source of evaluative threat because s/he is, or may potentially be, more proficient. If we move one step further, we may consider that coactors are not only individuals, but are also members of social groups, and groups are often stereotyped as holding or lacking specific intellectual skills. Therefore, social interaction in school setting

does not simply occur between one person and a coactor, who may turn out to be more or less competent in a given topic, but involve also involve an intergroup level: i.e., the interaction between me - as a member of a certain social group - and a coactor - as a member of another group (Level 3 in Doise's terms). Indeed, problems may arise when the other group is stereotyped as holding certain cognitive skills at a higher extent than my own group.

In the last few years an increasing body of research has dealt with the phenomenon of stereotype threat (STT, Steele & Aronson, 1995). STT refers to those situations in which, when social identity is made salient, members of groups that are stereotyped as lacking highly valorized cognitive abilities (e.g., women or ethnic minorities stereotyped as lacking math skills) have their performance disrupted on tasks presented as diagnostic of those specific abilities (Spencer, Steele, & Quinn, 1999). Research has shown that the activation of STT increases physiological arousal (Croizet, Després, Gauzins, Huguet, Leyens, & Méot, 2004), induces negative self-referred thoughts (Cadinu, Maass, Rosabianca, & Kiesner, 2005), reduces the working memory capacity (Bonnot & Croizet, 2007; Schmader & Johns, 2003), and also activates cortical regions devoted to the elaboration of social-emotional information rather than those involved in task-related processing (e.g., in math learning; Krendl, Richeson, Kelley, & Heatherton, 2008). In turn, all these factors are responsible for performance impairment in cognitive tasks. It is also worth noting that STT has been shown to disrupt female pupils' performance in math or pre-math tasks as early as at the transition between kindergarten and primary school (Ambady, Shih, Kim, & Pittiski, 2001; Neuville & Croizet, 2007; Tomasetto, Alparone, Rizzo, & Berluti, 2008).

Interestingly, STT appears to disrupt performances at a deeper level when members of the comparison group (i.e., the group stereotyped as being more competent at the task at hand) are physically present in the same setting (Inzlicht & Ben-Zeev, 2003; Sekaquaptewa & Mischa, 2003). Indeed, real mixed-gender classrooms are an excellent example of settings in which members of a group that is stereotyped as lacking math skills – namely, female pupils - undergo evaluative tasks in math in presence of members of a group stereotyped as holding those skills at a higher level – namely, male pupils. As expected, in a recent study Huguet and Régner (2007) have demonstrated that female pupils aged 10-12 had their performance thwarted at a math-related task when they were tested in mixed-gender classrooms, compared to a same-sex condition.

The experimental evidence reported in the above paragraphs is not meant at representing an argument, neither against the presence of schoolmates in the classroom, which would simply be an absurd option, nor against mixed-gender classrooms (segregating males and females may actually contribute to further enforcing the strength of existing gender stereotypes, rather than helping members of stigmatized groups). Rather, such evidence simply stresses the fact that individuals' cognitive performances are always embedded in a complex system of interpersonal and intergroup relationships, and that even apparently trivial features of the contingent situation – such as the mere presence of others in the evaluation setting – may unwillingly interfere with students' performance. By consequent, teachers should not overlook that not only the content of the task, but also the context in which the task is undertaken, concur to the quality of students' performance, irrespectively of their actual level of skills or learning.

5. A PROPOSAL FROM SOCIAL NETWORK ANALYSIS FOR EVALUATING ACTIVITIES IN E-LEARNING ENVIRONMENTS

In the previous paragraph we have focused on the influence that the second level of analysis has on the understanding of contextual factors. In particular, we have observed the influence of social interaction in school settings, which results in a series of moderating effects on students' performance in evaluative contexts. However, social interactions play a significant role also for defining, on the one hand, the relational structure that characterizes a class of students (which may be based, for instance, on collaboration, social support, information exchange) and, on the other hand, the students' social status and their role in this relational structure (Bronfenbrenner, 2004). Again, we can refer to the second level of analysis, when Doise (1982/1987) introduces the paradigm of the communication network that "*ha[s] often been used to show how the different communications systems which may exist between a number of people allow them to coordinate the information available in a more or less efficient way in problem solving*" (p. 12). Even if this paradigm is dated, since it derives from Moreno's sociometry (1951), which was developed during the Thirties and Forties, and from Bavelas' studies, which were carried out in the Fifties (1948, 1950), there is now a lot of interest on Social Networks Analysis applied to Web Communities and, specifically, to Web Communities in Educational and Vocational Environment (Freeman, 1986; Garton, Haythornthwaite, & Wellman, 1997).

Web communities are one of the two key aspects of e-learning; the other is constituted by the so called Learning Objects. These two different key aspects are also representative of different ways of conceiving knowledge transmission and construction in e-learning environments. In everyday discussions, and often improperly, the concept of e-learning (*electronic-learning*) involves multiple aspects of distance education, which range from content selection to the organization and coordination of specific on-line courses.

On the one hand, e-learning may be identified principally with forms of learning and training which are essentially based on interactions between group or community members: *Communities of Practice* (Wenger, 1998), *Knowledge Building Communities* (Scardamalia & Bereiter, 1994), *Learning Communities* (CTGV, 1993), *Communities of Learning and Thinking* (Brown & Campione, 1990), *Communities of inquiry* (Lipman, 1991). Learning processes that lie behind this mode of conceiving e-learning found their theoretical references on socioconstructivism (Doise & Mugny, 1997) and sociocultural approach to human cognitive development inspired by Vygotskij. From this point of view, individual cognitive development is conceived as a result of social interaction in which:

- the support and the sustain of either adult or expert peer partner is a decisive factor;
- there is the simultaneous presence of different points of view, and the consequent necessity of a negotiation of meanings of the task**),** (cfr. the notion of *sociocognitive conflict*; Doise, Mugny, & Perret-Clermont, 1974; see also Carugati & Gilly, 1993).

On the other hand, e-learning is also conceived as pure transposition via web of typical educational models of face-to-face classes. According to this approach, learning is conceived as a mere content supply. Therefore, the "e" component (electronic) refers only to the content in terms of design, supply and fruition. This is the case of Learning Objects, by which one

tends "to break educational content down into small chunks that can be reused in various learning environments, in the spirit of object-oriented programming" (Wiley, 2000, p. 7). Thus, content selection, construction and organization by educators, and content supply by web artifacts, become the very critical phases for learning processes. This idea of content modularity emerges from approaches that remind us of Mastery Learning years, which derived from that behaviorist technology, which Block (1974) proposed as the new promise for "teaching everything to everyone".

Summing up, we may suggest that it is possible to find the same ideas and representations of developmental and learning processes both in e-learning and in "presence" situations if we consider the following two points, i.e.: a) that knowledge is elaborated "in the mind" of the single person for being then used in the interaction with others, or b) that knowledge is constructed during interaction with others as a "collective mind", which is external to the single person, and which will be interiorized and elaborated by individuals only in a second moment.

Both of these two conceptions of e-learning require a change of perspective, i.e., a passage from "what students do in an e-learning environment" to their evaluation. Such a change is now taking place by means of the monitoring of students' actions within a web platform. When we refer to actions, we consider the perspective of Leont'ev (1978) about human activity, in which activity is seen as always collective and sustained by some social motive or necessity. Each human activity is constituted by individual actions, which are achieved by individual or groups, and directed to specific goals. Each individual action consists of operations, i.e., automatic acts without a voluntary control performed by the individual in the execution of some action. Since actions could be performed by a single person (e.g., the student's utilization of the resources proposed by the teacher in web platform), but also by a group (e.g., the discussions in a web forum), we can consider actions as individual (a student interacts with contents through web artifacts, e.g., a web platform) or as collective (a student interacts with other students through web artifacts, e.g., a web forum). In all of these cases, such actions related to the student's activity may be considered in terms of competence acquisition, because they are aimed at using web artifacts for knowledge acquisition (as is the case of individual actions), and at managing on-line interactions with others for collective knowledge, sharing and construction (as is the case of collective actions). If we consider the importance of competences and *learning outcomes* in *Dublin Descriptors*, and, at vocational level, the *Lifelong Learning Programme 2007-2013* launched by the European Union, in which web technologies are seen as one of the key tools for achieving the objectives of the programme (Pépin, 2007), we may easily realize that this issue is crucial not only in the field of academic research, but also in the field of professional training as defined by European policies.

Starting from these considerations, how can we monitor students' on-line activity in both individual and collective actions?

A quantitative technique for data collection about "what user do" in an on-line environment is to be identified in the web tracking (Calvani, Fini, Bonaiuti, & Mazzoni, 2005; Mazzoni, 2006, Proctor & Vu, 2005). Through web tracking it is possible to collect a number of details about the frequency of visits and time spent on web pages during the navigation on a web artifact (e.g., web site or web platforms). This data collection technique is a feature that we can find in almost all of the existing web platforms, and it is also provided by the Italian legislative decree concerning Distance University as a means for monitoring

and evaluating students' on-line activities. If, on the one hand, we can consider web tracking as a good technique for collecting data about individual actions, i.e., about the frequentation and the usage of web contents (Learning Objects) by students, we cannot affirm the same as far as the application of this technique to web communities is concerned. Of course, web tracking allows us to collect data on interactions between students, which may consist of, e.g., sent or received messages and sent or received replies. However, these data refer to individual characteristics (how many messages a student has sent, received, etc.) and do not provide any indication about addressees. Relational aspects, therefore, are not taken into consideration within the rough data collected by web tracking. Nevertheless, this information is available. In other words, web tracking may be employed also in order to collect data about to whom a message/reply is sent, and about the identity of the receiver of a given message/reply (the so called *relational data*), but these data are normally used only for summing and displaying the quantity of messages sent and received by single students. From this point of view, data obtained from web tracking could be used for analysis positioned at the first level proposed by Doise.

Now, if we consider web groups or web communities in e-learning environment, we have to consider that the final outcome of a collective activity does not derive from simple individual actions, but principally from collective actions performed by the online group or community. In this case we consider individual actions as separated from collective actions, and we have to take into account that group performance does not derive from a sum of individual actions, but rather from indicators that allow us to map the collective actions of an online group or community.

As previously outlined, relational data of web group/community could be collected by web tracking; this possibility, besides facilitating the application of quantitative analysis, allows to construct the adjacency matrix (Figure 1) of relational data for applying the Social Network Analysis (SNA) to group exchanges.

Starting from the transposition of relational data in a matrix, SNA allows, on the one hand, to graphically represent the network of relations by sociograms and, on the other hand, to analyze this network on the basis of notions that allow to describe the relevant communicative structure. Now, a very interesting aspect is that we can develop an analysis on two levels, i.e., by focusing on the single members and their relations in the network (*ego-centered analysis*) or by focusing on the network and its structural characteristics (*whole network* or *full network analysis*). Obviously, these two aspects are related. This means that for each whole network structural indexes we have also specific individual measures.

E.g., the density of a network, i.e., "*the proportion of possible lines that are actually present in the graph*" (Wasserman & Faust, 1994, p. 101) or more simply the percentage of aggregation of its members, derives from the degree of each member, i.e., the totality of direct contacts he/she has activated or received by others. Considering the centralization, i.e., the dependence of a network from its "most important" actors, we have, together with this whole index, also the centrality index of each member, i.e., his/her importance/prominence for the communicative structure. Thus, these related networks and individual measures allow us to perform map description of collective actions of a community. On the one hand, we can monitor and depict the role and function of each member in the community knowledge exchange (e.g., wideness and aggregation of his/her neighborhood or direct contacts, central or peripheral role in information exchanges/transmission, participation in subgroups, etc.); on

		Receivers					
		Stud1	*Stud2*	*Stud3*	*Stud4*	*Stud5*	*Stud6*
Senders	Stud1	0.0	0.0	3.0	4.0	0.0	0.0
	Stud2	0.0	0.0	2.0	0.0	0.0	0.0
	Stud3	3.0	4.0	0.0	0.0	0.0	0.0
	Stud4	2.0	0.0	3.0	0.0	0.0	0.0
	Stud5	0.0	0.0	0.0	0.0	0.0	0.0
	Stud6	1.0	3.0	2.0	2.0	0.0	0.0

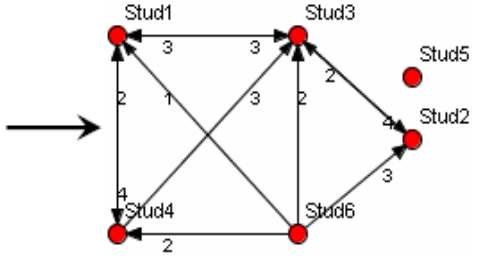

Figure 1. Adjacency matrix of exchanges between students in a web forum and sociogram representation by NetMiner[1].

the other hand, we can monitor the group/community while considering the aggregation of the communicative structure, the reciprocity in discussions, the number and density of possible subgroups, etc.. In spite of web tracking data, therefore, SNA indexes represent a second level of analysis as conceived in the theory of Doise.

In order to illustrate how web tracking data and SNA indexes may be utilized, we will briefly present a study (which has not yet been published), in which we have formulated a model for representing individual and groups profiles based on both individual (coming from web tracking indicators) and collective (SNA indexes) actions. The study concerns two groups of teachers in vocational training and one group of university students. Since it would be inappropriate to provide here detailed explanations of the complex phases of data elaboration, we will simply describe our model in its main features and functions, which are basically aimed at providing useful information for representing individual and group profile.

The model consists of five areas of actions: three areas of individual actions, collected by Web Tracking (platform use; loquacity; participation to discussions) and two areas of collective actions collected by SNA (role in group collaboration; dealing with group).

All web tracking indicators and SNA indexes have been elaborated so that we could obtain a graph for each participant, which describes his/her actual performance levels in each area in relation to the maximum performance level attained by his/her group. The same may be done for the entire group, in order to obtain a graph displaying the average performance of participants in each area in relation to the maximum performance level attainable by the group (Figure 2).

In summary, this model allows us to take into consideration and represent not only the individual actions a student performs within an e-learning environment, in order to interact with contents, but also the collective actions he/she accomplishes for interacting with his/her colleagues during on-line group collaboration. Further, as we show in figure 2, we can use this model for representing group performances, and thus for comparing different groups involved in virtual learning environment characterized by collaborative activities.

From this point of view, we can analyze class/group actions in virtual environment considering the three different levels of analysis proposed by Doise. The first level of analysis is represented by individual actions derived from web tracking data. The second level of analysis is represented by collective actions mapped by whole network structural SNA indexes. Finally, the third level of analysis is represented by the students' social roles in web

[1]Cyram (2004). NetMiner II. Ver. 2.5.0. Seoul: Cyram Co., Ltd.

interactions, as mapped by SNA individual measures. Obviously, these roles are not fixed: during different periods of a web forum a student could assume different roles (for instance peripheral or central), whereas the same role could be assumed by different students.

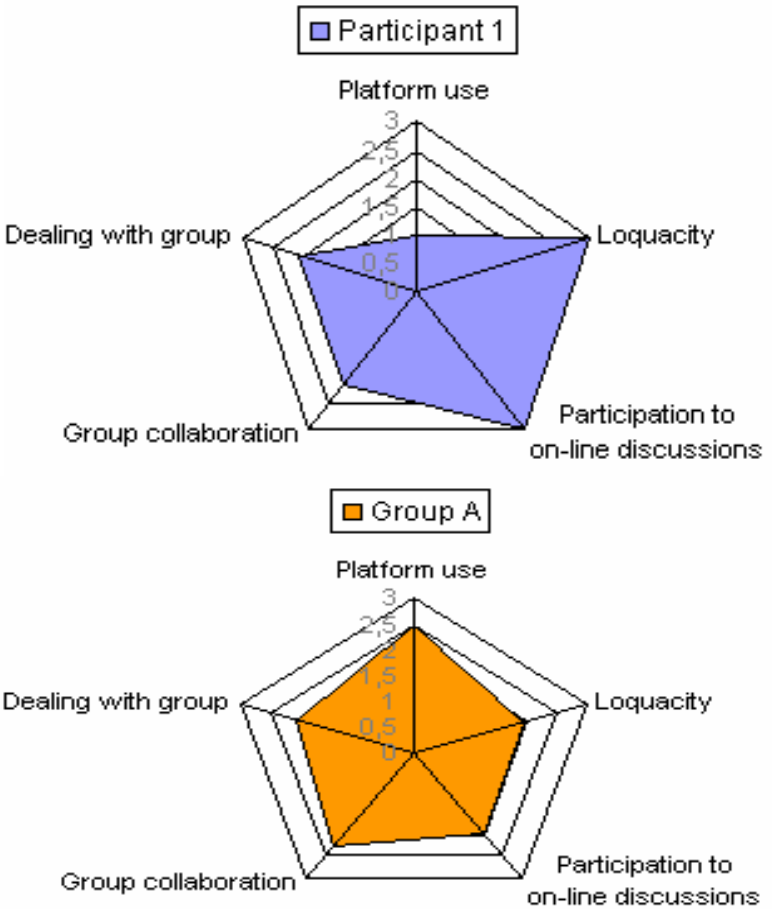

Figure 2. An example of performance attained by a participant and by his/her group.

CONCLUSION

The idea that our behaviors result from processes of analysis and evaluation of a specific situation is supported by numerous studies. Drawing on Weiner's metaphor (2006), we could consider ourselves as "judges" in a courtroom which, before delivering a judgment on a given event, and taking consequent action, evaluate all available information and evidence. Teachers' judgments precede educational practices, feedback and evaluation. However, these judgments are not solely based on the performance of pupils. As a matter of fact, there are several "contextual" elements that play a part in such a process. As we could notice in the course of the present chapter, the process that leads to the formulation of judgments is complex, and is characterized by the action of various factors. We explained how teachers' social representations influence the educational practices they adopt in class; how causes

attributed to succeeding or failing may influence judgments and evaluations; and how such a process involves the interaction of shared social norms and of given aspects of the school context considered. Next to these determinants of teacher judgments, we have also analyzed specific context-related elements that influence pupils' performances directly, and that therefore compromise the quality of those evaluations that consider performance as the direct indicator of pupils' achievement. Finally, we have dealt with an issue that is particularly relevant in today's society and culture, i.e., that of evaluation and monitoring within e-learning contexts. We could observe how evaluation, also as far as e-learning is concerned, may be seen as a process that is based not only on the pupil's individual performance, but also on specific information that takes into account the individual's relationships with his/her reference group, and also his/her role in managing and transmitting such information.

With the purpose of "giving psychology away", we believe that our contribution may offer some useful insights and ideas to be considered by teachers in their daily school activities. They may particularly contribute to raise awareness on those factors influencing the production of judgments, so that educational practices and evaluations may consequently improve the value of judgments and evaluations. This, in turn, may promote further improvement of educational contexts, and therefore encourage the creation of enhancing conditions, in which performances may take place and be evaluated according to more objective criteria.

Further considerations may be made as far as evaluation in e-learning contexts is concerned, which today is often at the center of debates and research. As a matter of fact, the data collected through web tracking may not be considered as representative of pupils' actions within a given virtual learning environment. Rather, they reveal a quite static picture of the frequency of visits to certain resources and, possibly, the completion or non-completion of given tasks. Such logic, however, does not provide any useful elements to those analysts, who wish to explore social aspects of e-learning, which concern, for instance, the network of relations that characterizes participants. In other words, it does not consider relations among individuals, i.e., how information is transmitted among them, and what subjects occupy more central or more peripheral positions within the managing of information. Hence the search for analytical models, such as Social Network Analysis, which we suggested, and which Doise himself refers to, becomes necessary in order to provide further useful tools to control and analyze complex situations, and to suggest interesting new perspectives for evaluation.

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Chapter 3

A PROBLEM-BASED APPROACH TO TRAINING ELEMENTARY TEACHERS TO PLAN SCIENCE LESSONS

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ABSTRACT

Pre-service teacher training can be short and hurried. It is often difficult to find time to develop the range of knowledge and skills we believe students should have in order to teach effectively. Attempts to cram students with what they need are understandable but risk producing superficial, unconnected learning. In the end, such learning is often worthless when it comes to putting it into practice. Recognising this problem in one of our courses, we came to accept that a quart will not go into a pint pot. Instead of trying the impossible, we set out to equip our student-teachers with skills which would enable them to teach effectively even when the particular science topic had not been covered in detail on the course. The skill we focused on was lesson planning in science, developed through a problem-based approach. This study describes the background, the problems and the outcomes, some of which were not quite as anticipated. It concludes with practical advice for those seeking a solution to the quart into a pint pot problem when training teachers.

INTRODUCTION

This study relates to the training of elementary teachers. Elementary teachers in much of the world generally teach a wide range of subjects and, unsurprisingly, cannot be experts in all of them (Allen and Shaw, 1990; Bennett and Carré, 1993; Edwards and Ogden, 1998; OECD, 2005). The problem is that time on elementary teacher training courses is often too short to cover everything so that there can be a tendency to be superficial (Bennett, 1996; Hirvi, 1996; OECD, 2005), something we call ‘the quart into a pint pot’ problem. Hiebert et al. (2003) met this problem when training teachers to teach mathematics in the USA. They

argue that there is no choice but to accept that we can never teach everything. Indeed, a frantic pursuit of subject knowledge may not be the best approach given that the learning is likely to be inadequate for many pre-service teachers' needs (Qualter, 1999; Smith, 1999). The solution, Hiebert et al. (2003) suggest, is to equip pre-service teachers with the skills to deal with the knowledge gaps themselves. This makes good sense. Teachers need this know-how not just for immediate use but also to meet the demands of change throughout their professional lives (Savin-Baden, 2000; Cheng et al., 2002; Tan, 2001; OECD, 2005). They also need to learn to integrate subject matter and pedagogical knowledge, cross the theory – practice divide and put their learning to use (Roth, 1999; OECD, 2005; Glassford and Salinitri, 2007) Accordingly, our aim was to help pre-service teachers develop skills which would enable them to plan science lessons effectively, confidently and independently, even if their initial knowledge of the science was relatively weak.

The Context

In the UK, the majority of elementary pre-service teachers are graduates who follow a teacher training course spanning one academic year (typically lasting from September to June). In England, such courses must satisfy the government's Training and Development Agency and are very constrained by their requirements. The Agency requires that student teachers spend at least 18 weeks of the 38 week course practising teaching children (5 to 11 years old) in schools. In the remaining weeks, these students must learn the elements of teaching the 'core' subjects (English, Mathematics and Science), several 'foundation' subjects (Geography, History, Art, Design and Technology, Music, Physical Education), Religious Education and learn about generic matters such as Special Education, the assessment of children's learning, inclusion, and citizenship. Time is tight and has to be used for essentials. To compound the problem in science, these students tend to have very varied backgrounds. Few have studied a science to degree level or even to the Advanced Level of the General Certificate of School Education, the highest school level in England. All have studied it to a lower level with an examination usually taken at 16 years old but this can be limited to a biological science or a physical science. As a consequence, there can be gaps in students' knowledge and misconceptions commonly found amongst school children are often evident. Our training course aimed to make good these deficiencies through science education lectures, knowledge and pedagogy workshops and supported self-study. The lectures dealt with, for example, children's common misconceptions, how to use analogies to support learning, how to use questions effectively, and creativity in science lessons. The workshops focused on major parts of the National Curriculum for Science in England for elementary children and aimed to raise student teachers' scientific knowledge and understanding and exemplify its teaching (DfEE, 2000). In the supported self-study sessions, students were set tasks to widen and deepen their scientific knowledge, with the help of a tutor, if needed. Nevertheless, students found lesson planning in science a difficult and lengthy process, some claiming to take twenty-four hours to plan one, sixty minute lesson. Given there is not time to address the teaching of all possible topics, many students depended on science tutors for detailed advice on lesson content and were often slow to cross the theory – practice divide and apply their science education knowledge in their planning. Given this, Hiebert at al's (2003) solution to the quart into a pint pot problem is attractive. With appropriate skills, these

students could collect, select and collate the science knowledge as they need it, both now and in the future.

Problem-based Learning

The introduction of problem-based learning (PBL) is generally ascribed to Barrows at McMasters University, Ontario, Canada, where he used it in medical courses in the late 1960s (see e.g. Barrows and Tamblyn, 1977). The essential feature of PBL is that students are set a realistic problem drawn from the field of study and they 'encounter the problem cold' (Schwartz et al., 2001, p. 2). Typically, the students work in groups to solve the problem. The expectation is that the task will motivate and generate durable, sound and integrated learning. It shifts the emphasis from the tutor and knowledge transmission to the student and knowledge construction, recognising that meaningful learning is a personal matter for the learner. The tutor's role is to facilitate the process of problem solving by, for instance, helping students clarify the problem, develop ways of working and find sources of information. The tutor does not provide a solution to the problem.

PBL provides a way of developing these skills through learning opportunities which capture the complexity of professional action (Savin-Baden, 2000). It has been found to be motivating, to produce long-term retention of knowledge, to enhance the ability to use resources, to cross the theory – practice divide in the workplace (Schwartz et al., 2001) and to develop skills needed to be a 'lifelong learner' (Beringer, 2007). Newman (2003), in a review of the medical education literature, concluded that PBL can produce meaningful learning and greater student satisfaction. A series of problems may also help students progress to greater complexity and integration of learning (Engel, 1991). Student course evaluations have also been found to favour a PBL approach (Vernon and Blake, 1993; Maudsley, 1999). The approach has found favour particularly in the education and training of medics, lawyers and engineers (e.g. Mackinnon, 2006). It is, perhaps, obvious that the work of such professionals can be cast in the form of practical problems. In the teacher training context, the task of lesson planning with limited subject and pedagogical knowledge can similarly be cast as a problem to solve. Reports of PBL in pre-service teacher training are rare but McPhee used a PBL approach with practising teachers to teach aspects of, for instance, school management at Glasgow University in Scotland. Most of his students reported that PBL 'made them think more about the topics than with traditional methods' and that their motivation was generally better (McPhee, 2002, p. 69). On this basis, a PBL approach may be able to meet the needs of pre-service teachers similarly. Problem-based approaches are often aimed at developing knowledge but the primary aim here was to help student teachers plan science lessons effectively even when their initial knowledge is limited. Of course, subject knowledge developed in the process is welcome but it would be disappointing if this was the only outcome.

Nevertheless, caution is needed (Albanese and Mitchell, 1993). Others studies, have been less positive. PBL can leave students with knowledge gaps and a tendency to reason backwards rather than forwards (Albanese and Mitchell, 1993). Newman (2003), in his medical education review, found that it does not always lead to a greater accumulation of knowledge or to better practice than other approaches. McPhee (2002) and Maudsley et al. (2007) also report that, although group work was popular, not everyone liked it. This is,

perhaps, a reminder that people may prefer to learn in different ways and one approach rarely suits everyone. Berkson (1993) and Colliver (2000) concluded that PBL was no more effective than other ways of learning. In addition, an exclusive emphasis on know-how may risk devaluing critical thought and could equate being professional with having a tool kit of skills. Moreover, if the approach replaces all others, students can be deprived of the benefits of an inspirational tutor and tutors may find being a facilitator less satisfying than other teaching roles (Davis and Harden, 1998; Mackinnon, 2006). In addition, PBL is likely to call for access to a significant range of resources, realistic problems can be difficult to find or construct and care is needed if assessment is not to be a burden. Given this, PBL should not be seen as a quick fix or the 'right' approach but as one in a range which, in some circumstances, offers advantages over the others.

In practice, PBL describes a variety of approaches (Boud and Feletti, 1996). In some, the problem is central and the course is organised around it. In others the problem may serve to stimulate and focus discussion in a seminar. Elsewhere, the 'problem' may simply be a case used to illustrate the information presented in a lecture. Barrows (1986) constructed a taxonomy which scores PBL approaches according to their potential to produce the motivation and learning described above. On this basis, greater potential is associated with giving the problem a significant opportunity to engage student thought and activity. When the problem is purely illustrative, however, the problem's potential in this respect is greatly reduced.

Here, PBL comprised one strand of the pre-service training course and used the slot previously allocated to supported self-study. Six problems were compiled for this strand. There was some slight re-scheduling of the lecture and workshop programs so that they might complement the problems but these did not address the problems or cover the science topics presented in them although their content might, on occasions, add to the quality of the solution if interpreted and applied. Given McPhee's findings that some students disliked group work, we felt it was important to recognise that they may learn in different ways. Accordingly, we extended autonomy to the way the students worked. Groups of between four and six students were encouraged to work together to explore each problem, identify what they needed to learn, explore resources, and consider the form of solutions. Nevertheless, they were not obliged to work as a group but, in practice, most chose to do so. As teachers in school, however, they would usually have to work alone on lesson plans so we felt that the skill had to be developed at the individual level. After the group work, therefore, each student developed his or her own solution to each problem.

Boud and Feletti (1996) described features typical of PBL, such as the early presentation of the problem, students working with a significant degree of autonomy, a tutor who facilitates but does not solve the problem, and a need for integration and application of knowledge. On this basis, this strand is clearly 'problem-based'. According to Barrows' classification, the strand has the potential to develop self-directed learning skills, to structure knowledge, foster practical reasoning, and encourage a positive motivation towards engagement with the activities. It should be added that adopting a different approach is not risk free. While we may have had some reservations about the existing course, the new approach replaced a part of it. If the approach fails, students could be worse off. It is important to consider the risk and how it might be managed. The strand was self-contained and, at least in the early stages, open to being discarded to allow a reinstatement of the previous strand.

The Problems

The strand's curriculum comprised six problems, each requiring the student teacher to engage in science lesson planning. Each problem drew on principles developed in the lectures and workshops but required more than that knowledge alone and much more in terms of personal skills. In a sense, the problems could also be described as nested in that, after the first problem, they could require skills and know-how practised in earlier problems. The first problem was given in the second session of the course and students were allowed two weeks to complete and return it for assessment. Subsequent problems were addressed similarly. In this way, students began lesson planning at the outset and continued to practise it in more demanding ways throughout much of the course. Principles of instructional design considered to be good practice in adult education were applied, such as, making the relevance of the task explicit, allowing autonomy in approach, making the level of demand progressively greater, and providing early feedback (Bohlin et al., 1993-4). An outline of the problems is provided below.

Problem 1

The aim of the first problem (see Box 1) was to help students develop skills in collecting, selecting and ordering relevant information for a lesson plan. Subject knowledge may be limited and few will know what is appropriate for the children or what they might do in the classroom at this stage.

Box 1.

Problem 1: Science Planning which Works for You

'You have a younger Key Stage 2 class (8 to 9 years old) You have to teach them an introductory lesson about Life Cycles but you can recall very little about life cycles. You have no idea how to introduce the lesson, how to explain what life cycles are, what kinds of words to use, or what activities the children might do.

Your task is to solve the problem. It has two parts:

- Find a straightforward way of collecting the information you need to teach the science lesson;
- Use it to plan the lesson.

Remember: The aim is to construct a way of science lesson planning which works for you.'

The introductory session of one hour was led by a tutor who helped to clarify the problem and drew students' attention to the National Curriculum (which locates the topic in the context of the elementary science required programme of study) and to sources of subject and pedagogical knowledge. Multiple copies of relevant books and wall charts for use with children of this age were available for the students to consult. Students were told that children's textbooks could be seen as science teaching models as they were often written by practising teachers who knew what was appropriate for the children. They were warned that they may not always be good models. The students used much of the time to examine the

materials and, in self-selected groups, discussed possible lesson content and make notes. The tutor's role was to clarify the problem (for instance, helping the students decide on a likely lesson duration) and ensure that students saw potential in the resources.

In the second, one-hour session, which took place one week later, the students focused largely on fixing and sequencing their lesson content. The terms used in a pro-forma for their lesson plan (Appendix A) were explained and the students began to complete it. Students were expected to supplement these one-hour sessions with work done in their own time, perhaps using the library, as needed. This completed pro-forma was submitted in the following week for assessment.

Assessment

The assessment of Problem 1 recognised the students' inexperience and that the central aim was for them to develop skills of collecting, selecting and ordering relevant information. Accordingly, the presence of certain features was noted but their quality was not commented on at this stage (the feedback sheet is included in Appendix A). As might be expected for such novices, a common fault was that there was too much in the lesson for young children. Matters of this kind were referred to in the tutor's general comment.

Subsequent problems provided opportunities for students to become more skilled at finding and choosing from useful subject and pedagogical knowledge. At the same time, they were a means of having the students work with and integrate knowledge presented in lectures and workshops, using this knowledge in lesson planning contexts. For instance, a lecture on 'Children's Learning in Science' showed how children may arrive with ready-made ideas which shape their thinking in science.

Problem 2

Problem 2 (see Box 2) asked students to plan a lesson to address a misconception /alternative theory which became evident in a lesson about Gravity.

Box 2.

Problem 2: Working with Misconceptions

'In a topic on Forces, you have to do work on Gravity. As a part of that, you have the children drop objects and find ways of slowing down their fall, as with parachutes (Lesson 1). You cleverly include an investigation in which the children have to find which kind of parachute works best: square, round, or triangular (Lesson 2). In the plenary session, you engage the children in a science conversation to develop their language skills and to explore their grasp of gravity. This is what happened (T = teacher):

T:	So, why do things fall down?
Donald:	Gravity. It pulls things down.
T:	That's good! Does gravity pull everything down?
Sacha:	No, not everything. I've seen feathers. They just go up!
Pauline:	And so do the fuzzy tops on dandelions. They just float away!

The problem is that you will need to address this in your next lesson. Plan a lesson to do so.'

Again, the tutor clarified the problem and helped the students discuss the ideas which might underpin the children's thoughts. The students drew on the resources and gathered ideas for teaching about gravity. Nothing in these resources matched this problem exactly but discussion amongst themselves helped them develop their thoughts. These were presented on a pro-forma like that provided for Problem 1. In this case, however, they were also asked to state what the parts of their approach were intended to achieve.

Assessment

While still recognising that students are inexperienced, some indication of quality is now provided for each part of the plan on a 1 to 5 scale (see Appendix 2). In addition, the plans of students who had shown a tendency to include too much in plans in Problem 1 were checked for this here. The tendency was found to be much reduced.

Problem 3

On the broader course of which the training in science teaching was a part, these students were urged to guard against the temptation to drill children to learn facts and neglect understanding. Problem 3 reflected that concern by giving the students a short transcript of a lesson on Plants, set out as in Appendix 1, in which the teacher fired only factual questions at the children and rehearsed their responses for quick recall. The students were asked to prepare a lesson on the same topic which addressed understanding. Like the one provided, this was to be presented in the form of a transcript. Tutors helped students clarify what understanding in science can mean.

Assessment

Like the assessment of Problem 2, this included an evaluation of each element of the lesson on a 1 to 5 scale. In this case, space was available after each element for the tutor to make a specific comment about it, if needed. Tutors noted that there was a tendency to refer to all practical activity as 'experiments'. This was taken to indicate that lectures and workshops had not been sufficiently clear in distinguishing between different kinds of practical activity and tutors decided to revisit this in the subsequent sessions.

Problem 4

Students were set the problem as in Box 3.

Outline lesson plans were provided for the two lessons and the students were to prepare similar outlines for (i) the more able children, and (ii) the less able children. They also had to prepare a test to assess the children's learning, allowing all to have some success and stretching those with more ability. The students could choose one of two approaches in compiling their test: a straightforward set of twelve questions or an 'active assessment' unit which tested knowledge through an activity which the children would see as a part of a lesson. A tutor reminded students of the need to assess factual knowledge and understanding. Attention was drawn to the choice of approaches to assessment. It was suggested that this choice allowed them to select according to their interests and perceived needs – a kind of personalised learning.

Box 3.

Problem 4: Personalising Lessons
'Children are different: some catch on quickly and succeed with ease, others are slower and find it a bit difficult. You must be able to tune your teaching to suit different needs. Your new class comprises 34 children. You are told that most seem to like doing science but six boys and four girls have difficulty with it. On the other hand, four boys and five girls are very good. You must teach this class about Materials and their Properties. The first two lessons are on Dissolving Things**.** Tune the lessons to meet the needs of these children and prepare to assess their knowledge and understanding in a way which recognises the children have different abilities.'

Assessment

This was an evaluation of the two lessons and the provision of a test of children's learning. The differentiation of each lesson into two parts, one tuned to the likely needs of the more able children and the other suited to the likely needs of the less able children, was assessed for each lesson with a grade and written comment. The provision of a test which was likely to allow a wide range of children to show what they had learned was similarly assessed.

Problem 5

The previous problem introduced the students to two sequential lessons. This problem (Box 4) has them plan for longer sequences and also plan to tie learning to work done in other subjects.

Box 4.

Problem 5: A Lesson Sequence
'You have to teach Electricity for either a Key Stage 1 or a Key Stage 2 class. This needs a progressive sequence of lessons. You are also expected to see what you might do in connection with Electricity in other areas of the curriculum in order to make learning more secure.'

Planning a sequence of lessons in detail would take more time than we felt was reasonable, given that the students had work in other subjects. In addition, the burden of assessing these plans would become significant. Accordingly, the response sheet had spaces set out for outlines of five lessons. A second response sheet provided spaces for ideas to do with electricity which might be used in other subjects.

Assessment

Here, the assessment was of the lesson sequence, the provision for progression of learning, differentiation according to ability, plans for assessing learning and cross-curricular ideas. Tutors commented on each in the spaces provided on an assessment sheet and graded quality on a 1 to 5 scale.

Problem 6

The final problem (Box 6) in the sequence returned to the planning of one lesson, to be set out on a pro-forma like that of Appendix 1. The aim was to have the students draw together various elements of good practice and show they could apply them in this lesson. At this point, students had visited their practice placements and some knew which topics they would have to teach.

Box 5.

Problem 6: Engaging Science Teaching

'The problem with some teachers is that they can't make science lessons engaging. An engaging lesson is one where children become engrossed, interested, make progress, and finish with satisfaction. It is hard to make every lesson engaging but when you achieve it, you will find it is very rewarding and want more.'

Plan an engaging lesson for a Key Stage 1 or 2 class for the topic of Sound or Light or Characteristics of Life, or Ourselves, or for the topic you have to teach in school.'

Engaging science teaching (Darby, 2005) was described as comprising:

i) Instruction: provision for interest and understanding;
ii) Relationships: a demonstration of teacher enthusiasm, the maintenance of an atmosphere conducive to learning, and support for individual children.

The students were expected to justify their lessons in terms of these elements on an additional sheet (Appendix 3).

Assessment

As well as continuing the process of skill development, drawing on prior lectures and workshops, this problem was also a test piece. It was assessed using a pro-forma similar to that of Appendix 2. As the lesson was set out in the same form as that of Problem 1 (Appendix 1), it allowed a direct comparison and a judgement of progress. In this instance, however, the Yes/No categories were replaced by 1 to 5 scales like those in Appendix 2 to provide a finer evaluation.

Notes on these problems were also provided for the tutors who would present and support the process. These followed the advice of Lynn (1999) and provided a brief abstract of each problem, a comment on pre-requisite knowledge, if any, the teaching and learning objectives, matters to bring to the students' attention or to discuss, possible student questions, pitfalls or difficulties, and the scope of the solutions expected for the given problem. Fortnightly meetings with these tutors took place on the day that the students returned their solutions to a problem. This reviewed the problem just completed and looked ahead to the next one.

INTERIM SUMMARY

Problem-based learning has many forms so some more or less distinctive features of this version are summarised below.

- Its primary purpose was to develop science lesson planning skills, particularly in conditions of low subject knowledge.
- It formed a discrete strand of the course, six problems defining its curriculum.
- The problems increased in demand in terms of the complexity of their context and the nature of the solution.
- Students were encouraged but not obliged to explore problems initially in groups.
- Students submitted their personal solutions to each problem.
- Tutors commented on these at the individual level and provided feedback on the process at the group level.

Evaluation

The Students' Views

There were 75 students in the cohort. Wee Heng Neo (2004) provides useful advice on collecting relevant evaluations of problem-based learning courses. Drawing on this, we asked students to contrast how confident they felt in planning a lesson for a topic they knew relatively little about at the start and near the conclusion of the PBL strand. (Responses to these and subsequent questions were marked on a 0 to 9 scale where 0 indicated 'not at all' and 9 implied 'easily', 'considerably', or 'very much', according to the question.) The mean score increased from 3.24 at the outset to 6.49 (a difference that was statistically significant, t-test, $p<0.0001$). Regarding the extent to which it helped students see how lecture and workshop content could be put into practice, the mean score was 5.59. It was 5.94, on average, for the extent to which the approach helped them plan lessons in an acceptable length of time on teaching practice in schools. The opportunity to work collaboratively was rated at 6.01, on average, and the extent to which the approach was found motivating received a mean rating of 4.99.

Three focus groups with about twelve students in each were drawn at random from the cohort of seventy-five students. One of the authors led each group and focused discussion on reasons for the above scores. Regarding confidence in planning, there was agreement that planning became easier with time and that the experience reduced apprehension and increased lesson planning skills. The students generally felt that the relevance of lecture and, particularly, workshop content was beginning to emerge in their minds as the course developed. Some said they were beginning to make deliberate links between this content and the PBL strand. Regarding efficient lesson planning, many students felt that they were clearly becoming more adroit at planning. Some students on school placement found themselves having to fit into and use existing plans and said they felt that PBL had prepared them to see weaknesses and opportunities in some of the work they were expected to deliver. Many found that collaboration allowed them to 'bounce ideas off each other', 'share experiences', 'build up ideas' and help each other. It also helped them to know that any concerns they had were

not unique to themselves. Some said they worked better alone, relying on books and the Internet for support. Nevertheless, these acknowledged that this simply reflected different preferences in learning. The students found the practical relevance of the PBL strand to be obvious and said this was motivating. They also found the regular, constructive feedback to be encouraging. A concluding comment was, 'I just want to say I had no knowledge of science but feel more confident because of this.'

The Course Tutors' Views

Three tutors (not the authors), all experts on science lesson planning, worked with the students on the PBL strand. They were interviewed individually and asked the same questions. The following collates their responses.

First, all tutors believed that the PBL strand helped the students develop science lesson planning skills. As evidence, for instance, they cited a steady refinement in the students' skills in using the sources of information and in producing appropriate lesson plans. Furthermore, all agreed that there was a progressive improvement in the students' ability to select suitable content. One also referred to an evident increase in confidence amongst the students in lesson planning. For instance, students said, 'Before I would have . . . But now I would . . .'

Second, all tutors agreed that there was evidence of an integration and application of knowledge developed in workshops and lectures to their planning. For instance, there was explicit reference to such knowledge in addressing the problems.

Third, all agreed that the students were motivated by the PBL approach. They described the strand as giving a clear purpose and relevance to the work from the outset. Students were willingly engaged on the task.

Regarding the assessment of solutions and feedback to the students, the tutors' responses were mixed. All said that these were not onerous, particularly with the use of a pro-forma. One said that 'even if it took longer, it was worth doing' because the outcome is valuable.

Overall, the tutors were very positive. One described the PBL approach as 'a major step forward', another described it as 'more valuable and worth doing' than what was done before, and the third felt that his supporting role was now more relevant and productive. There were some comments on the mechanics of the PBL strand, such as, the timing of the feedback, some details in the problems, and how to support a handful of students whose work was considered to be unsatisfactory.

In addition to these interviews, the course leader held meetings with these tutors after each problem. Initially, the leader felt that the tutors found it difficult to change from a desire to help the students solve the problem to one which showed more restraint. It was also felt there was some confusion between developing knowledge and developing skills, the latter being the priority in this strand. Discussion in the meetings attempted to clarify these points and, as the tutors' responses above show, was successful to a large extent. The meetings also provided an opportunity for dealing with mechanical and similar issues, for ensuring a common understanding of each problem and for consideration of assessment and feedback for consistency.

Discussion

The PBL strand was a response to comments by the previous year's student teachers regarding their fears and difficulties in planning science lessons. The evaluation of the strand was not intended to compare the effectiveness of PBL with what went before: comparable data was not available and the aims of previous years were not identical. Furthermore, the data reflects largely perceptions of performance and not performance itself. While perceptions and performance could be related, one is not a stand-in for the other. The PBL strand was also one part of the course and, although the other parts did not practise lesson planning directly, success is, strictly speaking, a property of the course as a whole.

Given these caveats, the students' reported a very large increase in their confidence in planning science lessons which they ascribed to the PBL strand (effect size, 2.17; anything greater than 0.8 is considered to have a large effect, see, e.g. Kinnear and Gray, 2005). The views of the course tutors supported this perception. To this extent, the PBL strand was effective.

The tutors believed that the PBL strand helped the students to apply their learning from other parts of the science course to their lesson planning and to plan science lessons in school in an acceptable length of time. Although generally true, it should be added that such views were not unanimous amongst the students. The responses in the focus groups indicated that integration and application of knowledge from across the course was only beginning to develop. Regarding planning lessons in an acceptable length of time, most found that this was so.

One of the effects of PBL commonly reported is a liking for the opportunity to work collaboratively and to find the approach motivating. Here, a positive response to collaborative work was noted although, as described above, this was not intended to be a strong feature of the strand, given the need for teachers to plan independently in school. But, once again, this response was not unanimous. Overall, perceptions of the motivation stimulated by the strand could be described as luke-warm with only two-thirds of the group scoring it at 5 or more. This is contrary to the enthusiastic reports of several other PBL users regarding motivation but PBL has generally been used in what might be described as 'mono-cultures', that is, courses which focus on one discipline. Post-graduate, pre-service training for the elementary school recruits students largely from mono-cultures and obliges students to learn in areas they may not voluntarily choose themselves. In short, their general disposition towards science learning can be hesitant, even reluctant. On this basis, a luke-warm response may be an achievement. Certainly, the student focus groups were positive about motivation (but bear in mind that the course leader led the focus group discussions). At the same time, a significant objective of PBL elsewhere has been to develop well-founded and durable *knowledge* at the end of each problem. Here, subject knowledge was secondary to the main objective of developing *lesson planning skills* over a series of problems. It may be that extended skill development is not as motivating as an immediate and evident accumulation of knowledge. The tutors, however, were very positive about motivation although this may reflect their experience of what it was before the PBL strand was introduced.

A few additional comments may be helpful to those interested in using a PBL approach in pre-service teacher training. Teaching is an idiosyncratic, creative activity (Hilty, 1995; Groves et al., 2005) and this PBL approach recognises this by encouraging students to develop their own ways of doing things. The tutors were very positive about the course. Some

of this may stem from the novelty of PBL and an increase in students' willing engagement compared with earlier years. But, given the student responses, the tutor perceptions do seem to be fairly well-founded. The preparation of the problems (by the authors) was a time-consuming task but, on reflection, the tutors may have benefited from more preparation for their role. Others have noted that changing from teacher/expert to what Maudsley (1999) describes as a more shadowy figure is not as easy as might be supposed. In assessing progress, tutors can also be attracted strongly to the quality of the product and neglect to appraise and advise about skill development. Pro-formas reduced the burden of marking to what tutors felt was an acceptable level while still providing useful formative feedback for the students. They may also be used to direct tutors' attention to skill development. PBL approaches generally call for a ready access to sources of information. Providing resources can be costly. In this instance, access to the Internet was made available and about a dozen books, largely for children, were provided for each group to consult.

CONCLUSION

Broadly speaking, the main goals of the PBL approach were achieved and, for most students, PBL met the promises of its advocates. The students reported that the PBL strand greatly increased their confidence in planning science lessons when their knowledge of the science was initially limited. Furthermore, they generally found it helped them apply learning from other parts of the course to their planning and to plan in an acceptable amount of time. The tutors agreed with the students and felt that they were better at planning because of the strand. On this basis, we can recommend that others consider it as a way of working when the aim is to develop lesson planning skills. Nevertheless, the approach should not be seen as a panacea. There were students who either did not perceive PBL as benefiting them greatly or as being particularly motivating or who found collaboration welcome. This is a reminder that students prefer to learn in different ways and PBL may not be the best way for everyone. Given that, PBL is best viewed as one approach amongst several. There may be occasions when a pragmatic mix of approaches is the best way of working, even within a PBL strand. This is something we intend to explore in the future.

APPENDIX 1

PROBLEM 1: SCIENCE LESSON PRO-FORMA

Topic: Life Cycles Key Stage 2

Key Science Knowledge (e.g. as stated in the National Curriculum)

Everyday examples and other sources of interest

'By the end of the lesson' goals*

a) The children should know:

b) The children should understand:

c) The children should be able to do:

Your lesson agenda (listing the main events of the lesson, in order)

1.
2.
3.
4.

Lesson outline (A more detailed version of your agenda)

Class management plans

Key Questions to check on learning goal attainment. (Your questions should relate to * above and should be listed overleaf.)

Problem 1. Science Lesson Pro-forma – Feedback

Name: ……. Group: …1..…2…..3….

PLANNING SKILLS (P1)	✓ EVIDENCE ✓
1. Is key science knowledge underpinning the lesson identified?	**YES** ☐ **NO** ☐
2. Are some everyday examples and other sources of interest / relevance given?	**YES** ☐ **NO** ☐
3. Are "end of lesson goals" identified? a) The children should know… b) The children should understand… c) The children should be able to do…	**YES** ☐ **NO** ☐ **YES** ☐ **NO** ☐ **YES** ☐ **NO** ☐
4. Is there a short lesson agenda, listing the main events of the lesson, in order?	**YES** ☐ **NO** ☐
5. Is there evidence of a lesson outline (a more detailed version of the lesson agenda)?	**YES** ☐ **NO** ☐
6. Is there some evidence that class management is being thought about?	**YES** ☐ **NO** ☐
7. Are there some key questions to check on learning goal attainment, relating to the "end of lesson goals" (see 3 above)?	**YES** ☐ **NO** ☐

GENERAL COMMENT:

Signed (tutor): …… Date: ……..

APPENDIX 2

Problem 2: Working with misconceptions – Feedback

Name: …… Group: …1..…2…..3….

EVIDENCE BASE	QUALITY (1 = weak; 3 = satisfactory; 5 = excellent)				
1. Lesson goals - Does the plan include evidence what the pupils will know, understand and be able to do?	1	2	3	4	5
2.Everyday examples - Are examples from the real world / everyday life used to make relevance explicit and generate interest?	1	2	3	4	5
3. Lesson agenda and outline - Is there a clear lesson agenda, summarising the structure, content and organisation of the lesson in order? - Is it clear what the lesson is designed to achieve?	1	2	3	4	5
4. Management and safety - Are matters of health and safety considered and dealt with appropriately?	1	2	3	4	5
5. Questions - Are key questions justified and sequenced to support learning?	1	2	3	4	5

GENERAL COMMENT:

Signed (tutor): …… Date: ……..

APPENDIX 3

Problem 6: Engaging science

How does your lesson plan make provision for the Instructional Dimension?
(Avoid general answers: be specific in your response)

1. *Interest (e.g. What will you do? What approach will you use? How will you maintain this interest? What will you say? What is Plan B for generating interest?)*

2. *Supporting understanding (Specify what techniques you will use: e.g. describe an analogy and its limitations. What else will you do?)*

How will you attend to matters of the Relational Dimension?
(Avoid general answers: be specific in your response)

3. *Enthusiasm (e.g. Where will you use it? Why? What do you hope to achieve?)*

4. *Atmosphere (e.g. What atmosphere will you develop? How will you do it?)*

5. *Individual support (e.g. When will you provide this? How will you provide this? How will you show that each child's learning matters to you?)*

Describe here additional matters you have considered in your lesson to demonstrate your knowledge and skill development during the course.

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Chapter 4

AN EMPHASIS ON INQUIRY AND INSCRIPTION NOTEBOOKS: PROFESSIONAL DEVELOPMENT FOR MIDDLE SCHOOL AND HIGH SCHOOL BIOLOGY TEACHERS

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ABSTRACT

The problem of how to make science instruction in schools more authentic has been the subject of much debate. National reform recommendations, as well as a number of research studies, stress the need for science classrooms that more closely match the domain of the professional scientist. This chapter, a report of a qualitative research study, examines the experiences and outcomes of a group of practicing science teachers, from central Appalachian schools, who were engaged in a professional development workshop. Two organizing themes, guided inquiry and representation of scientific thought and knowledge by way of inscription, characterized the program. Participants were engaged in a number of guided inquiry activities. They were asked to link these activities to their home states' curriculum standards and to consider how they could incorporate such activities in their own classrooms. Further, participants made inscriptional-type entries in their laboratory notebooks throughout the duration of the workshop. Participants indicated that the workshop provided them with helpful experiences toward implementation of standards-based instruction they could use in their own classrooms. A survey indicated that students had, indeed, incorporated many of the workshop's activities into their teaching. Further, we found that students tended to transform basic and concrete inscriptional representations of their work [such as narrative statements, diagrams, etc.] into more complex ones [such as tables or graphs] when they dealt with data from long-term inquiry activities, as opposed to short-term activities or simple observations. We hope that the activities and outcomes described in this chapter will be useful to both science teachers and science education teachers at all levels of education.

INTRODUCTION

A number of reform recommendations have emphasized the need for science instruction, at all levels of education, to increase the use of scientific inquiry in the classroom (AAAS, 1993; NRC, 1996; NRC 2000). While the bulk of these recommendations have been in place for over a decade, instruction by way of inquiry has been slow to find its way into the classroom. A further component of the reform recommendations is that students should be able to not only design and carry out their own inquiry-based investigations but that they should also be able to communicate effectively and scientifically about the same. Specifically, students should become adept with the use of mathematics and be able to construct conclusions and arguments based on scientific data (NRC, 2000). A plethora of research shows that the average science student, as well as the average science teacher, is severely lacking in these skills (Greeno, Hall and Rogers, 1997; Roth, McGinn and Bowen, 1998; Bowen and Roth, 2002). The question quickly becomes, then, how can teachers pass the skills of inquiry and scientific representation to their students when they themselves are often deficient in these skills? Two examples of quality workshop-type endeavors to address inquiry skills among practicing science teachers have reported success (Hogan and Berkowitz, 2000; Bell, et al., 2003). Although the foci of the workshops vary, the common theme is that immersion in the process of inquiry helps to promote inquiry skills among teachers. In other words if the teachers have experience with the process; if they have practice and a good model, then their inquiry-based teaching skills should improve. The same line of thinking presumably follows for the improvement of inscriptional and representational practices. Previously we reported use of inscriptional practices in a preservice secondary science course taught by a scientist (Lunsford, Melear and Hickok, 2005) and have detailed production of inscriptions by another cohort of students in that course (Lunsford, Melear, Roth, Perkins and Hickok, 2007) . However, a review of the recent literature revealed no studies concerning inscription production and/or use with practicing science teachers as the primary participants. This chapter reports such a situation. A biology-focused workshop emphasizing both inquiry and inscriptional practices for high school and middle school science teachers was sponsored by the Appalachian Math and Science Partnership (AMSP). This group has, as one of its goals, a commitment to improving mathematics and science scholarship in central Appalachian schools. Participants in the workshop constitute the research population for the present qualitative study.

DETAILS OF THE WORKSHOP

The participants, (n = 11) were a group of United States high school and middle school science teachers from Kentucky, Tennessee and Virginia. The workshop was based at a major public university in Eastern Tennessee. Three primary instructors, as well as some guest speakers, lead the workshop. The instructors included a science education professor, a botany professor and practicing high school science teachers. Each instructor brought their own areas of expertise to bear, including teaching by inquiry and providing help with inscriptional practices. The workshop met for a total of ten weekdays. The participants' respective state science education goals and standards were incorporated with national science education

reform recommendations (AAAS, 1993; NRC, 1996). All participants engaged in the workshop and research study with informed consent.

Program Activities

With such a heavy emphasis on inquiry in place, a common goal of the various workshop activities was to provide models for the participants that they could, in turn, utilize in their own classrooms. Some activities were, arguably, not inquiry-based. However these activities continued to emphasize the goal of teaching around biological themes and learning biological content within the context of scientific observation, bringing a more authentic element to the workshop than inclusion of mere paper and pencil activities would have (NRC, 1996). The specific activities participants were involved in are summarized below. In all cases, students were specifically asked to link the activities to their home state curriculum standards and to consider how the activities could be used in their own teaching.

Fast Plants ™. Fast plant is the trade name for a cultivar of the herbaceous plant, *Brassica rapa*, commonly called yellow mustard. Fast plants are ideal for use in educational settings because they are small, easy to grow and have a relatively short life cycle. Various genetic strains of the organism are commercially available to add to the inquiry-based opportunities the plant may foster (www.fastplants.org). Students grew and observed the organisms early in the workshop.

Aquarium. In this activity, students designed and constructed a small aquarium of approximately four-liter capacity. The activity emphasized the concept of a balanced aquarium that is so constructed to require no artificial aeration, filtering, etc. Students were provided glass or plastic containers such as goldfish bowls, gallon-sized glass jars, etc. for use in the course. Plus, a complete 40 liter aquarium was given to them at the end of the workshop. Organisms for the aquaria were provided by the instructor and included guppies (*Poecilia reticulate*), various species of aquatic plants including Elodea (*Elodea Canadensis)*, Milfoil (*Myriophyllum*), and others. The living organisms for this activity are easily obtainable from pet shops and similar suppliers (Morholt and Brandwein, 1986). Participants observed the aquaria over time.

C-Fern ©. C-Fern is the trade name of a cultivar of the fern *Ceratopterius richardii.* The organism is easy to culture and has a short life cycle. Gamete producing structures are easily visible. Microscopic magnification adds to observable details at the cellular level and thus provided participants with skill-building practice on the use of the microscope. Various genetic strains of the plant are commercially available and well suited for the short, guided inquiry activities typical of the workshop (Hickok, Warne, Baxter and Melear, 1998).

Dung farm. In this activity, students collect animal feces from the field and observe them over a period of time. Through the addition of moisture, various organisms may begin to appear upon the dung. Fungi, in particular, are common. Members of the genus *Pilobolus* are frequently observed on horse dung. Plants and small animals may also be observed in some cultures (Morholt and Brandwein, 1986; Chamuris and Counterman, 1999). Some students chose to grow C-Fern©, described above, in their dung farms.

Nature walks. As the name implies, nature walks are short excursions into the field for purposes of observing, collecting, photographing and/or otherwise recording biological activity. Teachers often act as a coordinator or organizer of such walks, although a guest

speaker may provide additional support. The nature walks may or may not be built around some theme or content objective. Specific activities participants engaged in during the nature walks included, but were not limited to, collection of dung pellets (see above) collection and observation of mushrooms, some of which were used for mushroom spore printing activities; observation of spider webs [by way of sprinkling cornstarch on the webs], observation of plants, animals and other aspects of the environment. Students carried along their inscription notebooks and made entries in them during the nature walks.

Roly-poly. The common names roly-poly, sow bug and pill bug are often applied to a group of animals in the phylum Arthropoda, class Isopoda. Collectively, the various genera and species may be called isopods (Miller and Harley, 2002). These organisms require very little in the way of care and are ideal for inquiry-based activities involving behavioral responses to various environmental stimuli. These organisms may be collected from the wild or bought commercially and kept in culture (Burnett and Ivanov, 1992).

Millet. Millet is the common name given to a group of several genera of grasses [family Poaceae] including *Echinochola* and *Pennisetum* (Radford, Ahles and Bell, 1968). Since the plants are used as animal feed and as ground cover, seeds are widely available. They germinate quickly, are easily grown with minimal care and can be used in many simple experiments (Llewellyn, 2002).

Jewel wasps. The jewel wasp, *Nasonia vitripennis,* is a solitary wasp that is parasitic upon fly pupae. They have a short life cycle and are available commercially. Thus, jewel wasps are ideal for classroom observation and experimentation. A web site maintained by Northern Illinois University provides information about the organism and its uses in science education. (www.bios.niu.edu/bking/nasonia.htm)

Natural dyeing. The natural world is filled with various materials in rocks, plants and animal tissues that may be used to color thread, cloth, paints, etc. Many scientific investigations may be derived from these materials. Students may pursue investigations concerning sources of dyes, types of cloth or thread added to the dye and time of exposure (Monhardt, 1996).

Mealworms. Mealworm is the common name for the larval stage of the darkling beetle, *Tenebrio molitor.* These organisms are easily cultured in a grain-based food (Borror and White, 1970) and are ideal for inquiry activities relating to behavior, development and many other topics (Llewellyn, 2002).

Rubrics. Scoring rubrics are a type of evaluation instrument that lists expected tasks and skills that a student should complete with regard to an assignment, as well as quantifiable standards at which the student may perform those tasks and skills (Enger and Yager, 1998). Rubrics are valuable for helping both the student and teacher get the most out of a learning task and have recently been considered in terms of their usefulness for the evaluation of inquiry-based learning activities (Lunsford and Melear, 2004). The concept of scoring rubrics was a central, organizing theme in the AMSP workshop. Students were presented with a rubric for evaluating a major assignment during the workshop (see below) and were asked to design a rubric they could use to evaluate inquiry activities in their own classrooms.

Inscription notebooks. In the field of science, inscriptions are defined as recorded representations of scientific evidence and reasoning. They may take the form of written statements, lists, photographs, tables of data, graphs or mathematical formulas (Latour and Woolgar, 1979). Inscriptions are a powerful and effective means by which an individual's scientific thought processes may be moved into a social arena (Lynch and Woolgar, 1990). A

further characterization of inscriptions is that simpler ones such as tallies, lists or data tables may be transformed into more complex ones such as graphs, equations or concept maps that represent science in a more abstract way (Roth, 1995). During the AMSP workshop, students were required to maintain an inscription notebook that was ultimately evaluated with a rubric (Figure 1) that was designed, in part, with uses of inscriptions by professional scientists in mind (Lunsford, 2002/2003; Lunsford, Melear and Hickok, 2005; Perkins and Melear, unpublished).

Presentation. Students were required, individually or as members of a small team, to put together an oral and poster board type presentation to summarize a detailed inquiry-based, project they were involved in during the course of the workshop. Further, they were asked to incorporate pertinent inscriptions they generated while engaged in the inquiry activity. These presentations were recorded on videotape.

Outcomes

The success and usefulness of the AMSP workshop may be considered in a number of different ways. Results of student evaluation sheets, pre and post assessments and the actual work and reflections of the students are examples. All data sources and artifacts were coded and analyzed in terms of the outcomes listed below.

Final AMSP biology institute evaluations. Ten completed participant evaluation sheets survive as artifacts from the workshop. Students were asked a number of questions regarding their experiences and were asked to comment in detail to support their answers. A summary is shown below.

Did the institute provide you with inquiry-based strategies for your classroom? If yes, how? All 10 respondents affirmed that they did, indeed, obtain such strategies as a result of their participation. Common themes in their responses included the fact they actively participated in inquiry-based activities and were allowed to design their own experiments.

Did the institute provide information and strategies for Standards-based biology instruction? If yes, how? Again, all participants answered "yes" to this question. One student commented that "we are starting to see connections that lead to the different standards being covered in one activity."

Two surveys were administered to all participants. On Survey 1, students were asked to identify and rank, in order of interest, the activities from the workshop that they will "use in your class (in the upcoming) year." Table 1 presents a summary of the participants' responses to this question. In order of preference, students indicated they would most likely use the aquarium activity, C-Fern®, nature walks, millet seeds and roly-polys. These were the group's top five choices among the various activities. Approximately six months after the AMSP seminar, participants were again surveyed (Survey 2). They were asked to list and rank the same activities from the workshop according to whether or not they had actually been used in their own classrooms. These results are shown in Table 2.

Students were invited to provide clarifying written comments on their uses of the various activities from the workshop in their own classrooms. Without specific prompting on the issue, seven of the nine participants who returned surveys indicated that they were using student laboratory notebooks for the purpose of recording inscriptions and/or reflective journal entries.

Table 1. Ranking of Activities by Participants in Survey 1: Which Activities Are You Most Likely to Use in Your Own Classroom?

Ranking of Activity	Name of Activity
1 = most likely to use	Aquarium
2	C-Fern
3	Nature Walks
4	Millet
5	Roly Poly
6	Mealworm
7	Jewel Wasp
8	Dung Farm

Table 2. Ranking of Activities by Participants in Survey 2: Which Activities Did You Actually Use in Your Own Cla**ssroom?**

Ranking of Activity	Name of Activity
1 = used most often	C-Fern
2	Aquarium
3	Roly Poly
4	Millet
5	Mealworm
6	Dung Farm
7	Jewel Wasp
8 = used least often or not at all	Nature Walks

One student indicated that she had used a rubric similar to the one utilized during the workshop (Figure 1) to grade inscriptions generated by her students. Two of the participants noted, again without specific prompting, that they had been expanding the general use of inquiry-based activities in their own classrooms since the workshop. Randomly selected examples of comments made by the participants on Survey 2 are included below.

- (I use) science notebooks and inscriptions daily in all classes. (I also use the) inquiry method very frequently.
- I am planning to use the millet seeds to introduce/apply the scientific method. I am also planning to use the C-Fern as part of the alternation of generations lesson during the sexual reproduction unit. I am very excited.
- The journals have become a major part of my class and I could not imagine not using them.
- I taught physical science and chemistry this semester. I used inscriptions for pre-assessment, to gauge mastery level, and for review. I have included inscriptions in tests.
- I have included inscriptions and journal entries in my daily lessons.
- My favorite things so far are the aquarium and the inscriptions. I have used inscriptions a lot. I have found that they are very useful in all my classes. The aquarium has been a great treat for the kids. We discuss many topics through observation.
- I have extensively used journals in my Honors Biology classes with great success.

Summary of student presentations. At the final meeting, students presented an oral summary of one detailed inquiry activity in which they were involved. The presentations were enhanced by poster board backdrops. Nine such presentations were given, with two involving students working in pairs. The choice of whether to work singly or in pairs on the presentation was left to the discretion of individual students. Table 3 presents a brief summary of these presentations. These presentations were videotaped and analyzed in terms of several criteria. First, the types of inscriptions selected by the presenters for inclusion on their project posters were noted. We were particularly interested in the numbers and types of abstract inscriptions (graphs, tables, etc.) used. Abstract inscriptions imply a more advanced and detailed treatment and consideration of results by the students and a link to the mathematical world of representation (Roth, 1995; Lunsford, et al., 20070. Also, a primary goal of inquiry-based learning is that students will come to understand the nature of science and the process skills of actual scientific work (Enger and Yager, 1998; NRC, 2000). To that end, we assume that if students specifically report new questions generated by their inquiries and/or offer suggestions to improve future replicates of their experiments, then mastery of these process skills is demonstrated. Finally, one primary goal of the AMSP workshop was for participants to practice and gain skills in use of lab equipment, especially the microscope, and computer technology. These findings are also noted in Table 3.

Inscriptional practices of participants. The participants in the AMSP workshop recorded a number of inscriptions. Most of the inscriptions were entered into the student's individual laboratory inscription notebooks, copies of ten of which were available for analysis. Some inscriptions were exclusively recorded on poster boards for consideration during the students' oral presentations. These later inscriptions survive only on film recordings of the said presentations.

Table 3. Summary of Participant Presentations

Topic of Presentation	Examples of Inscriptions on Poster Board	Did the Student(s) Identify Potential New Research Questions Based on Their Research?	Did the Student(s) Make Suggestions to Improve Their Research?	Examples of Lab Equipment or Technology Used During the Inquiry
C-Fern Reproductive Success Verses Number of Male Gametophytes in Culture [1]	written statements, table, graphs	yes	no	microscope, computer
C-Fern Ratios of Male and Hermaphroditic Gametophytes in Culture	written statements, bar graph, pie chart	said so but did not identify specific questions	no	microscope, digital camera, computer
C-Fern Spermatozoon Chemotaxis	written statements, table	no	no	microscope, computer
Millet: Depth of Planting Verses Germination Ratios	written statements, tables, graphs	yes	no	measurement devices, computer
Natural Dyes: Concentration of Dye Verses Color Intensity	written statements, table, photographs, scale of color intensity	yes	yes	digital camera, computer, measurement devices
Nasonia: Age of Host Verses Number of Offspring [1]	written statements, tables, photographs	yes	yes	flex cam, computer
Nasonia: Number of Offspring Produced Compared With Published Data	written statements	said so but did not identify specific questions	no	microscope, computer
Nasonia: Effect of Refrigeration	written statements, table	yes	no	microscope, computer
Nasonia: Factors Influencing Respiration	written statements	yes	yes	respirometer, computer

Figure 2 provides a summary of the types of inscriptions recorded for the top five activities participants identified as being the ones they would most likely use in their own classrooms (see above). It should be noted that the rubric used to evaluate the students' lab notebooks (Figure 1) is intended to provide authentic guidance to the students as they work. In constructing the rubric, we reasoned that professional scientists are, in a sense, indeed "graded" on their ability to produce quality, understandable representations of their work. Promotion, publication and professional standing are examples of the sorts of evaluation paybacks enjoyed by many professional scientists (Lynch and Woolgar, 1990).

[1] This presentation was by two groups of students.

Criteria	None	Poor	Fair	Adequate	Good	Excellent	Points Possible
*General Use of Inscriptions Total number of inscriptions used to represent observations and experimental designs in the laboratory notebook. # required for category	0 0	4 4	8 8	12 12	16 16	20 20	20
*Improvement over time Choice of material for inscriptions, better quality, increasing incidence of social use and transformation of inscriptions etc.	0	2	4	6	8	10	10
*Social Use or Construction of Inscriptions Documented use of your inscriptions in communicating with others. Also, any documented peer discussion of how to best construct or transform a specific inscription. # required for category	0 0	4 1	8 2	12 3	16 4	20 5	20

Figure 1. Rubric for Evaluating Laboratory Inscription Notebooks (Continued on next page).

Criteria	None	Poor	Fair	Adequate	Good	Excellent	Points Possible
Construction of Hypotheses Detailed documentation of conversations between yourself and others concerning your experiments or your reflective personal thoughts as you use observations to guide your rational development of hypotheses and creative ways to test them. # required for category	0 0	4 1	8 2	12 3	16 4	20 5	20
*Evidence of Transformation Cascades Transformation of simpler and less abstract inscriptions *(lists, Vee diagrams, sentences, drawings, photographs, maps, tables, etc.)* into more complex and abstract ones *(concept maps, graphs, composite drawings, equations, etc.)* # required for category	0 0	4 1	8 2	12 3	16 4	20 5	20
*Neatness and Clarity Includes labeling of figures, listing names of partners, dates, references to other pages, units of measurement, etc.	0	2	4	6	8	10	10
Total							100

Figure 1. Rubric for Evaluating Laboratory Inscription Notebooks.

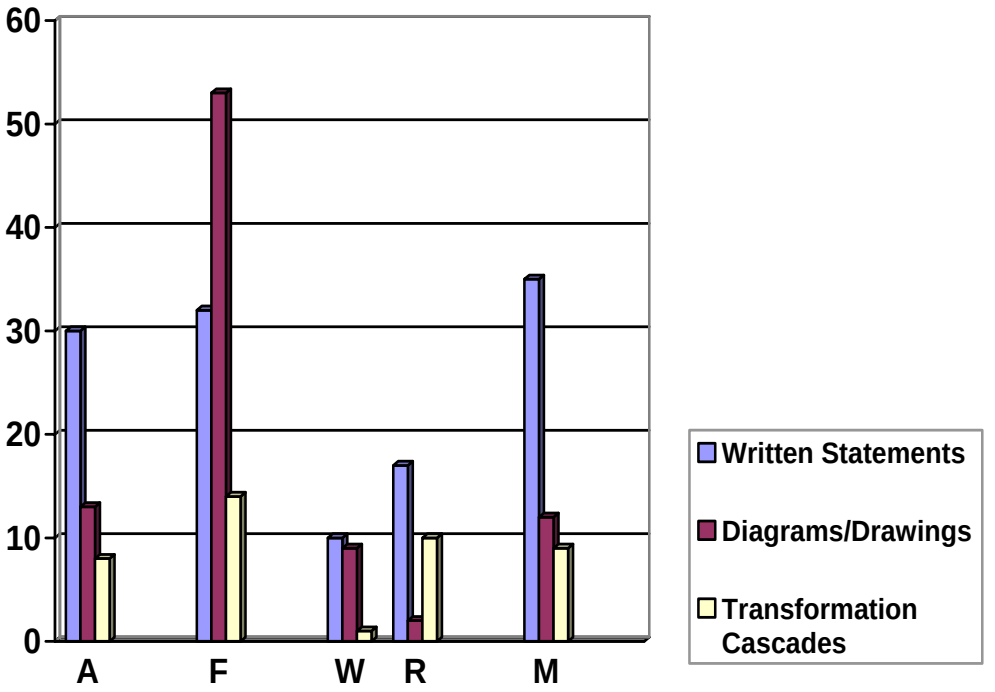
Some may be too quick to criticize our practice of setting guidelines such as these for students to follow in keeping their laboratory notebooks. In all of our teaching that has involved use of the rubric, an important and critical theme has emerged. Students initially tend to view the minimal numbers of inscriptions required with trepidation. As their work advances, however, the numerical requirements quickly become a non-issue with students. In other words, students routinely and easily exceed the minimum numbers listed on the rubric. Further, they report to us, both anecdotally and empirically, that the rubric helps them to better understand and utilize the whole notion of inscriptions, coupled with the authentic context of inquiry [Lunsford, 2002/2003]. Put simply we believe that when it comes to inscriptional practices, by asking for more we get more and it benefits the students. The students become more practiced and accomplished with inscriptional representation when the rubric is used.

CONCLUSION

As previously indicated, the primary goal of the AMSP institute was to provide students with experiences that would foster their ability to design inquiry-based classroom activities that are rooted in the science frameworks for their respective states. Figure 3 provides a summary of the students' responses as to how the various activities relate to their various state science education standards. It is of note that this figure was based on individual inscriptions from the students' laboratory inscription notebooks. The authors extended the individual student responses and integrated them into the *Benchmarks for Science Literacy* [AAAS, 1993] to avoid a cumbersome comparison of various state science standards. It is of note that the C-Fern, Nature Walks and Jewel wasp activities were listed by students as means by which to address all types of biological content standards they identified. Curiously enough, no student incorporated the Fast Plant® activity into his or her lists. The authors believe that this activity would, indeed, address a number of science standards. This was one of the earliest activities students engaged in, before being asked to link the activities to the standards. Also, only one student did extensive inquiry on the topic of natural dyeing. This topic is also not included on the students' lists.

As recorded in Table 2, all participants constructed a number of inscriptions in their laboratory notebooks. They took advantage of numerous opportunities to transform some of their more basic inscriptions such as written statements, lists and tables into more abstract ones such as graphs and charts. It is of note that students tended to display and refer to these more abstract inscriptions as they presented results of a long-term inquiry activity to their peers. Data from activities involving the C-Fern®, roly-polys and millet were transformed most frequently into abstract inscriptions.

Only one abstract transformation was noted among the participants' notebooks for the nature walk activities. This is consistent with predictions made by Roth, McGinn and Bowen [1998] that longer term, inquiry-based activities [which the interesting and well-received nature walks clearly were not] would tend to yield more abstract representations of scientific thinking and knowledge. Nature walks provided the greatest stimulus for the construction of diagrammatic inscriptions. Students primarily made drawings of organisms observed during the walks.



A = aquarium
F = C-Fern
W = Nature Walks
R = Roly poly
M = Millet

Figure 2. Summary of Inscriptions Recorded by Participants. Actual numbers of inscriptions constitute the vertical axis.

It is important to note that these activities can help address curriculum standards involving ecological relationships among organisms (See Figure 3). Also they can help students to sharpen their observational skills and can provide links to inquiry activities. In the present study, for example, students collected fecal pellets during a nature walk that were ultimately used for the dung farm activity.

Other outcomes of the AMSP workshop that are worthy of note involve the participants' ability to identify and improve upon design flaws in their experiments. This is a goal of good inquiry-based teaching and learning (Roth, 1995). Oddly enough, only three students or teams explicitly identified means that could improve a future replicate of their inquiry. Seven of the students or teams identified potential new research questions their inquiry had raised. This is another goal of quality inquiry-based learning (Roth, 1995).

In summary, then, it is clear that the AMSP workshop for science teachers, emphasizing inquiry-based activities as a means to address multiple science goals and standards, was a measurable success. Similar types of workshops may help other science teachers to broaden their inquiry-based teaching repertoire and may, therefore, benefit their students.

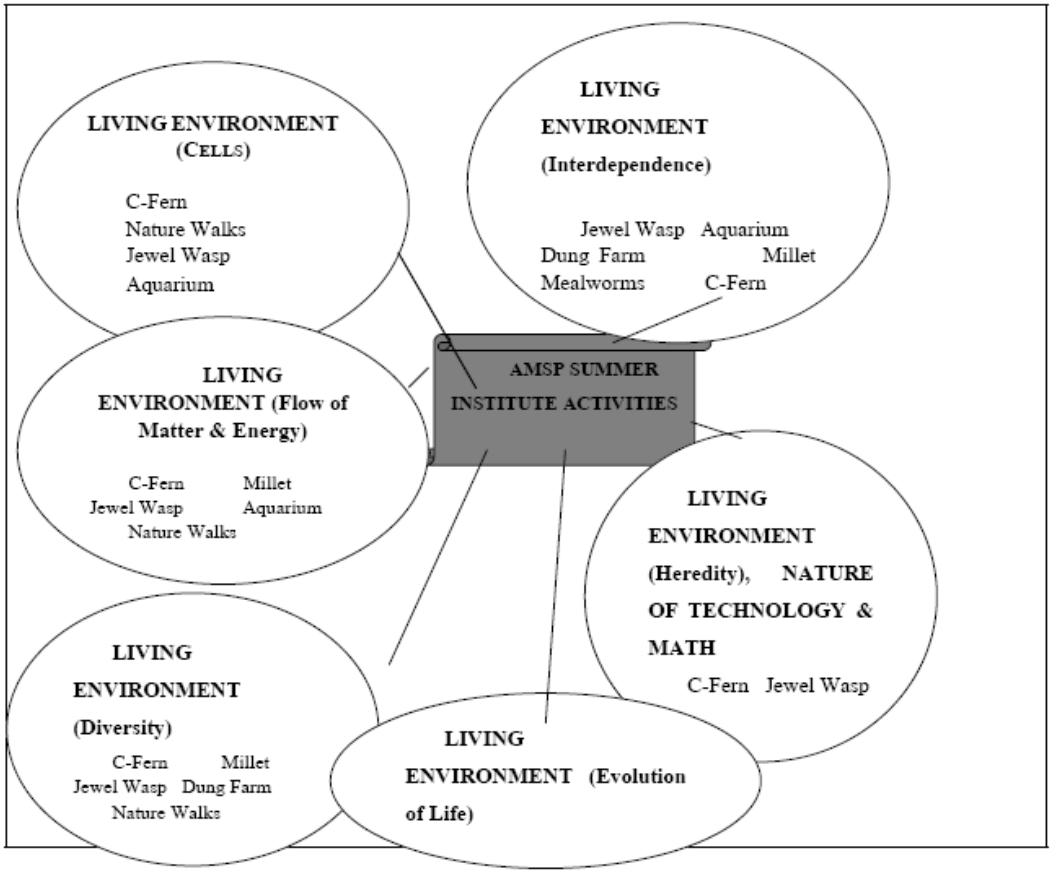


Figure 3. Correlation of Activities to Benchmarks Based on Student Responses.

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Chapter 5

FACILITATING SCIENCE TEACHERS' UNDERSTANDING OF THE NATURE OF SCIENCE

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ABSTRACT

Recent research in science education has recognized the importance of understanding science within a framework that emphasizes the dynamics of scientific research that involves controversies, conflicts and rivalries among scientists. This framework has facilitated a fair degree of consensus in the research community with respect to the following essential aspects of nature of science: scientific theories are tentative, observations are theory-ladden, objectivity in science originates from a social process of competitive validation through peer review, science is not characterized by its objectivity but rather its progressive character (explanatory power), there is no universal step-by-step scientific method. This study reviews research based on classroom strategies that can facilitate high school and university chemistry teachers' understanding of nature of science. All teachers participated in two Master's level degree courses based on 34 readings related to history, philosophy and epistemology of science (with special reference to controversial episodes) and required 118 hours of course work (formal presentations, question-answer sessions, written exams and critical essays). Based on the results obtained this study facilitated the following progressive transitions in teachers' understanding of nature of science: a) Problematic nature of the scientific method, objectivity and the empirical nature of science; b) Kuhn's 'normal science' manifests itself in the science curriculum through the scientific method and wields considerable influence; c) Progress in science does not appeal to objectivity in an absolute sense, as creativity, presuppositions and speculations also play a crucial role; d) In order to facilitate an understanding of nature of science we need to change not only the curricula and textbooks but also emphasize the epistemological formation of teachers.

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Keywords: *Science teachers, Nature of science, History, philosophy and epistemology of science*

INTRODUCTION

Research in science education shows that in most parts of the world, both high school and freshman students are not sufficiently motivated to pursue careers in science. Different research perspectives have attributed this state of affairs to various factors. The perspective based on history and philosophy of science has attributed this to the particular methodology employed by science teachers, textbooks and curriculum developers (Clough, 2006; Jenkins, 2007; Niaz, 2008a; Osborne, 2007; Stinner, 1992). For example, although the idea of testing and hypothesizing is most germane to the physical sciences, its presentation in the classroom is devoid of one of the most important aspects of progress in science, viz., rivalry between conflicting hypotheses. Despite all the reform efforts, classroom environment in most parts of the world is still characterized by a 'rhetoric of conclusions' (Schwab, 1974), in which students are told that they must learn this as a famous scientist said so. Ironically, the famous scientist generally had to struggle and argue with his contemporaries in order to present a particular theory, which contrary to popular belief is bound to be superseded, that is the tentative nature of science. It is precisely for such reasons that research in science education has recognized the importance of understanding science within a framework that emphasizes the dynamics of scientific research that involves controversies, conflicts and rivalries among scientists. It is plausible to suggest that such discussions based on 'science-in-the-making' and vicissitudes of the scientists can stimulate students' interest in learning science. Both students and teachers would be more motivated if they knew that are present day theories will change and that they could play an important role in this endeavor. In contrast, our present textbooks, teachers and curricula provide a vision of science which is static and immune to change. Furthermore, teacher education research is difficult and constitutes a relatively new field:

> At the same time, teacher education is a relatively new field of study. Those who have traced its development observe that rigorous, large-scale research on teacher education is difficult, time-consuming, and expensive to conduct; thus, some of the theoretical and methodological advances seen in more mature fields, for example, research on student learning, are just beginning to emerge in research on teacher education (Borko, Liston and Whitcomb, 2007, p. 3).

The objective of this article is to review research based on classroom strategies that can facilitate high school and freshman university chemistry teachers' understanding of the nature of science, that is how scientists do science.

NATURE OF SCIENCE

Despite some controversy with respect to what constitutes the nature of science for science education, a certain degree of consensus has been achieved within the research

community with respect to the following aspects (Lederman et al., 2002; McComas et al., 1998; Niaz, 2001, 2008b, 2008c; Osborne, 2007; Osborne et al., 2003):

1) Scientific theories are tentative.
   Scientific theories do not become laws even with additional evidence.
2) Scientific laws being epistemological constructions, do not describe the behavior of actual bodies, and thus many of our well known laws are 'irrelevant' (Blanco and Niaz, 1997; Giere, 1999).
3) Observations are theory-ladden.
4) Objectivity in science originates from a social process of competitive validation through peer review.
5) Science is not characterized by its objectivity but rather its progressive character (Lakatos, 1970, explanatory power).
6) Scientific progress is characterized by conflicts, competencies, inconsistencies and controversies among rival theories.
7) Scientists can interpret the same experimental data in different ways.
8) Scientists are creative and often resort to imagination and speculation.
9) There is no one way to do science and hence no universal step-by-step scientific method can be followed.
10) Scientific ideas are affected by their social and historical milieu.

HOW TO FACILITATE SCIENCE TEACHERS' UNDERSTANDING OF THE NATURE OF SCIENCE?

This section reviews research based on classroom strategies that can facilitate high school and university freshman teachers' understanding of nature of science. All teachers participated in two Master's level degree courses based on 34 readings related to nature of science, history, philosophy and epistemology of science (with special reference to controversial episodes). The two courses required 118 hours of classwork (formal presentations, question-answer sessions, written exams and critical essays). Some of the relevant units of the courses were the following: a) History and philosophy of science in the context of the development of chemistry (examples of some readings: Matthews, 1994; Niaz, 1998); b) Conceptual change in learning chemistry (examples of some readings: Niaz, 1995; Niaz et al., 2002); c) Nature of science (examples of some readings: Smith and Scharmann, 1999; Niaz, 2001); d) Critical evaluation of nature of science (examples of some readings: Lederman et al., 2002; Osborne et al., 2003). Results reported here are adapted from: Niaz, 2008b, 2008c.

Problematic Nature of the Scientific Method, Objectivity and the Empirical Nature of Science

Results reported in this section are based on participating teachers' written responses to the following exam questions:

Question 1:

According to McComas et al. (1998), cited in Reading 2 (pp. 466-467) there are various myths associated with the 'nature of science.'

a) Do you share the thesis that there are myths with respect to the nature of science? Explain.
b) What other myth would you add besides those mentioned by McComas et al. (1998).
c) Just as there are myths with respect to the nature of science, do you think there are myths with respect to chemistry education?

Question 2:

The scientific method is generally schematized as, "Observation, experimentation, enunciation of laws and theories, confirmation of the enunciated laws and theories" (Reading 3, Solbes and Traver 1996, p. 106).

a) Based on your experience as a teacher, do you think many of the chemistry textbooks represent science in this manner? Can you illustrate with an example.
b) Do you think that this is a good way to represent chemistry?
c) What changes would you suggest in order to improve the presentation of chemistry in textbooks and the classroom?

Results

At the beginning of the course teachers were simply aware that ideas like the scientific method, objectivity and empirical nature of science were considered to be controversial by philosophers of science. As a next step (progressive transition) this study provided the opportunity to understand that there are myths associated with the nature of science (Question 1). Participants suggested other myths besides those discussed in class, viz., limited intellectual horizon of the students (primarily due to the rigidity of the scientific method), science is a domain reserved for geniuses and men, learning is associated with memorization of formulae to solve algorithmic problems (cf. Pickering, 1990); and lack of a differentiation between idealized scientific laws and observations (cf. Niaz, 1999). Idealization in science, viz., scientific laws being epistemological construction do not describe the behavior of actual bodies, is considered to be "… as one of the major stumbling blocks to meaningful learning of science" (Matthews, 1994, p. 211).

Question 2 facilitated teachers' understanding of the scientific method within the context of chemistry textbooks. Almost all teachers agreed that chemistry textbooks presented science as an illustration of the scientific method in which: Robert Millikan (oil drop experiment, cf. Niaz, 2000) is presented as a 'god', there is lack of an understanding that Bohr's postulates represented the 'negative heuristic' (Lakatos, 1970), that is hard core of his theory, and postulation of the scientific method not as an alternative but rather as obligatory for the scientist. Teachers also suggested that presentation of chemistry in textbooks and the classroom could be improved by: introducing history and philosophy of science, recognition of the role of suppositions and hypotheses in the construction of knowledge and that it is the

scientific community that plays the role of the arbiter (peer review) and not the scientific method.

Kuhn's 'Normal Science' Manifests Itself in the Science Curriculum Through the Scientific Method

Results reported in this section are based on participating teachers' responses to the following question:

Question 3

Collins (2000) has a presented a trilemma with respect to teaching science due to the following conflicting requirements (reproduced in Reading 9, Osborne et al., 2003, p. 694):

a) The possibility offered by science to discover and create new knowledge.
b) The dogmatic and authoritarian way of teaching science, based partially on Kuhn's (1962) 'normal science.'
c) The necessity to teach nature of science in order to appreciate and understand the different aspects of scientific development.

What strategy can you suggest in order to resolve this trilemma?

Results

Participating teachers were aware that 'normal science' is an important aspect of Kuhn's *oeuvre*, and could be summarized in the following terms:

> Normal science is a conservative enterprise. Kuhn characterized it as 'puzzle-solving activity'. The pursuit of normal science proceeds undisturbed so long as application of the paradigm satisfactorily explains the phenomena to which it is applied. But certain data may prove refractory. If the scientists believe that the paradigm should fit the data in question, then confidence in the programme of normal science has been shaken (Losee, 2001, p. 198).

Before analyzing the results to this question it is important to note that Kuhn's (1962) *Structure of Scientific Revolutions* (SSR), has had considerable influence on science education research (Matthews, 2004). Loving and Cobern (2000) have conducted a citation analysis of Kuhn's SSR (based on Web of Science) in two of the leading journals in science education and concluded:

> It is important to point out that as each science education research article citing Kuhn was analyzed, it became apparent that almost all authors were citing Kuhn for support of some position. None of the articles examined from 1985 to 1998 in *JRST* [Journal of Research in Science Teaching] and *SE* [Science Education] offered any real critique of Kuhn's positions ... This suggests that what was mutual exclusivity of science education and philosophy of

> science in the twenty years following *SSR*'s publication ..., more recently may have turned into a mutual admiration society for Thomas Kuhn (p. 199).

This is a cause for concern and also shows how Kuhn's ideas have been accepted uncritically in science education and hence the need for making teachers' aware of arguments both in favor and against Kuhn.

This exam question provided the opportunity to deal with the horns of a trilemma: On the one hand school science generally tries to inculcate a dogmatic and authoritarian approach (this is known to be true and so you must learn, memorization), whereas science also presents a popular culture that promotes emancipation based on scientific discoveries. In this context, it is worthwhile to make teachers and curricula more conscious of how the inclusion of nature of science in the classroom will be resisted and even perhaps found contradictory. Seven participants explicitly stated that Kuhn's (1962) normal science manifests itself in the science curriculum and the textbooks through the scientific method. Following are examples of participants' responses who considered that Kuhn's (1962) 'normal science' manifests itself in the science curriculum and the textbooks through the scientific method:

> "… science in the classroom is presented from the positivist perspective in which the scientific method dominates the scenario --- this is what defines science. Similarly, only normal science is taught, as this is what appears in the textbooks and has consensus. This in itself creates a big problem by forcing students to memorize and repeat without understanding what science is all about."

> "… of the different ideas that can be included in school science, it is the tentative nature of science that can help most in undermining the influence of Kuhn's normal science."

> "… I suggest eliminating the second horn of the trilemma, that is science cannot be taught as suggested by Kuhn's (1962) normal science, with no reference to the problems and controversies. It is precisely due to this that school science has so many distortions of what real science is."

These responses clearly show that teachers in this study developed a more critical stance towards Kuhn's ideas and even suggested ways to undermine his influence. It is precisely such understanding of the dynamics of progress in science that can facilitate students' and teacher's interest in science.

Progress in Science Does Not Appeal to Objectivity in an Absolute Sense, as Creativity, Presuppositions and Speculations Also Play a Crucial Role

Results reported in this section are based on participating teachers' written responses to the following question:

Question 4

Martin Perl, Nobel laureate in physics 1995 in his search for the fundamental particle (quark) has elaborated a philosophy of speculative experiments: "Choices in the design of speculative experiments usually cannot be made simply on the basis of pure reason. The

experimenter usually has to base her or his decision partly on what feels right, partly on what technology they like, and partly on what aspects of the speculations they like" (Perl and Lee 1997, p. 699). Given the methodologies of Thomson, Rutherford, Bohr (Reading 5, Niaz, 1998 and Reading 14, Niaz et al. 2002), Millikan and Ehrenhaft (Reading 6, Niaz, 2000), in your opinion, what are the implications of this statement for teaching chemistry?

Results

It is important to note that Martin Perl and colleagues are at present working on a Millikan style methodology in order to isolate quarks (cf. Rodríguez and Niaz, 2004, for a comparison between Millikan's research methodology and Perl's philosophy of speculative experiments). The rationale behind using this episode from the history of science was to present an experience from a leading scientist working on cutting-edge experimental work (science-in-the-making) and how a scientist goes about in order to cope with difficulties. Thirteen participants found this item interesting and challenging, and although most presented positive implications, there were four who suggested negative implications. Following are some of the examples of positive implications for teaching chemistry:

> "According to Lakatos, theories can 'live' together for some time and after a period of arguments and confrontation the scientific community decides in favor of one or the other. Similarly, it is probable that Martin Perl considers the conjugation of speculation and reason as an important element in looking for an answer to a particular question. In the Millikan-Ehrenhaft controversy, Millikan based on the 'negative heuristic' of his research program decided to discard some of the data. This was perhaps a recognition that besides reason, speculation and intuition also played an important part… A similar process occurred in the case of the atomic theories [Thomson, Rutherford, Bohr] … This shows that everything cannot be solved by logic, and it is necessary to look for other alternatives provided they are consistent and well justified … Far from confusing the students, these episodes can arouse their curiosity and hence interest in science"

> "… in the work of Thomson, Rutherford, Bohr, Millikan and Ehrenhaft besides logic, speculations played an important part … this reconstruction based on the history of science demonstrates that scientists adopt the methodology of idealization (simplifying assumptions) in order to solve complex problems … it is plausible to hypothesize that students adopt similar strategies in order to achieve conceptual understanding" [For idealization cf., McMullin 1985; Niaz 1999]

> "… statement by Perl helps to 'humanize' chemistry … it opens a new window with respect to scientific knowledge … discussion of such issues in the classroom can facilitate conceptual change towards constructivist views … it will also require innovative teaching strategies …"

> "The picture that emerges from these episodes shows that controversy and speculation played an important part in the construction of knowledge ... This requires the preparation of critical persons who can defend their positions ... In this regard the teacher is responsible for not inhibiting students' creativity"

> "… how many scientific advances have not been presented just because the author could not substantiate his claims based on rigorous reasoning and perhaps also the fear that the

scientific community may not accept … dissemination of the work of Millikan, Ehrenhaft and Perl among teachers … could contribute to facilitate scientific progress"

"… Millikan did not manifest in public the speculative part of his research [Holton, 1978]… Perl, however has affirmed publicly that at times he speculates … Perl's affirmation manifests what Millikan in some sense tried to 'conceal', viz., science does not develop by appealing to objectivity in an absolute sense and that science does not have an explanation for everything and hence the need for research. Acceptance of the fact that science does not have an absolute truth and nor an immediate explanation for everything, would change students' conception of science and chemistry in particular. This will show chemistry to be a science in constant progress and that what is true today may be false tomorrow and may even help to originate a new truth --- sequences of heuristic principles" [cf. Burbules and Linn 1991]

CONCLUSION

It is important for teachers to understand that science does not advance by just doing the experiments and having the data. Progress in science inevitably leads to controversies and alternative interpretations of data. This task is difficult to accomplish as most science curricula, textbooks and teachers present science as 'normal science' (Kuhn, 1962), which is different from what science is all about. This study shows that given the opportunity to reflect, discuss and participate in a series of course activities based on various controversial episodes directly related to the chemistry curriculum, teachers' understanding of nature of science can be enhanced.

It is plausible to suggest that interactions among participants and teacher-participants in this study, facilitated the following progressive transitions in teachers' understanding of nature of science:

1) Problematic nature of the scientific method, objectivity and the empirical basis of science.
2) Myths associated with respect to the nature of science and teaching chemistry.
3) Understanding of the scientific method within the context of chemistry textbooks and not just as a concern of philosophers of science.
4) The role of speculation and controversy in the construction of knowledge based on episodes from the chemistry curriculum.
5) Science does not develop by appealing to objectivity in an absolute sense, as creativity and presuppositions also play a crucial role.
6) Differentiation between the idealized scientific law and the observations is crucial for understanding the complexity of science.
7) Kuhn's 'normal science' manifests itself in the science curriculum and textbooks through the scientific method and wields considerable influence. Given teachers' criticism of dogmatic and authoritarian ways of teaching science, the concern with respect to the scientific method is quite understandable.

These issues have educational implications and are important for deepening teachers' understanding of the nature of science. As compared to previous research, this study provides an explicit teaching strategy for introducing different aspects of the nature of science as part

of the regular classroom activities. At this stage, a word of caution is necessary as the relationship between different topics of the chemistry curriculum and history and philosophy of science (HPS) is complex. Given the difficulty of understanding the nature of science even for researchers in science education, it is plausible to suggest that participants in this study may not have understood the nature of science in all its complexity. Furthermore, it is essential to understand that the level of complexity at which the nature of science can be introduced would vary from the secondary to the freshman university level (cf. suggestions by Smith and Scharmann, 1999). However, it is plausible to suggest that such courses could motivate teachers to question the 'conventional wisdom about the empirical nature of chemistry' and pursue further studies in the nature of science within a HPS perspective.

Finally, it is important to recall philosopher-physicist Stephen Brush's (1978) advice to chemistry teachers:

> Of course, as soon as you start to look at how chemical theories developed and how they were related to experiments, you discover that the conventional wisdom about the empirical nature of chemistry is wrong. The history of chemistry cannot be used to indoctrinate students in Baconian methods (p. 290).

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Chapter 6

THE IMPACT OF IN-SERVICE EDUCATION AND TRAINING ON CLASSROOM INTERACTION IN PRIMARY AND SECONDARY SCHOOLS IN KENYA: A CASE STUDY OF THE SCHOOL-BASED TEACHER DEVELOPMENT AND STRENGTHENING OF MATHEMATICS AND SCIENCES IN SECONDARY EDUCATION

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ABSTRACT

The aim and purpose of the Classroom Interaction Study was to assess or measure the success or impact of the School-based Teacher Development (SbTD) and Strengthening of Mathematics and Sciences in Secondary Education (SMASSE) In-service Education and Training (IN-SET) programmes against envisaged outcomes (success indicators) in the projects with regard to teacher pupil/student interactions within the classroom setting. It also gave teachers the opportunity to give perceptions what they considered to have been the achievements of the two programmes. The classroom observation approach aimed at describing what teachers and pupils' did in the classroom or the teacher-pupil interaction. The observations focused on three main areas, namely: the frequency with which instructional materials were used, how the teacher utilised class time, and the amount and form of interaction observed between the teacher and pupils/students.

From the observations, there seem to be a number of features of classroom behaviour in the teaching of sciences and mathematics. Teachers generally spent much of their class time presenting factual information, followed by asking pupils individually or in chorus to recall the factual information in a question and answer exchange. Students

> were rarely asked to explain a process or the interrelation between two or more events, and the teacher rarely probed to see what elements of the material or process the pupils did not understand. This interrogatory style was an evaluative exercise, not one that sought to increase pupils' understanding.

INTRODUCTION AND BACKGROUND TO THE STUDY

It is now nearly over 40 years ago when Beeby pointed out that in the context of planning education for development, attempts to change the quality of learning in schools had to be linked to improvements in the education of teachers if they were to be effective (Beeby, 1966). Yet this area has received relatively little attention from policy-makers, donors and researchers since then. Though development agencies have supported a range of teacher education projects, few have contained support for research on learning processes and practices. As a result, the evidence base is weak, and much policy on teacher education has not been grounded in the realities that shape teacher education systems and their clients.

Perhaps most surprisingly, the World Declaration on Education for All (EFA), which emerged from the conference at Jomtien in 1990, devoted scant attention to the problems of teachers and teacher education, despite their centrality to the achievement of better learning outcomes. It was not until ten years later, at the Global Forum on EFA in Dakar, Senegal during which it became clear that in many of the countries which had fallen well short of the goals set at Jomtien, teacher supply and teacher quality were amongst the most important constraints. In the Dakar Forum, therefore, teacher education moved up the agenda of the EFA forum to the extent that the Sub-Saharan Regional Action Plan included it as one of its ten targets, namely:

> Ensuring that by the year 2015, all teachers have received initial training, and that in-service training programmes are operational. Training should emphasize child-centered approaches and rights and gender-based teaching (UNESCO, 2000).

But the extensive implications that this target had for teacher training systems were not elaborated; nor was the evidence base for the advocacy revealed. This has tended to be reflected in some of the on-going developments. For example, the Association for the Development of Education in Africa (ADEA) has ten thematic international Working Groups, one of which is focused on the teaching profession. However, the objectives of this group are primarily concerned with improvements in the management, employment benefits and professional support for teachers. Initial training and in-service do not feature as primary concerns, neither does research on practice. There are few information and development activities that could guide policy and practice in low-income countries, especially in Sub-Saharan Africa (Stuart and Lewin, 2002).

And yet in many of the less industrialized countries, especially in Africa, teacher education is in a crisis. Inherited systems of teacher education have proved increasingly unable to satisfy the dual demands for higher quality training and substantially increased output called for by commitments to universalize primary schooling (Ncube, 1982; UNESCO, 1997). Many education systems still contain high proportions of untrained teachers; at the primary level most who enter teacher training will only have completed secondary school.

The quality of primary schools is such that many are unable to provide a supportive professional environment for trainees of the kind possible where staff are fully trained and often graduates. Donor enthusiasm for new pedagogy, which frequently advocates learner-centered approaches, group work, attention to special needs, and a panoply of methods of training associated with best practice in rich countries, has sometimes sat uneasily with the realities of the training environment, the teacher education infrastructure, and different cultural and professional expectations of the role of the teacher. Much of the rhetoric of reform has been difficult to translate into real changes in practice (Kunje, 2002).

As a way of improving teaching skills of teachers, especially at the primary and secondary school levels, a number of countries, with donor support have mounted school-focused INSET programmes to meet specific needs of schools, especially as a means of halting the declining quality of education. Such INSETs have focused on two main areas, namely, the problem of reducing significant numbers of unqualified and under qualified teachers and improving the teaching of particular areas of the curriculum (Bude and Greenland, 1983). The implementation and effectiveness of these programmes have, however, not been adequately evaluated, although there are some notable exceptions which suggest their potential usefulness. Rogan and MacDonald (1985), for example, highlight the success of an INSET programme for science teachers in South Africa entitled, *the Science Education Programme (SEP*). It used a model involving cycles of workshops for teachers and follow-up support in the classroom. This model was successful in improving teacher performance in the classroom. A critical feature of the phased approaches or models is their cyclical nature. Each cycle of the model feeds into the next over a long period of time, usually a number of years.

The conventional course-based model of in-service education and training has been severely criticized in recent years because of its tendency to be over-generalized, over-theoretical and to ignore the problems faced by teachers when they return to their schools and implement the new ideas gained. Moreover the course-based model which tends to operate on the ‘cafeteria menu’ basis does not usually encourage teachers to consider the needs of their schools when applying for a particular course, especially when this takes place out of school time. Several writers have argued that, if it is to be effective, INSET should be related to particular innovations and to functional groups in the schools, that each school should devise its own staff development policy and the local authorities should provide external support for this process. Staff development should also try to meet the needs of both individuals and the organization as whole, that effective staff development policies are directly related to the overall policy of the institution and that new methods, like job rotation and sabbaticals, should be encouraged in these staff development policies (Bolam, 1983). This thinking has led to the notion of school-focused INSET targeting the needs of particular schools and individual teachers.

The available literature seems to endorse most of the strategies for school-focused INSET programmes, but presents little evidence to support their use. For example, needs assessment is widely supported in the literature. However, there are few examples of programmes in which INSET providers assessed teachers’ training needs. Lubben (1994) is alarmed that this is particularly so in developing countries. One of the reasons for this could be attributed to the lack of empirical research and knowledge about the actual process of needs assessment (O’Sullivan, 2002). There is also a dearth of knowledge concerning the determination of content, effective training processes and follow-up strategies. The available literature on content for INSET is mainly concerned with whether the content should be more or less

theoretical, rather than pedagogical (Greenland, 1983; Hawes and Stephens, 1990; Heneveld and Craig, 1996).

The literature on training processes tends to be dominated by a concern to promote reflective approaches to training rather than focus on specific practices and technical competence. However questions are beginning to be asked in the literature about the extent to which these approaches are useful in developing countries' contexts (Stuart and Kunje, 1998). Similarly, very little empirical research has been conducted which supports the critical role of follow-up, throws light on the process used or demonstrates the effectiveness of particular follow-up strategies (Lockheed and Verspoor, 1991). Indeed the lack of follow-up is highlighted as the reason for the limited implementation of INSET in the classrooms in industrialized and developing countries (Lamb, 1995; Yogev, 1997).

The literature on evaluation has also been found to provide inadequate guidance for practice. Avalos (1985) lamented the failure of many INSET programmes to adequately evaluate their effectiveness. Fuller's (1987) review reports the evaluation of only six studies. Greenland's (1983) notable study of INSET in Africa pointed out that of the 60 separate INSET activities researched, approximately half included a formally conducted evaluation, but in "only six cases was there actual follow-up at the school level to judge effectiveness" (p. 107). Useful evaluation has not improved in recent years. Yogev (1997) points out that "evaluations do not usually provide systematic information on the effects of SBI (school-based INSET) on classroom behaviour or on actual changes in teaching practices, nor on the impact of SBI on students". This is a cause for concern. It effectively means that no sound judgements can be made between one type of training and another.

The literature explains an apparent gap in the research. Greenland (1983) asks, what counts as evaluation evidence; is it pupil achievement, teacher performance, teacher opinion or all the three? Evaluation of effective INSET presents extremely difficult methodological problems. Consequently, researchers and INSET trainers have shied away from addressing these difficulties. Little (1994) points out that evaluation mainly gathers quantitative data, concentrating on numbers of seminars and workshops conducted, teachers trained, materials delivered, and so on. Such data fails to indicate the effectiveness of a programme, if implementation in the classroom is taken as the indicator of effectiveness. Some key studies, therefore, suggest a useful method or approach of evaluation: the collection of baseline classroom data at the beginning of a programme and its comparison with evaluation data collected upon completion of the programme.

Although many of the INSET programmes are geared towards improving teacher-pupil classroom interactions, literature indicating effectiveness in this area has been quite scanty. While many impressive classroom studies have been conducted in the developed countries, especially the U.S.A., much less is known about life inside Third World classrooms. The International Association for the Evaluation of Educational Achievement classroom environment study (1987), however, did reveal some interesting descriptive findings. Focusing on Nigeria and Thailand, researchers found that in over two-thirds of the observation segments, teachers were simply lecturing at the class. In much of the remaining time, students were sitting alone (on the floor or at desks) working on assigned exercises. When teachers posed a question, these utterances usually were directed at the entire class, not spoken to an individual student. The teachers' questions most often requested a single piece of factual information, rarely requiring complex cognition (Anderson, Ryan and Shapiro, 1987).

An attempt made to present the realities of life in the classrooms for both teachers and pupils in the above selected studies are not different in many of the Third World countries in general, and Africa in particular. The basic assumption is that such presentations are a reflection of the teacher-pupil interactions in the classroom through which schooling actually takes place. In other words, all the aims and objectives of both the formal and informal curriculum are converted into concrete actions carrying messages, some overt and some hidden, to consumers of the process. This is the predominant classroom interaction that many INSET interventions try to change in Third World teaching situations.

INSET PROJECTS IN PRIMARY AND SECONDARY SCHOOLS IN KENYA

The two recent INSET projects that are intended to improve teachers'-pupils' interaction, among others, have been the Strengthening of Mathematics and Sciences in Secondary Education (SMASSE) and the School-based Teacher Development (SbTD), which is part of Strengthening Primary Education (SPRED 3). The two were first launched on a pilot basis and later transformed into nation-wide projects involving many primary and secondary school teachers.

The SMASSE Project:

SMASSE is a joint project between the Ministry of Education, Science and Technology (MoEST) and Japan International Agency (JICA). It was started in July 1998 as a pilot project and expanded to cover the entire country in July 2003. Its overall goal is to upgrade the capability of Kenyan teachers in the teaching of Mathematics and Science (Physics, Biology and Chemistry).

The project was launched following a general demand for INSET among teachers and secondary school heads. Since 1994 the Kenya Secondary School Heads (KSSHA) had been advocating for an INSET and had attempted to organise cluster schools' INSETs in the Coast, Nairobi and Central provinces.

The Kenya Government's goal of making Kenya a newly industrialised country by the year 2020 appears to have been another reason for institutionalising an INSET in mathematics and sciences as a way of improving the quality on instruction and performance. Overall student performance in mathematics and science in the Kenya Certificate of Secondary Education (KCSE) has generally been quite poor over the years.

Before launching the SMASSE project, a baseline survey was carried out in 1998 to establish the status of secondary school mathematics and science. The baseline survey identified some major areas that were said to lead to negative attitudes and poor performance in these subjects. These were as follows:

- Attitudinal factors;
- Teaching methodology;
- Mastery of content;
- Professional interaction for teachers;

- Development of teaching/learning materials; and
- Administrative factors.

On the basis of the baseline survey, the project recognised the need to enhance the quality of teaching in terms of the above issues through an INSET project. Its main purpose is to strengthen mathematics and science education at the secondary school level through an INSET of serving teachers in the country.

The Kenya Science Teachers' College was identified as the institutional partner for the project. In the mid-1990s, the Kenya government had made a request to the Japanese government to upgrade the college's laboratories, which were now considered ideal for the SMASSE INSET project.

The project adopted a cascade mode of INSET training. There are two levels of training, one at the national level and another at the districts' level. At the national level, national trainers train key district trainers, while at the district level, district trainers train teachers in their respective districts.

To ensure the quality of mathematics and science teaching and their steady improvement, the project promotes an ASEI (Activities, Students, Experiments and Improvisation) movement, which is key in the project for lesson innovation. Activities for the students such as practical work, discussion, presentation and others, should be carried/practiced more in the lesson to promote students' active participation. Students not the teacher should be placed at the centre of lesson presentation. How the students learn should be given priority over how teachers teach. Students should also be given opportunities to perform experiments, which enhance an understanding of concepts and principles in mathematics and science. When conventional apparatus are not available, teachers should make efforts to give experiments by improvisation using locally available resources. Improvisation should also be for creating interest in the learners.

The ASEI movement is made possible by Plan, Do, See and Improve (PDSI) practice. Which means, Plan: Careful preparation based on the learners' needs and problems; Do: Teach the lesson, using well-chosen and planned activities; See: Evaluate the lesson at all the stages of its development. Improve: Feedback-the evaluation results to improve lesson instruction and future planning and implementation (SMASSE National INSET Centre, 2003).

MANAGEMENT AND SUPPORT SYSTEM OF SMASSE

At the time of launching the programme, Government of Kenya provided full time personnel to the National INSET Centre while the Japanese International Cooperation Agency (JICA) provided Japanese experts to assist in the planning and implementation of the INSET activities. The team of experts developed training materials that were used in the national and district INSETs. At the district level training, the key trainers adapted the materials to the local situation and needs.

The INSET programme adopted a cascade system for its activities, with two levels of training, one at the national level and another one at the district level. At the national level, the national trainers train district (key) trainers. At the district level, the district trainers train

teachers in their respective districts. To enhance the cascade system, the following were among the key administrative structures:

- *National Coordinator:* at the national level, the Senior Deputy Chief Inspector of Schools coordinated the project. The officer planned, organised and administered funding as well as monitoring and evaluation of SMASSE activities at all levels.
- The Kenya Science Teachers College (KSTC) houses the National INSET Unit, which runs the project on a daily basis and also trains district trainers, awards certificates, monitors and evaluates activities and issues guidelines on the INSET system, quality of teaching and learning.

District INSET Centres: The DEOs, inspectors, head teachers and district trainers shouldered the responsibility of organising, funding and conducting INSETs. More specifically, the centres liased with the DEOs in the selection of teachers to attend the INSET, sensitised head teachers to support and fund the INSET, monitored the progress of trained teachers, and were the custodians of facilities, equipment and materials supplied.

The SbTD Project

The launching of SPRED was as a result of the perceived decline in the quality of primary education in the country. Kenya's educational provision had grown rapidly since the attainment of independence in 1963. This growth had culminated in the rise of the GER to 95% in 1990. Despite such growth, enrolment had been declining over the years, falling to the figure of 88.8% in 1999. The negative trend was attributed to a number of factors, the main one being economic decline, with parents bearing the cost of school buildings, textbooks and uniforms. Another factor cited was the quality of teaching and learning (MoEST, 1997). The Ministry of Education's National Baseline Survey of 1998 showed that there was a limited range of pedagogic practices in the MoEST public schools, which provided little opportunity for pupil interaction or practical activity.

To arrest the decline in enrolments and improve the quality of primary education, the British Government through the Department of International Development (DFID) supported a joint intervention, the Strengthening of Primary Education (SPRED) Project. The first phase ran from 1993 – 1996 and although it was considered successful in achieving many of its aims, it was found to have limited impact at classroom level. This was ascribed to the lack of involvement of some of the key stakeholders and the utilization of a cascade model of training. Another perceived weakness was the opportunity cost for the pupils as the in-service training took the teachers away from the classroom.

SPRED 3, a three-year Project whose implementation commenced in July 2000, sought to address these weaknesses. The primary purpose of the project was to improve access of poor children to better quality primary education. The project had two components: the text book programme; and the School based Teacher Development programme (SbTD) which advocated a school based model of teacher development, supported by self-study distance education materials. This approach was supported by research findings that showed that distance education was one of the most successful means for upgrading primary teachers

(Lockhead, 1991). Distance education had also been found to be more cost effective, than a face-to-face model in the training of large numbers of teachers. Similarly, opportunity cost for the pupils was low, as the teachers continued to study while teaching.

Collectively, the two components were being used as strategies for addressing critical issues in the primary education system, namely:

- Declining enrolment, attendance, and retention rates;
- Rising costs of education to the parents;
- Elusive quality and relevance of education; and
- Need for equitable distribution of basic teaching and learning resources.

With regard to the SbTD in particular, its main aim was to develop teachers who reflected on their teaching and could respond to their children's needs and support their learning. The project's specific objectives were as follows:

- To develop teachers' ability to reflect on all aspects of teaching and learning;
- To develop teachers' understanding and belief in the central role of talk in learning;
- To guide teachers to understand and believe in the importance of children being actively involved in their own learning;
- To encourage teachers to plan for collaborative learning;
- To improve teachers' classroom management and assessment skills;
- To help teachers to identify and give attention to children with special educational needs;
- To raise teachers' awareness of gender issues and to address them in their own teaching;
- To develop teachers' ability to provide guidance and counselling to their pupils; and
- To help teachers to implement change in their schools (GOK/DFID, 2000).

The project assumptions were that a reduction in costs to parents (through supply of textbooks) would increase access, while improvements in the quality of teaching and learning (through the delivery of SbTD) would enhance retention.

The underpinning principle of the SbTD project was more than improving the quality of teaching and learning; it also aimed at playing a key role in developing mainstream the MoEST systems for in-service training to ensure that SbTD is professionally sustainable and indeed institutionalized within the MoEST. This was said to be a shift from the traditional donor-driven projects, which tended to operate through parallel rather than mainstream structures.

The programme was also designed to ensure that training at the teacher level was of consistent quality through distance learning materials (modules) and that teachers could get professional support at all levels, i.e. school, zone, district, division, province and MoEST (INSET). To support this principle the design and implementation of the project was geared towards capacity building, developing and strengthening mainstream systems, involving key stakeholders, gender equality and quality assurance.

At the primary school level, the course was expected to target motivated and committed teachers who were willing to improve their own teaching and the quality of learning in the

schools. Three teachers from every school were to be selected by the subject panels and endorsed by the whole staff. Each of the three teachers referred to as Key Resource Teachers (KRTs), would specialise in Mathematics, Science, or English. Their role was to go beyond improving their own teaching skills, as they would be required to work with their school subject panels to improve the teaching in their subject areas. Such teachers were to be selected according to set criteria, which would include gender, motivation, commitment and professionalism, among others. Their key function would be:

- To work through the distance education learning materials; and
- To lead professional development in their schools through their subject panels (GOK/DFID, 2000).

MANAGEMENT AND THE SUPPORT SYSTEM OF THE SBTD PROJECT

It was recognized from the onset that for the SbTD to be professionally sustainable it needed to be institutionalized within the MoEST. Moreover the national scale of the programme and the distance education design presented an opportunity to develop and strengthen MoEST in-service system and structures. In February 1999 a MoEST INSET Unit was established within the Inspectorate headed by Deputy Chief Inspector of Schools. This is the Unit that manages the SbTD project. The main focus of this Unit is the development of the SbTD project and establishment of a sustainable mechanism for national in-service delivery. The Unit manages material development, administration, support and information flow.

Being a distance education project, SbTD required ongoing professional support at all levels. The success and quality of the SbTD depended on the quality and effectiveness of support to KRTs. The project had to put in place support mechanisms at all levels. Key stakeholders were sensitized to help them understand their role in supporting the programme.

At the national level the INSET team together with the Steering Committee members undertook the development of modules for KRTs and Training Handbooks for other cadres. The focus of the handbooks was to provide knowledge about the course and seek the support of the District Education Office (DEO) office, the Head Teachers, the Inspectors, and the Zonal Teacher Advisory Centre (TAC) Tutors who would in turn support the KRTs.

The Support System ensures that various Support Cadres are adequately trained and resourced to successfully implement the SbTD programme. The training offered to these different cadres was different from the typical cascade model of training which filters down through different layers, hence compromising quality. The training focused on the actual support that the KRTs required, and the need for them to engage in a process of self-reflection and professional development. Some weeks were organized for TAC tutors to deepen their basic skills needed for SbTD and encourage a reflective monitoring and tutoring approach. It also gave the TAC tutor the opportunity to share experiences and facilitate ongoing improvement.

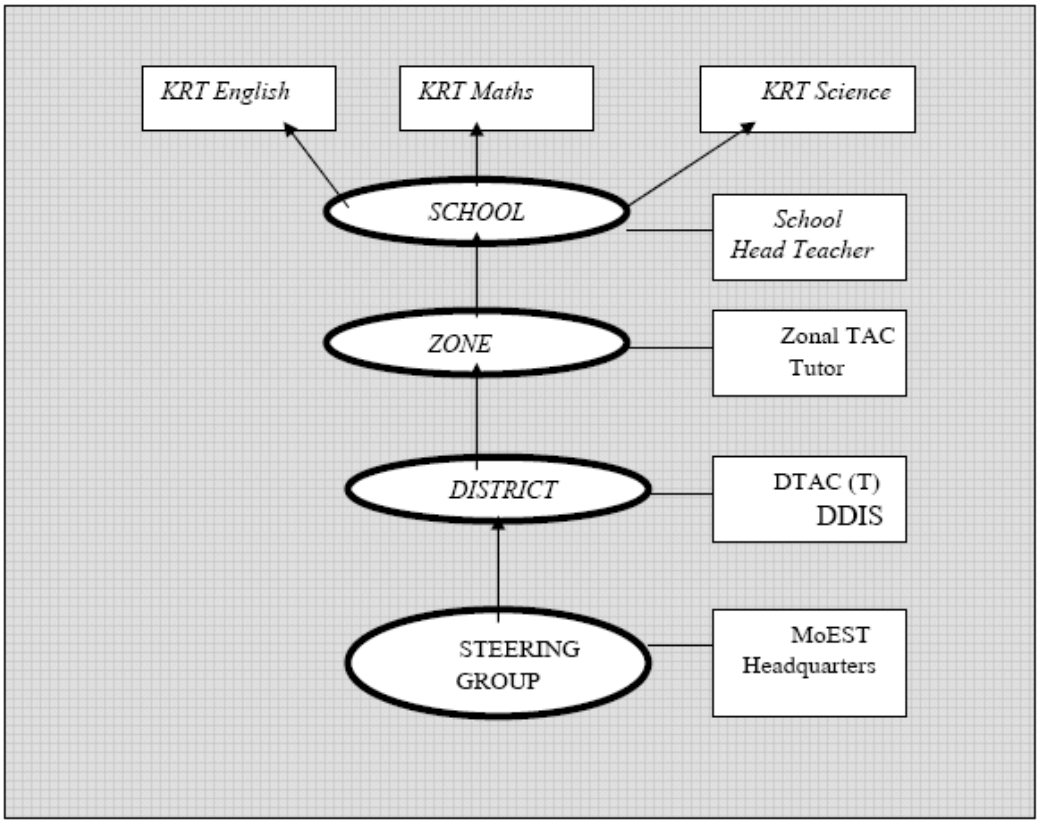


Figure 1. The Management Support Structure of SbTD.

Focusing more on the support system, it should be realised that the programme had to mainstream the support within the existing structures. The TAC Tutors periodically visited teachers in schools, observed them teach, organised face-to-face tutorials as well as marked Tutor Marked Assignments (TMAs). The role of the TAC Tutor was very important in developing teachers professionally.

PURPOSE AND OBJECTIVES OF THE CLASSROOM INTERACTION STUDY

The purpose of the study was to assess the effectiveness of the SMASSE and SbTD INSET projects on classroom interaction. More specifically the study was guided by the following objectives:

- To assess teachers' perceptions about the implementation and effectiveness of the SMASSE and SbTD in-service programmes and the challenges experienced by schools in the teaching of mathematics and sciences and sustaining of these projects;

- To assess pupils/students perceptions about their teachers' classroom behaviour with particular focus on their taking greater responsibility of their own learning processes and the general classroom atmosphere; and
- To assess the effects of the two in-service programmes on teachers' teaching approaches, especially embracing changes in teaching skills, classroom management and teacher-pupil/student interactions.

DESIGN AND RESEARCH APPROACH

The research design was participatory. Based on the objectives of SbTD and SMASSE projects, discussions were held between the project coordinators and the researchers in order to build consensus that the Classroom Interaction Study required an action-oriented research approach. This embraced the use of a participatory approach in which all the parties involved in the programmes were part and parcel of conducting the study. Such action research was fundamentally a problem-solving activity, which was not based on making judgment about the SbTD and SMASSE programmes, but focused on the participatory identification of the two project's impact on the teaching-learning processes by teachers and students, in collaboration with the researchers, with the research tools acting as the media of interaction.

Data Collection

This section focuses on the sampling procedures and research instruments. The study design and approach were discussed and approved in two workshops the held at the JICA Center in Hiroshima in March 2004 and the University of the Philippines in February, 2005

Study sample: On the basis of resources available for the study, the researchers adopted a case study approach in selected primary and secondary schools located in four districts of Kenya. These were Nairobi, the country's capital city; Kiambu, a peri-urban rural district situated next to Nairobi; Kajiado and Garissa districts, which are predominantly rural-pastoral districts in the Arid and Semi Arid (ASAL) regions of the country. Since the main focus of the study was to assess the effect of the two INSET projects on classroom interaction, this called for a purposive sampling of a relatively small number of schools in each district based on the recommendations of the education 'Quality Assurance and Standards' officers in the districts, but also taking into consideration their geographical and administrative locations. Consequently, 6 public secondary and 4 primary schools were sampled in each of the districts of Nairobi, Kiambu and Kajiado, while 4 secondary and 2 primary schools were sampled in Garissa due to the expansive distances between the schools. In each of the secondary schools, 1 mathematics, 1 physics, 1 chemistry and 1 biology who had participated in the SMASSE programme were targeted, while non-SMASSE teachers in the same subjects were randomly selected. With regard to the SbTD project, 2 mathematics and 2 science teachers (KRTs), who had participated in the project, and 1 non-SbTD teacher in each of the subjects were randomly selected. Therefore, teachers trained in SbTD and SMASSE projects at the primary and secondary school levels, respectively, were involved, as well some control group of teachers who had not been trained in the two programmes. The actual sample was as shown in Table 1.

Table 1. The study sample

Instrument	Project	Kiambu	Kajiado	Nairobi	Garissa	Total
Interviews	SMASSE	28	23	17	11	79
	Non-SMASSE	10	7	9	4	30
	SbTD	17	13	16	10	56
	Non-SbTD	6	6	7	5	24
Lesson observations	SMASSE	12	10	13	10	45
	Non-SMASSE	7	6	5	5	23
	SbTD	8	9	11	5	33
	Non-SbTD	3	4	4	5	16
Focus Group Discussions (FGDs)	Primary Schools	5	4	6	5	20
	Secondary Schools	9	5	10	5	29

Research Instruments: To capture the various aspects of the SbTD and SMASSE projects, a number of data collection instruments were designed for the key participants involved in the research. These included:

- Interview schedule for the SMASSE teachers in Mathematics, Physics, Chemistry and Biology and SbTD teachers in Mathematics and Science. The interviews focused on their perceptions about the implementation and effectiveness of the SMASSE and SbTD in-service projects and the challenges experienced by schools in the teaching of mathematics and sciences and sustaining of these programmes. Non-SMASSE and non-SbTD teachers were interviewed about the general problems they experience in the teaching of these subjects in secondary and primary schools. The interview schedule was validated leading researchers in the Department of Educational Foundations at Kenyatta University.
- Focus group discussion guides for upper primary school pupils and students from the four grades of secondary school were designed and they focused on pupils'/students' perceptions about their teachers' classroom behaviour with particular attention on their taking greater responsibility of their own learning processes and the general classroom atmosphere; and
- Classroom observation guides for SMASSE and Non-SMASSE teachers in Mathematics, Physics, Chemistry and Biology and SbTD and Non-SbTD teachers in Mathematics and Science subjects were constructed. This required the construction of an observation instrument which could be used to reliably to record actions engaged in by teachers over sampled class periods. The behavioural scales were developed to measure discreet behaviours of the individual teacher and dominant pupil/student behaviours in which the entire class was engaged. The observation instrument focused on three main areas, namely; (a) how the teacher utilized class time, (b) the frequency with instructional materials were employed, and (c) the amount of and form of interaction observed between the teacher and pupils/students. The observation instrument contained two parts. The first part included a continuous assessment that required the observer to estimate the proportion of time the teacher

behaved in specified ways. For instance, each observer estimated the share of total class time the teacher lectured/presented information, led a recitation and other logistical tasks. These estimates were for the entire 40-minute period. The second part consisted of an estimation of pupil/student behaviours engaged in by the entire class during the same period. Observers, for example, checked if pupils/students were reading a textbook, i.e. if a majority of pupils/students were engaged in this particular activity. The instrument, therefore included basic descriptions of the classroom behaviours, subject taught and instructional materials in use on the basis of both the teacher actions and pupils'/students' behaviour with regard to time use, all which constituted pupils'/students' interaction. The observation instrument was validated by members of the Teaching Practice Unit of Kenyatta University.

The three approaches were considered necessary to generate a wide range of data for the classroom impact study of the two projects. For the SbTD and SMASSE Mathematics and Science teachers, it was appropriate to hold face-to-face, in-depth discussions to obtain more insights in the operations of the projects, since they were key in their implementation. Pupils and students, on the other hand, were perhaps the most crucial stakeholders in the SbTD and SMASSE projects since they were the end-beneficiaries of an improved teaching and learning process. As such, their views on what went on in the classroom were essential in gauging the success of the implementation and the direction the projects have taken. It was in this regard that their views were sought through FGDs.

In the light of the research design adopted, it was important to undertake largely qualitative and some quantitative analyses of data collected for a more in-depth and systematic evaluation of the projects' implementation and impact on the classroom teaching and learning processes.

An important factor that needs to be taken into consideration with regard to the results of the study is that since both the SMASSE and SbTD are now national programmes, a purposive sample of four districts, although selected on the basis of some geographical settings and particular features regarding programmes' implementation, tends to limit the generalization of the findings.

The School Settings

Before focusing on teachers' and students' perceptions and classroom interaction practices, it is useful to briefly discuss the general classroom settings in both secondary and primary schools in the country.

Secondary Schools: Classrooms in the secondary schools are generally large, bright rectangular rooms with windows running full length of both sides of the classroom. Some have wall displays that are not heavily utilized apart from timetables and class rotas. In some of the older schools many classrooms contain old, and at times damaged desks and chairs, and it is not uncommon to see children sharing chairs throughout a lesson. The classrooms vary in tidiness. Each classroom has a cleaning rota of students, but the care and energy that they put into this very dusty activity depends on the enthusiasm of the class teacher or duty master in maintaining a clean school.

The practical subjects are normally accommodated in specialized units, in the form of workshops for technical subjects and home science, and laboratories for sciences. The latter are furnished with bench-tables and stools. For most established secondary schools, utilities and services such as gas, water and electricity are provided.

Instructional time is normally forty minutes, but frequently, two forty-minute lesson periods are blocked together for the practical subjects especially in the science subjects.

Primary Schools: These vary so enormously that it is not quite easy to generalize about them. In some places classes are taken in the open air and the quality of the physical facilities and the teaching/learning materials are dependent on capacity of the surrounding communities to mobilise the necessary support resources. On the whole, urban primary schools have superior learning facilities. The poor teaching and learning throughout the country has however, been exacerbated the government's decision to provide free primary and secondary education from January 2003 and January 2008 repectively. It is now very common to find classrooms which were constructed to house 40 pupils crowded with 90 pupils or more.

Analysis of Results

In the following sections, we present the results of the study.

Teachers' assessment of the effect of INSET projects on classroom practice: Teachers were asked about what they perceived to be the effect of the INSET projects on their classroom behaviour. Their perceptions are as presented in Table 2.

Table 2. The effect INSET programmes on classroom practice

Item	SMASSE Total No. of Teachers 79				SbTD Total No. of Teachers 56			
			Not specified				Not specified	
	No.	%	No.	%	No.	%	No.	%
Prepares schemes of and lesson plans	73	94.0	6	6.0	50	90.3	6	8.7
Combination of student-centred methods, questioning and lecturing	51	63.2	28	35.8	32	57.9	24	42.1
Improvised materials, labs and equipment and textbooks	59	75.4	20	24.6	30	54.4	26	44.6
Groupwork, experiments, field work, writing notes, asking questions, and lecturing	52	65.8	27	34.2	36	64.7	20	34.3
Home work- regular assessments and assignments	76	96.0	3	4.0	45	81.3	11	9.7

On the overall, teachers were of the view that the projects had considerably improved their classroom performance. With regard to preparations of schemes of work and lesson plans, 94.0% (79) of SMASSE and 91.0% (56) of SbTD were of the view that they very frequently prepare these documents, although there was no reflection of this in the observed lessons. Furthermore, as a result of the projects, 64.0% (79) of SMASSE 57.9% (56) of SbTD respectively, reported to be using a combination of pupil/student-centred teaching approaches alongside questioning and lecturing. An important teaching approach that emerged from the two programmes is the need to improvise in the use of teaching/learning materials and a generous use of materials to "bring reality into the classroom setting". This was mentioned by 75.4% (79) of SMASSE and 54.4% (56) of SbTD teachers respectively. Among the methods that were predominantly applied in the classroom situation include group work, field work, giving notes asking questions and lecturing, which were cited by 65.8% (79) of SMASSE and 64.7% (56) of SbTD teachers. The training programmes are also said to have placed a strong emphasis on giving pupils/students regular assessments and assignments, which was mentioned by 96.0% (79) of SMASSE and 81.3% (56) of SbTD teachers respectively.

TEACHERS' NARRATIVES

The following teachers' narratives support what they perceived to have been the impact of the programmes on lesson preparations and classroom performance as discussed in above and were typical of responses by most teachers who had participated in the two programmes.

Box 1. Biology Teacher (SMASSE)

Relevance in Teaching: Preparing practical lessons in physics. Involving students more practically in lessons.

Preparation for Teaching: Schemes of work, lesson plans, lesson notes, teaching aids, three-dimensional teaching aids.

Methods Used in Lesson Presentation: Group activities/discussions, class presentation, practical activities, lecture method.

Teaching/Learning Materials: Textbooks, 3 dimensional models, drawings/manila paper.

Pupils/student involvement in T/L process: Group discussion and presentation, class exercises, solutions on board by different students.

Distribution of Responsibilities by Gender: When classes are combined, the following duties are distributed equally: group secretaries, group chairmen, cleaning b/boards, and facilitation for discussions.

Frequency of Homework: Given, marked and discussed daily; peer marking in objective question tests and those with short, precise answers.

Lesson Evaluations: Daily evaluation-help in preparing for remedial lessons after school/class hours.

Support from School in Teaching: Organisation of tuition and revision programmes for form 4 students. Provision of teaching resources. Extra hours for teaching on Saturdays.

Opportunities for Teaching subject: Currently there is high interest in physics being

observed in students due to improved teaching methods.

Obstacles: Large numbers of students/class sizes.

Impact of In-Service Course on Teaching Quality: Preparation of teaching resources. Involving the students more in lessons. More positive to peer and self-evaluation.

Sustaining In-Service Course: Having a school-based programme with external supervisors for everybody

Box 2. (Mathematics Teacher (SbTD)

Assistance in Classroom Teaching: It has simplified teaching; since it has taught me how to involve pupils in their learning, e.g. peer teaching and peer marking.

Teaching Preparations: Schemes of work, lesson plans, collect and store teaching aids. Has set up a resource center.

Teaching Methods: As much as possible uses pupil-centred and practical approaches.

Teaching/Learning Materials: Normally use bottle tops, stones, sticks, old cans, boxes and so on-pupils assist in collecting them.

Student Involvement in Teaching/Learning Process: Group work, peer teaching and marking, demonstrating working out problems on BB, asking and answering questions.

Student's Homework: An assignment after every lesson. Students evaluate themselves, practice and also to make them work ahead of the teacher, revise past lessons. From their answers, one evaluates the effectiveness of teaching and can decide to move ahead or give remedial teaching.

Lesson Evaluation: After every topic, students get an evaluation. CATS (major) twice in a term and one exam termly. Practical evaluation through hands on experiments. Peer evaluation using an observation guide-once a term. On daily basis by marking pupils' books. Helps to know their weaknesses and decide on how to adjust teaching.

Support From School: Support is good; buying of equipment, academic trips, time off to attend training.

Distribution of Responsibilities by Gender: Normally mixed equally, in group work the group leaders and secretaries are usually shared between boys and girls.

Lesson evaluation: Support from school: School has helped in establishing a resource center. Unavailable resources are brought on request. Teachers are cooperative-interact on how to improve teaching.

Opportunities: Pupils are usually very interested in learning mathematics. Locally available resources are plenty for improvisation.

Obstacles: Classes are usually too large-marking is a problem and also giving individual attention for weak students is hard.

Impact of In-Service Course on Quality of Teaching: Helped to create a maths panel with colleagues and this has improved the quality of teaching and learning. Learners no longer fear maths and their performance has improved.

Sustaining the In-Service Course: Those who complete the course should be promoted to the next grade as an incentive so as to encourage others to put more effort in studying and practicing what they learn.

Challenges in the Teaching of Mathematics and Science in Schools:

Teachers were asked to identify some of the challenges they experience in the teaching of mathematics and science and how INSET projects should be sustained. Their views are summarized in Table 3.

Among the key challenges in the teaching of mathematics and sciences in secondary and primary schools include, the negative attitudes by the students towards these subjects, which were mentioned by 61.3% (79) of SMASSE teachers and 57.2% (56) of SbTD teachers. They also mentioned large and overcrowded classes as well as lack of teaching facilities and equipment, which were mentioned by 56.2% (79) and 58.4% (79) of SMASSE and 54.8% (56) and 74.6% (56) of SbTD respectively. Teachers also mentioned weak support they get from their schools in the teaching of these subjects, which was attributed to lack of adequate funding. This was mentioned by 54. 8% (79) of SMASSE and 61.9% (56) of SbTD teachers. The Ministry of Education came under very severe criticism for lacking regular INSET programmes, which was mentioned by 88.1% (79) of SMASSE and 91.0% (56) of SbTD teachers. They also have poor motivation, not only in the teaching of mathematics and sciences, but also towards their entire teaching career due to bad working conditions and remuneration as well as lack of recognition by the Ministry of Education for teachers who had participated in these projects by way of promotion or some form of other professional advancement. This particular aspect was cited by 68.6% (79) of SMASSE and 75.5% (56) of SbTD teachers.

Table 3. Teachers' challenges in teaching mathematics and science

Item	**SMASSE Total No. of Teachers 79**				**SbTD Total No. of Teachers 56**			
			Not specified				**Not specified**	
	No.	%	No.	%	No.	%	No.	%
Negative attitudes by pupils/students	48	61.3	31	38.7	32	57.2	24	42.8
Large and overcrowded classes	44	56.2	39	43.8	31	54.8	25	45.2
Lack of teaching facilities and equipments/materials	45	58.4	34	41.6	42	74.6	14	25.4
Weak support from schools	43	54.8	36	44.2	35	61.9	21	39.1
Lack of In-service education and training programmes by Ministry of Education	70	88.1	9	21.9	51	91.0	5	9.0
Lack of motivation for teachers	55	68.6	24	31.4	40	75.5	16	31.4

PUPILS'/STUDENTS' PERCEPTIONS ABOUT THEIR CLASSROOM INTERACTION

Pupils'/students' attitudes and views were captured through the FGDs. It should be noted form the outset that a majority of pupils/students were not aware that specific programmes for their teachers had been running, in this case either SbTD or SMASSE. On the whole, therefore, pupil's assessment of the teaching and learning processes, including the performance of their teachers, was quite objective.

As a way of assessing their classroom interactions with teachers students/pupils were asked to first of all discuss what they liked most about mathematics and science subjects. It is apparent from their answers that the things they liked most had more to do with being given more opportunity to participate in the lessons. For example, secondary school students liked mathematics more when they worked in groups, as well as when given individual attention by their teachers to enable them clearly understand 'the concepts'. They also mentioned being given chances to work out examples on the chalkboard before the entire class. Also commonly cited were teachers' friendly attitudes, teachers giving students a chance to ask questions on aspects they did seem to understand, and demonstrating the application of the subject in everyday life, especially when teachers asked more challenging questions. These views were not different from those of primary school pupils. They, for example, specifically mentioned, "the teacher making the lesson quite interesting by putting in humour, which makes us find it easy to learn, in particular the art of playing with numbers". This was said to be done by teachers who seemed to have a strong command of the subject and went beyond what was contained in the class textbook. Pupils also appeared to like teachers who gave explanations using diagrams and practical illustrations.

It was more or less for similar reasons that students/pupils seemed to enjoy the science subjects. Secondary school students, for example, tended to like science subjects when their teachers engaged them in 'experiments and practicals'. In this way, they said, they ended up discovering their own information and acquiring knowledge. Students also liked the teaching of sciences through the use of illustrations and demonstrations, as well as being given the opportunity to discuss and relate the scientific knowledge to real situations in life. They also seemed to like the subject when teachers make deliberate efforts to interest them in these subjects, especially by asking them questions that required reasoning and encouraging them to learn more on their own through assignments. While primary school pupils shared the same views with secondary school students on things that made them like science subjects, they appeared to take more interest in learning sciences when they were taught through "nature" or "the surrounding environment".

Conversely, students/pupils tended to have least interest in mathematics and sciences when there was not much involvement in the teaching and learning process. For example, secondary school students tended not to like the teaching of mathematics when their teachers bored them with long explanations and calculations on the chalkboards. They also tended to dislike the subject when it was taught without application to practical situations and the teachers appeared to be 'rushing in order to complete the syllabus', and did not give students the opportunity to clearly understand what was being taught. Students also felt that some mathematics teachers handled them in a manner that made them discouraged, especially in response to their (students') self-initiated questions. Such teachers, it was pointed out,

resorted to using abusive language, like referring to students as, *majambazi* (gangsters) and the like. They also seemed not like the idea of some teachers frequently asking students to carry on with the marking of their own work, without sufficient guidance from them. Primary school pupils also shared these perceptions, but also added the demand by teachers for them to memorise formulae that had not been clearly explained, the frequent use of punishments when they failed to get correct answers to certain mathematical problems were given as reasons why they did not like the subject.

Students/ pupils do not like most of the teaching of science subjects for similar reasons. They however, added that the teaching, and hence understanding, of sciences became difficult because many practicals were skipped due to the lack of necessary apparatus and their teachers made little or no effort to improvise for them. Many of the secondary schools not only lacked science laboratories for specific science subjects, but also had no laboratories and science apparatus of any kind, and yet a number of science subjects were compulsory in the Kenya Certificate of Secondary Education (KCSE) examination. In one focus group discussion, students mentioned some cases when their colleagues for the KCSE examination happened to see and were asked to use a microscope for the first time during the practical biology examination paper. In many cases during science lessons, teachers normally carried out the experiments, denying students a "hands-on experience". Due to the lack of apparatus, many science topics were taught 'theoretically'. Students also mentioned that their teachers normally dictated long and incomprehensible notes. This was made even more difficult as a result of lack of textbooks. In one particular secondary school in Nairobi, there were 3 textbooks in chemistry, 9 in biology and none at all for physics in a class of 43 students. Some primary school science teachers who were not conversant with their subject content tended to resort to the use of vernacular in trying to explain difficult scientific concepts. In this regard, the lack of interest in learning of sciences would begin right from the primary school, where the subject was not taught practically, and the main source of information, the textbook, was unavailable.

In the context of lack of teaching and learning facilities, when students were asked to mention some ways in which they were involved in the learning of mathematics and sciences, the use of group work and discovery learning methods, which were key approaches advocated by both SbTD and SMASSE, were very rarely mentioned. Although students occasionally mentioned being divided by their teachers into groups for purposes of discussions, this was not necessarily confined to teachers who had participated in these in-service programmes. The main classroom activities which both pupils and students indicated they participated in most included; answering the teachers' questions, working out exercises in their exercise books, copying the teacher's notes, solving problems on the chalkboard, listening to the teacher's explanations, observing demonstrations by the teacher, doing tests, exchanging exercise books to mark assignments, occasionally being allowed to ask questions and to do experiments on their own. These were given as main ways in which most teachers involved the students/pupils in the science and mathematics lessons.

On the basis of our discussions with the pupils/students, it was therefore difficult to attribute such approaches to changes brought by the SMASSE and SbTD programmes. This was more so given that to the pupils/students, there was no difference in approaches to teaching between those teachers who had participated in the SbTD and SMASSE programmes and those who had not. Any difference between them was adjudged by the pupils/students to stem from the personality and character of the individual teacher. In other words, there were

good programmes' teachers, just as there were good non-programmes' teachers and vice versa. On the same continuum, one found that both programmes' and non-programmes' teachers had serious flaws in their handling of pupils/students. One of the things that the programmes were meant to do was to improve pupil-pupil and pupil-teacher classroom interaction, which was generally not being demonstrated, as reflected in the FGDs with students and pupils.

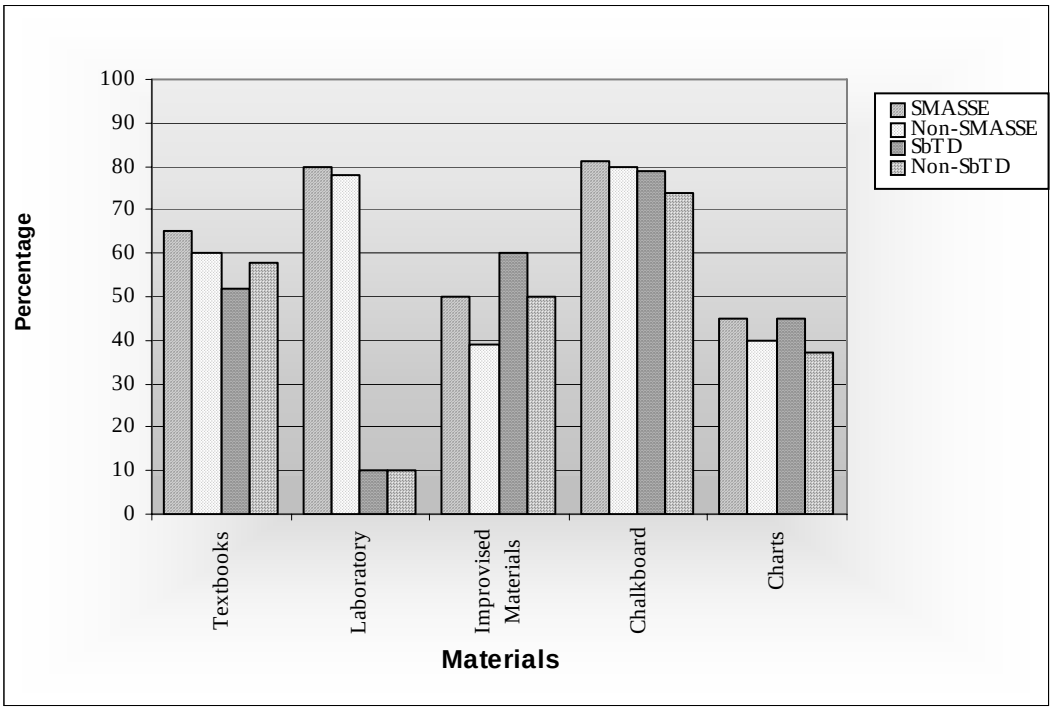
THE DOMINANT CLASSROOM INTERACTION PRACTICES

Classroom observations aimed at describing what teachers and pupils/students did during the lesson, or teacher-pupil, pupil-teacher, and pupil-pupil interaction. The observations focused on three main areas, namely; the frequency with which instructional materials were used, pupils'/students' dominant classroom activities and how the teacher utilized class time.

Teachers' use of instructional materials: Figure 2 illustrates the general findings about the teachers' use of instructional materials within the secondary and primary schools for both SMASSE and SbTD trained teachers and teachers who did not participate in the two projects. These behaviours emanated from the science and mathematics lessons observed by the researchers.

The figure shows that in most of the classrooms observed, the chalkboard was a commonly utilized material in the schools, with about 81% (45) of SMASSE, 80% (23) of non-SMASSE, 79% (33) of SbTD 75% (16) and of non-SbTD teachers. This was followed by the use laboratories in the sciences by 80% (45) and 78% (23) of SMASSE and non-SMASEE teachers respectively in secondary schools as this not a common facility in most primary schools. Another commonly used material was the textbook, which was used by 65% (45) and 60% (23) of SMASSE and non-SMASSE and 52% (33) of SbTD and 58% (16) non-SbTD teachers respectively. In situations where most pupils lacked textbooks, teachers normally read from their textbooks. Textbooks were in use by 65% (45) and 60% (23) of SMASSE and non-SMASSE and 52% (33) and 58% (16) of SbTD and non-SbTD respectively. While both the SbTD and SMASSE projects placed considerable emphasis on the need to improvise the teaching/learning materials from the local environment, this seemed to be a much more common feature with the SbTD trained teachers, who constituted 60% (33) and 50% (16) non-SbTD of the teachers compared to 50% (45) SMASSE and 40% non-SMASSE teachers. Though hampered by lack of manila paper, charts were however, more commonly used in secondary schools with 45% (45) of SMASSE and 40% (33) non-SMASSE, 45% (33) and 38% (16) of non-SbTD as illustrated in figure 2.

Dominant pupil/student activities: Figure 3 shows the dominant classroom behaviour in which a majority of the pupils/students were engaged in. It is seen that very rarely was there a small grouping of pupils engaged in separate activities. In secondary schools, 80% (45) and 82% (23) of the students in SMASSE and non-SMASSE lessons were observed to be passively listening to the teacher lecturing, compared to 72% (33) and 71% (16) in SbTD and non-SbTD classes. Another very dominant behaviour was answering questions, which was observed in 43% (45) and 40% (23) for SMASSE and non-SMASSE classes and 55% (33) and 57% (16) of SbTD and non-SbTD classes respectively.

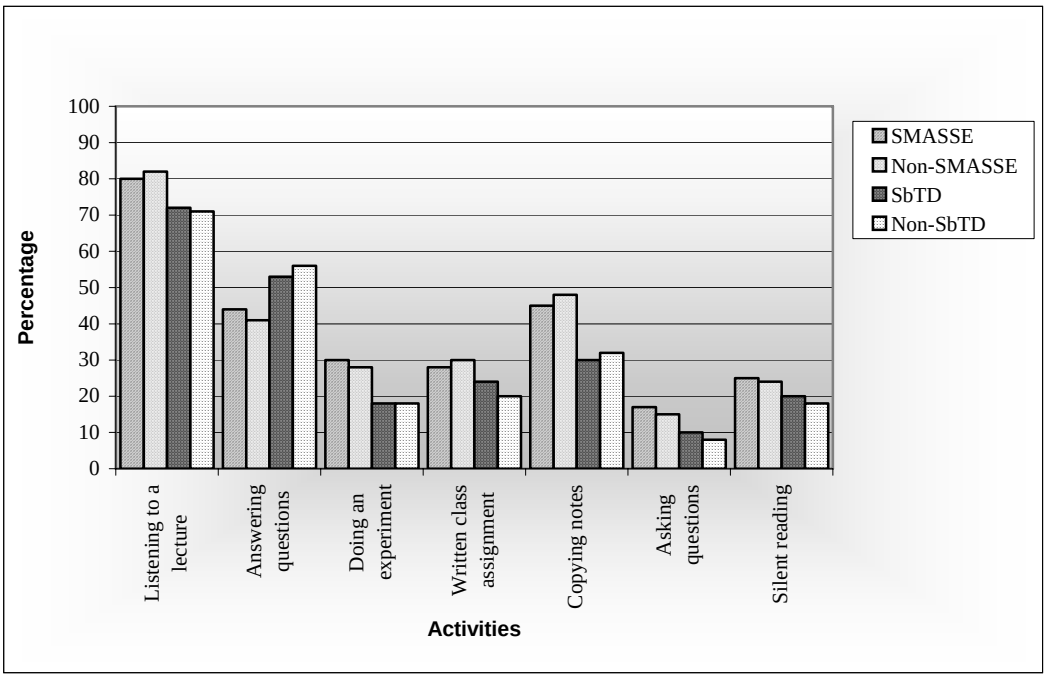


No of teachers
SMASSE 45
Non-SMASSE 23
SbTD 33
Non-SbTD 16

Figure 2. Teachers' Use of Instructional Materials.

Copying notes represented 45% (45) and 48% (23) of SMASSE and non-SMASSE and 30% (33) and 31% (16) of SbTD and non-SbTD of lessons, respectively. Class written assignments accounted for 28% (45) and 30% (23) of SMASSE and non-SMASSE and 25% (33) and 20% (16) of classroom behaviour of SbTD and non-SbTD lessons.

Teachers' time use and teaching behaviour: Figure 4 presents how teachers used their class time. It is seen that 70% (45) and 72% (23) of SMASSE and non-SMASSE teachers and 60% (33) and 63% (16) SbTD and non-SbTD teachers respectively, used much of their time presenting material or lecturing to the entire class. Giving notes was another dominant activity occupying 50% (45) and 48% (23) of the SMASSE and non-SMASSE teachers, while occupying 39% (33) and 41% (16) of SbTD and non-SbTD time respectively. Asking questions was equally a major feature of the classroom approach, constituting 42% (45) and 45% (23) of SMASSE and non- SMASSE teachers, 40% (33) and 42% (16) of SbTD and non-SbTD teachers. These were followed by giving and marking assignments and demonstrations.



Estimated no. of pupils
SMASSE 1800
Non-SMASSE 920
SbTD 1915
Non-SbTD 760

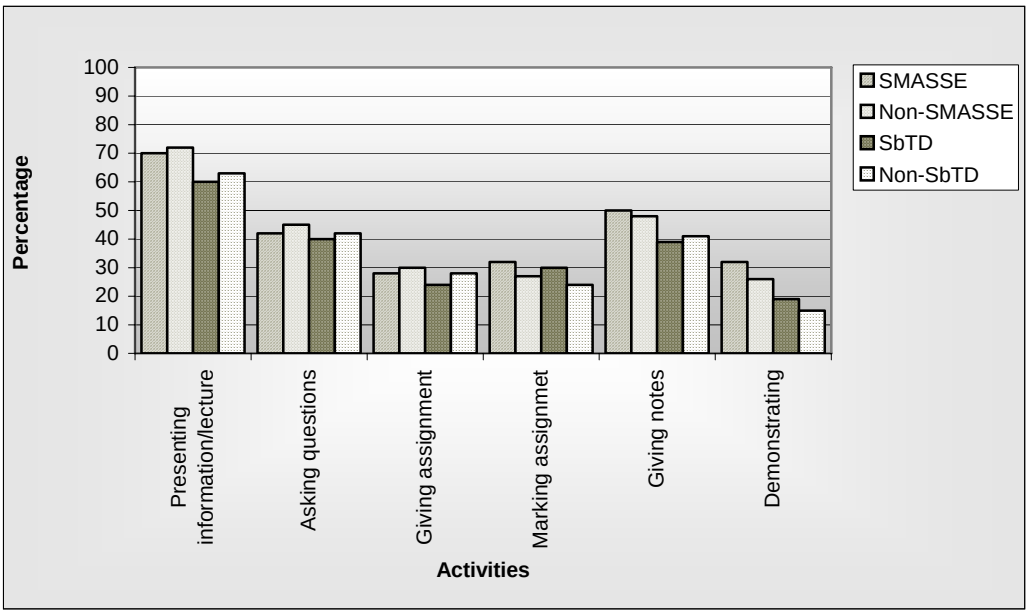
Figure 3. Pupils'/Students Dominant Class Activities.

Nature of the Dominant Teaching/Learning Activities

The following section focuses on the nature of the dominant teaching/learning activities, namely; lecturing, question and answer exchange, written exercises and copying and taking notes.

Presenting information/lecture method: The main teaching strategy that characterized primary and secondary school teaching was the large amount of teachers' talk, which involved mainly the teacher presenting information or lecturing to the pupils/students, inter-sparsed with questions, generally asked to the whole class, with predetermined answers. A minimal amount of time was spent by teachers talking to pupils on an individual basis and throughout most of the lessons observed, the pupils/students played a passive role. A considerable amount of teaching-learning time was also spent with pupils silently working on teacher assigned tasks. These tasks were generally 'whole class' assignments at which the pupils were expected to work independently at the same rate.

Moving from this individual lesson to the wider school day, one was immediately and forcefully struck by the sameness of the lessons.



No of teachers
SMASSE 45
Non-SMASSE 23
SbTD 33
Non-SbTD 16

Figure 4. Teachers' Time Spent on Classroom Activities.

Allowing for the individual teacher differences in style, it seemed that irrespective of the subject under consideration or whether the pupils were in primary or secondary school level, all lessons were characterized by this same routine, namely the teacher presenting information/lecturing to pupils or asking whole-class directed questions and pupils working silently at the teacher assigned tasks. In both of these routines, the pupils played an almost totally passive role in terms of verbal and hands-on involvement.

Question and answer exchange method: This was the principal form of oral exchange in the classroom. Students/pupils were required to provide very brief answers to the teachers' questions, based on the recall of topics encountered in the previous lesson. The teacher rarely probed for the students' thinking following an incomplete or incorrect response. The approach being more usual to pass on from one pupil to other until the correct response, as designed by the teacher, was provided.

A common technique was for the teacher to ask a question and then to select a volunteer from those pupils who had raised their hands. Another frequently used technique was for the teacher to ask a question and then direct it to a specific pupil by name.

In the question and answer routines during lessons, the rapidity with which the teacher fired the questions and the fractional time allowed for a response were deterrents to pupil participation. Pupils/students needed time to organize their thoughts, and even more so if these were to be presented in a second language. The 'wait time' in the order of several seconds not only provided little thinking 'space' for the pupils, but also raised the chances of the pupils constructing unacceptable responses.

One important feature of the classroom exchanges was usually the questions asked by the teacher about some 'known information'. The teacher knew the answer to the question, and the teacher's reaction to the pupil's response told the pupil how well he/she had met the teacher's expectations. This kind of classroom talk was entirely teacher-directed and gave virtually no recognition to the ideas that pupils brought with them to the lessons. The question and answer exchanges were generally routine at the beginning of lessons, but could also occur at the conclusion of a lesson, when the teacher was led to suspect or thought he/she had completed the topic more rapidly than anticipated and was left with five or ten minutes to fill. Associated with the question and answer exchange was the common practice of students completing the teacher's sentences in a chorus form.

Written exercises: The working of examples by both primary and secondary school learners to provide practice in writing and computing skills were quite common in mathematics and science subjects observed. On the whole, textbooks provided a sequential series of exercises through which each class progressed. It was routine that after a review of the previous lesson and an introduction of the new topic, the lessons proceeded with the teacher working through one or two examples on the board, after which a series of questions were assigned to the pupils/students for working in their exercise books. While the students were working out the assignment, the teacher walked round the classroom, checking and marking individual work. As the students completed the questions, the teacher, if there was still enough time, intervened to work through the same questions on the board. The written exercises were often continued as homework, which could be taken by the teacher for marking and for reviewing during the next lesson. As a variation of the written exercises, the teacher would invite student volunteers to work out examples on the board, while the rest of the class watched.

Taking/ Copying Notes: Copying notes from the board was a common activity in some of the science subjects. Teachers normally explained that that were no suitable textbooks for particular topics and it was necessary for students to have complete sets of notes in preparation for the future examinations. This was especially so for theory parts of the science lessons. In some schools, a number of teachers had prepared typed sheets of notes for handing out to students. These were quite useful for memorization in preparation for examinations.

In some of the science lessons, sets of worksheets intended to serve as notes had been developed to accompany laboratory activities. It often became feasible to complete the worksheets without reference to other materials. This was largely because the worksheets tended to pick out the main points from the textbook and students seemed not to like making notes from the texts, which was seen to be quite tedious. Of course the completion of worksheets to serve as notes required that students filled in the correct answers to the questions. At points designed to encourage students to record their personal observations, they tended to wait for the teacher-approved observations before writing in the worksheets.

The above general description was based on a limited number of observations of science and mathematics lessons, in which there were a number of key features of classroom behaviour. Teachers generally spent much of their class time presenting factual information, followed by asking pupils individually or in chorus to return the factual information in a question and answer exchange. Students were rarely asked to explain a process or the interrelation between two or more events, and the teacher did not normally probe to see what elements of the material or process the pupil did not understand. This interrogatory style is an evaluative exercise, not one that sought to increase pupils' understanding.

Some Examples of Good Classroom Interaction Practices-Observations: Although most of the observed lessons did not reflect lesson practices advocated in the two training programmes, the following were some few examples of good classroom interaction practices observed in a few of the classes.

Box 3. Mathematics Lesson- Secondary School (SMASSE)
Topic: Sequences and Series

Lesson Introduction: Due to the method adopted to introduce the concepts of 'Sequences' and 'Series' the introduction took 12 minutes during which the teacher gave out match sticks and students worked in groups to form various figures in order to discover for themselves the meaning of the two concepts. This was effectively carried out with the teacher visiting each group to explain.

Lesson Activities: The major activity during this phase was the presentation of results by each group in front of the class. The teacher played the role of a facilitator and guided students to effectively explain the two concepts. All the students were actively involved in the lesson. The teacher was friendly, confident, resourceful and had good class control.

Lesson Conclusion: The lesson was well concluded with students being chosen at random to complete various terms in the sequences and series given on the board. The lesson ended with an assignment being given out.

This was a lesson in which creativity was evident, which went a long way in simplifying the concepts and ensuring effective learning.

Box 4. Science Lesson- Primary School (SbTD)
Topic: Energy. Sub-Topic: Light

Introduction: The lesson was introduced in a very lively manner with the learners being asked to close their eyes. After this, the learners were actively involved in naming instances that require light in order to perform certain activities, and sources of light. This phase took about 6 minutes and both girls and boys were involved in contributing.

Lesson Activities: The lesson was systematically taught according to the lesson plan. The learners were actively and meaningfully involved in the lesson through group work and hands-on activities using candles, match boxes, rolled exercise books, torches and straight plastic pipes to discover how light travels, with clear guidance from the teacher. There was also an effective use of appropriate motivation and reinforcement techniques. There was a gender balance in the construction of groups, distribution of questions and group responsibilities. The teacher made purposeful movements to each group. Girls seemed more active in answering questions and performing the group activities-the teacher intervened to encourage boys. The teacher was knowledgeable, confident, friendly and creative. She used the lesson plan and notes very well.

Lesson conclusion: The lesson was well concluded in 5 minutes, with the learners answering simple recall questions about the experiments they had done and their observations. The lesson concluded with an assignment on the major points.

DISCUSSION

The key objectives of the SMASSE and SbTD programmes were premised on making the primary and secondary school syllabuses pupil-centred, with large and essential components of practical work in the classrooms, laboratory or science room, and use of the discovery method to transfer useful skills and knowledge to pupils. The starting point for all the activities was that the pupils' own environment, experiences and skills were to be developed in a problem-solving context. The two programmes emphasised the fact that pupils would acquire skills in observing, measuring and estimating; indeed the main concept was to involve pupils practically in learning science and mathematics by using of a wide range of measuring instruments with skill and accuracy.

The analysis of classroom observation data shows that the main areas stressed by these programmes namely; the pupil-centred practical component and the development of concepts relating to the physical environment, were quite problematic to attain. It was observed that the practical component based on 'discovery learning,' which was presumed to be an essential part of the science lessons, had very little to do with the observed classroom processes, probably due to lack of time or lack of equipment. Teacher demonstrations were also not common, and where they occurred, it was with the teacher usually 'doing' and the class 'observing' and answering simple routine questions. There appeared to be very little concern with development of manipulative skills that would be of value in pupils' every day life. The major form of verbal interaction within the classroom, apart from the teacher lecturing and pupils listening silently, was the teacher asking questions and pupils giving answers. The questions mainly involved simple factual recall, and pupils' answers were often of a single word or a sylsed repetition of the question that included the answer. The teachers generally asked very few 'why' or 'what do you think' questions, although this tended to vary from one teacher to another and from subject to subject. The pupils themselves rarely spoke except when they were spoken to. Throughout the classroom lesson observations , very few pupils' questions were found.

From the lesson observations, as already noted, classroom activities did revolve around the transmission of knowledge, and the teachers' main concern was to 'teach' something they considered important, while the learners main concern was to 'learn' it. In this process, the utility value of the lesson for both the teachers and students seemed to be one of working towards 'passing the terminal examinations'. To carry out their main task of transmitting knowledge and achieve that end, teachers generated the kinds of learning experiences already described. It was generally difficult to discern and describe the pedagogical principles behind their actions, especially after having undergone the intensive SMASSE and SbTD in-service training programmes. What featured most was that they appeared to be strongly based on the rote learning approach, and most probably reflected the way themselves were taught at school. This style was quite widespread and was representative of what normally used to take place and continues to take place in the primary and secondary school classrooms, a fact that seems to have been taken for granted by the two INSET programmes.

With all the emphasis on pupil-centered approaches in the INSET programmes, there was little evidence that this had translated into practice in the actual classroom processes. Pupils normally had greater opportunities to participate in the teaching/learning process through answering the teacher's questions, but their own contributions were often generally ignored.

The extended question and answer sessions were a common feature at the start of lessons and also at the end of long sessions of the teachers' talk. In both cases it seemed to be viewed by the teacher as both a revision and an evaluation exercise. Within these sessions, it was a common practice for the teacher to completely ignore many pupil responses and only acknowledge certain 'correct' answers. There might be a variety of reasons why teachers used this kind of technique. First, they could have felt that time was short and they did not wish to be sidetracked by the incorrect answers. Second, they might not have had the knowledge base to deal with the suggested pupils' answers.

Whatever the overt reason, it is suggested that the technique was used by teachers as a control mechanism to reinforce their status and authority in the classroom. In any social interaction between individuals, as has been argued, the person who defines the ground-rules of the situation and decides what is acceptable and unacceptable takes on a position of power and exercises authority. The 'other' party is then placed in a submissive situation. In the classroom situation therefore, the teacher's apparently arbitrary decision to respond to or ignore the pupils' participation in dialogue strongly reinforces his/her position. This not only demonstrates the teacher's authority in social interactions, but also plays a vital role in his/her authority to define the usefulness of pupil knowledge (Prophet and Rowell, 1990).

From a teaching-learning perspective, the arbitrary nature of rejection precluded opportunities for pupils' cognitive development. Incorrect answers were a valuable resource for teachers who could use them to identify slight misunderstandings or complete lack of comprehension in the pupils. Ignoring pupil responses reinforced a behaviouristic approach to teaching, which placed emphasis on the rote learning model through the right and wrong pupils' responses.

As a response to the arbitrary rejection of pupil responses by the teacher, pupils in turn appeared to answer teachers' questions in a random manner. Guesses were the accepted order of things, and it seemed more important for the pupils to participate by saying something, however wrong, rather than not respond at all. The 'random' selection of pupils' answers was again indicative of a major problem area for them in terms of the mental development of ideas. The emphasis on rote learning and correct response meant that no attention was being paid to the crucial issue of concept development in the subject area, such that any 'learning' that took place remained superficial, since no real cognitive demands were being made on the pupils by the teacher.

One of the most commonly used question and answer technique for the science subjects involved pupils completing, the teacher's sentences, often in chorus. The completed sentences or words were then often repeated by the teacher. This seemed to be as a result of a number of issues. First, in some classes observed, pupils especially at the primary school level had some major difficulty with their ideas in English. Often the teacher was impatient and did not allow for 'wait time' for the pupils to organize and express their thoughts. In situations where teachers were aware of the problem, and allowed pupils time to organize their thoughts, as well as gave them encouragement for the expression of ideas in their own words, the amount of content covered was normally reduced, and therefore appeared as if less work was being done. Furthermore, faced with large classes and a variety of language incompetence, one of the "coping strategies" utilized by teachers was 'sentence completion'. By simplifying and actually phrasing the idea for the pupils, while still leaving them some input in the form of a missing word, teachers seemed to feel that they were resolving the problem. The simple repetition of the word or the complete sentence was then perceived as the reinforcement of

the idea, although based on a fundamentally flawed concept of learning, which postulates that the repetition of words leads to an understanding of the meaning of the words. In reality, the widespread use of the strategy seemed to have the opposite effect, namely that pupils would nominally complete the syllabus, but only at the expense of any conceptual development at a personal level (Prophet and Rowell, 1990).

As clearly demonstrated in the narratives, the SMASSE and SbTD programme teachers did appreciate the need to adopt student-centred approaches to teaching as advocated by the two INSET programmes, and indeed claimed to be putting them into practice, although this was not reflected in the classroom interaction processes observed. Apart from some of the factors already discussed, there seemed to be general apathy towards the application of the new methods of teaching due to what the teachers perceived as "poor management of the training programmes and the failure of government recognition" of their participation in the two programmes, although the study did not focus much on this particular area as it was not its main thrust. For example, during the SbTD training, teachers were asked to contribute Kenya Shillings 1,200 towards their training and the purchase of training materials, with a tacit understanding that the course would count in their professional and academic growth by being issued with certificates on conclusion of the course, which would lead to promotions and entrance into institutions of higher learning. For some unclear reasons, the Ministry of Education seemed to have reneged on this issue, leading to teacher dissatisfaction and increased lack of interest in the programme. As for the SMASSE, teachers also voiced their dissatisfaction about its poor management which has also been supported by many complaints in the dailies, especially making attendance of the programme mandatory and the perceived lack of incentives, particularly non-payment of per diems, at times occasioning teacher walk-outs from the training centers. They also complained about the government's failure to recognise their participation in the programme, which would have contributed to their academic and professional mobility growth.

CONCLUSION

In conclusion, the SMASSE and SbTD projects set out a child-centred learning experience which students/pupils were expected to be exposed to during the teaching situation, an approach that would draw on their everyday experiences in order to give them the opportunity to express and develop their own ideas. This was to be achieved by offering a programme of studies with a greater emphasis on 'practical' rather than the usual rote learning exposure. The classroom interactions documented in this study showed that such an approach remained a long time ideal. The teaching portrayed in these observations placed emphasis on the acquisition of limited skills associated with the specific responses required in achieving success in the terminal/national examinations. The dominant mode of interaction was that of transmission of information from teachers to students, accompanied by repetition and drill. Knowledge seemed to be a commodity to be poured into empty vessels. What appeared lacking from these interactions was any recognition of the beliefs and values which students brought with them to the classroom or even an acknowledgement that students had already-constructed structures for interpreting their world. The imposition of the teacher's way of seeing things not only limited the expansion of the students' expressive capacities, but

also served to inhibit the development of connections between students' existing ideas and those presented in class. Learning involves linking that which is to be learned with what is already known, requires some modification of the existing conceptual framework. The current classroom practices, with their outstanding lack of student expression of ideas, are likely to extend the separation of school knowledge from everyday knowledge.

The fact that students were communicating in a second language raised the question of the extent to which this impeded the articulation of thoughts their through oral or written expression. Words serve as a focus for the elaboration of ideas, and talking or writing enhances the generation of clear understanding. The lack of confidence in the usage of the English language was frequently reinforced overtly by the teacher's impatience and covertly by the teacher's avoidance of student contributions. Many teachers attempted to compensate for the students' language difficulties by reducing the content of the lesson to a simplistic account of ideas, which, instead of stimulating students' thinking with previously encountered ideas, faded into the oblivion of repeating the familiar. Trying to break out of the vicious circle by involving students in higher order thinking could bring about some inevitable frustration and was avoided by most teachers. Teachers were faced with the dilemma of choosing between an emphasis on the development of personal understanding through talking and writing and an emphasis on the completion of the syllabus in preparation for the examinations. It would have been suicidal not to cover all the necessary topics in preparation for these examinations.

The study also observed general apathy and lack of interest in applying student-centred teaching approaches by teachers who had participated in the two programmes as a result of what was perceived to be "poor management of the INSETs and government's failure to recognize participation in them, and to lead towards their professional and academic development".

It is therefore clear from the schools where these classroom observations were carried out that claims for a 'student-centred or 'practical' teaching as advocated by the SMASSE and SbTD INSET programmes remain a pipe dream. The teaching remains firmly an authoritarian and teacher-centred mode where the pupils are generally passive recipients of content-based verbal information. The development of concepts, attitudes, and manipulation skills, emphasized in these INSET programmes appeared not to be taking place. It was emphasized from these observations that the stipulated processes were actually being inhibited, rather than being developed and enhanced in the classrooms. It is however, appreciated that while it might be easy to lay the blame on the teachers for the apparent failure to implement the laudable set of objectives of the two INSET programmes, there was a complexity of situations which were obviously beyond their control. Faced with large classes, syllabuses overloaded with content, high expectations from pupils, parents, head teachers and the local communities who perceived examination success (even though unattainable by the majority of pupils) as the priority of the schools, and examinations which still emphasized and rewarded simple rote learning and recall skills, it was no surprise that teachers utilized a set of strategies that ensured their survival in the classroom, but failed to take cognizance of individual pupils and their development.

The findings of this study in no way negate the need for in-service training programmes. The Ministry of Education Science and Technology needs to recognize the fact that that there are many key players in the education system and that indeed in-servicing of teachers cannot be the responsibility of any one player, be they donor agencies or NGOs. There are many

providers with different focuses. All these efforts need to be appreciated and properly harmonised and guided. Therefore there is need to put mechanisms in place for continuous processes of in-servicing primary and secondary school teachers. In order to improve the coordination of in-service providers and programmes especially at primary and secondary school levels, the INSET Unit in the Ministry of Education should coordinate and ensure that in-service initiatives are decentralized, institutionalized and sustained. INSET structures should be enhanced at Provincial and District levels. One key area is to address is accreditation and certification of in-service courses. This was viewed as a means of ensuring that quality training is provided and the professional and academic growth of teachers is rewarded and sustained.

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Chapter 7

CLASSROOM DISCOURSE: CONTRASTIVE AND CONSENSUS CONVERSATIONS

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ABSTRACT

Researchers claim that classroom conversations are necessary for supporting the development of understanding and creating a sense of participating in the discipline, yet we know there is more to supporting productive talk than simply having a conversation with students. Different types of conversations potentially contribute differently to the development of student understanding and identity. We have been investigating the strengths and limitations of two such conversations: contrastive and consensus conversations. Within a contrastive conversation students have the opportunity to make their own thinking explicit and then compare and contrast their strategies to the thinking of others. Consensus conversations ask students and the teacher to begin to put ideas on the table for consideration by the whole group—much like a contrastive conversation—but then go on to leverage the classroom community as a group to build a temporary, unified agreement about what makes the most sense for the class to adopt and use. Here, we detail both types of conversation, their affordances and challenges, and investigate the conditions under which a teacher may want to orchestrate a contrastive or a consensus conversation.

Keywords*:* Classroom Discourse, Classroom Practices, Elementary Education

When thinking about how to help a student grow into and understand the world around them, teachers have to consider many factors and a multitude of pedagogical options. One of the most important things to consider is the nature and character of one's interactions with one's students. Students may learn from books, computers, direct observation, and one

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another, but in the elementary classroom all of these experiences are typically mediated by the teacher through conversations with individuals, small groups, or the whole class. It is in these dynamic, complex, and at times highly personal interactions where students have opportunities to articulate and reformulate their understandings and teachers have opportunities to guide student development and thought.

Given the range, complexity and contingent nature of interpersonal interactions, how should a teacher who wants to help each child develop to his or her fullest potential think about and plan instructional conversations? While a complete answer to this question is beyond the scope of this paper, we wish to offer a few observations that will move us towards this larger goal. The types of classroom conversations we wish to focus on in this paper are ones in which the students are inventing, articulating, sharing, and critiquing their own solutions and strategies to intellectual problems. However, within this class of conversations there are many choices to be made. As students are developing new understandings about subject matter, how should the discussion be organized to help students share their own and learn from other's ideas? How do certain ideas and theories gain collective momentum, while others die out? How does a teacher ensure that every student is engaging with the material at a level that makes sense to him and at the same time is offered continuous opportunities to develop his understanding further?

Our interest in this subject began a few years back while working with a group of 7-9 year old students on mapmaking (Enyedy, 2005). We did not want to simply share the conventions of mapmaking with them, but rather, wanted them to make sense of the need for the conventions themselves. For example, in trying to help a partner find a hidden object, the students invented the concept of bird's eye view. They ran into problems when they drew their maps from a particular point of view because important objects and landmarks were hidden behind other objects. Several students brought up the idea that drawing the maps from a bird's eye view might be clearer. A debate then ensued, until ultimately the bird's eye view faction convinced the others that this solution indeed answered all of their concerns, and the class adopted this strategy in moving forward with their mapping.

In the same classroom, during mathematics, students engaged in conversations where they shared multiple strategies for solving a common problem. Students articulated their own strategies, compared them to their classmates', and attempted to solve the problems in new ways that pushed their understandings. In the math conversations each student used strategies that made sense to them and shifted to new, more advanced strategies when they understood them.

We noticed that both types of conversations with students were quite powerful, and started to consider when and how teachers orchestrated them. We began to think about when it was productive to guide students toward one understanding as we had in the mapmaking work, and when it was most productive to encourage multiple strategies, as we had in the mathematics conversations. In this paper, we hope to address both of these types of conversations, from the point of view of teacher role, costs and affordances.

THEORETICAL FRAMEWORK

Classroom talk clearly exists within every classroom. Researchers claim that classroom conversations are necessary for supporting the development of understanding and creating a sense of participation in the discipline. However, we also know there is more to supporting productive talk than simply having a conversation with students. We are beginning to understand the different types of conversations that can occur in classrooms and how these conversations can support student learning. We now see the need for characterizing the types of conversations teachers and students can have, making explicit the goals and affordances of the conversations, and providing enough detail so teachers can see how to support the occurrences of such conversations.

There are some well documented structures for classroom conversations, but not all of these are productive. No one would deny that the most dominant classroom discourse pattern is the IRE pattern, where teachers Initiate a question, students Respond, and teachers Evaluate the response (Cazden, 2001; Doyle, 1985; Mehan, 1985). The IRE pattern exists in classrooms across contexts and content domains, but has been shown to push students to think of classroom discourse and the academic disciplines in terms of being right or wrong. We know that even in classrooms where teachers are attempting to teach for understanding teachers often maintain this pattern. Spillane and Zeuli (1999) found in their study of reform minded mathematics teachers that the teachers predominantly engaged in procedure bound discourse; they rarely asked students to do more than provide the correct answer. Teachers in this study were engaged with a reform minded curricula which supported engagement in conversations around students' mathematical ideas. Neither taking a reform minded approach nor following a rich reform based curricula enabled teachers to move beyond the IRE discourse pattern (Spilanne and Zeuli, 1999) see also (Smith 2000). We recognize that changing long standing ways of engaging with students is challenging and we believe that if we are to help teachers engage in different forms of conversation with students we need to be explicit about what kinds of conversations they might have, why they are productive and what it takes to engage in them.

In the second edition of her book *Classroom Discourse*, Cazden (2001) points out that increasingly teachers are being asked to add non-traditional discussions to their repertories to better support the development of students' higher level thinking. She also points out that the, "challenges of deciding, planning and acting together across differences of race, ethnicity and religion are growing…[so more than ever] we need to pay attention to who speaks, how we provide opportunities for varied participation and who receives thoughtful feedback." (p. 5)

We see two conversations as standing out as potential contributors to the development of understanding. In one of these conversations, we use coming to consensus as a classroom community to accomplish these goals. Consensus conversations ask students and the teacher to begin to put ideas on the table for consideration by the whole group and then build a unified idea of what makes sense together. We also see the potential to develop understanding through contrastive conversations. In contrastive conversations students have the opportunity to make their own thinking explicit and then contrast it with the thinking of others—providing opportunities for reflection and revision of thinking.

Both consensus conversations and contrastive conversations, as we define them, provide opportunities for students to make their thinking explicit. Explicit student thinking can then

be used as the basis for further reflection and conversation. Contrastive and consensus conversations differ in the ways teachers make use of student ideas and orchestrate the class's making sense of the ideas. In a consensus conversation, orchestration involves supporting students as they compare and contrast the ideas on the table so that they can choose *the one* that works best for them in accomplishing their shared goals at that point in time. In a contrastive conversation, ideas are put on the table by individual students, and orchestrating the conversation around the ideas involves eliciting the full range of ideas and then helping students to see the similarities and differences between the ideas. We argue that neither conversation is better than the other, but rather they serve different purposes and can be used to accomplish different goals.

We intend here to detail the similarities and differences around the conversation goals, and the nature and affordances of the conversations. To do this we first provide explicit examples of these two types of conversation, highlighting how these conversations occur and the teachers' role in supporting the conversation. These examples are provided with very little analysis. Our goal is to provide the reader with two concrete examples that illustrate some of the many similarities between these two types of conversations, and also demonstrate the breadth of difference between them. Given the similarities, we recognize that in some ways it might be more intuitive to talk about these conversations as one type of conversation, but we think if we are to help teachers and researchers establish ways to support the development of conversations in classrooms we must begin to tease apart and detail the various conversations that can productively occur.

EXAMPLE OF A CONSENSUS CONVERSATION

At a point about half way through a unit on mapping, a classroom of second and third grade students engaged in an instructional conversation that ended with a consensus about how to represent the height of buildings and other objects on a bird's-eye-view map (for a complete description and analysis of this activity see Enyedy, 2005). A day or so before this discussion the students had built a city out of wooden blocks and mapped it from the bird's-eye-view. At the end of the period they had cleaned up the blocks leaving only their maps and memories of their cities. Rebuilding the block city from the maps became the class's next activity.

However, before they went to rebuild the city the students discussed what was going to be hard about the task. They quickly discovered that they could not tell how high any of their buildings were just from looking at their maps. The class agreed to solve this problem so that next time they made a map they could note height. Because of our goals and pedagogical commitments, we did not tell them how to solve the problem. Instead, we let them invent their own personally meaningful ways to represent height on a two dimensional map.

The class invented three ways to do this. First, and most common, was to add shadows to an object on the map to show that it was not flat, but had some height (Figure 1a shows a representation of a step pyramid using shadows). The second invention was to draw the base of the object, the top of the object and a line in-between the two (Figure 1b shows a map of a cone using this method). The length of the line between the base and the top would be how tall the object really was, with a longer line showing a taller object.

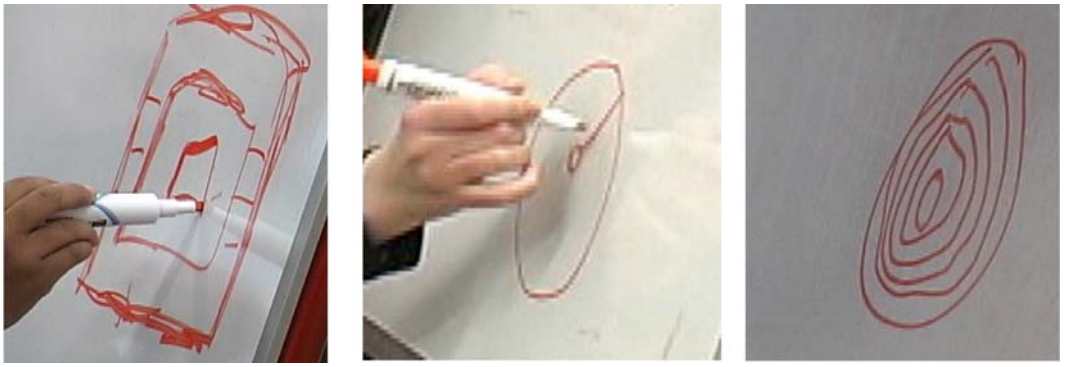

Figure 1a, 1b, and 1c Three invented solutions to show height.

The third invention was to use concentric shapes, one inside the other, to represent the change in height, much the same way that contour lines are used in conventional maps (Figure 1c shows another representation of a cone using concentric shapes).

With three ideas displayed on the whiteboard the conversation spontaneously turned to comparing and elaborating the different ways of representing height. One student (the one who had invented the base-to-top method) stated that he thought the concentric shapes method could either be seen as being a tall cone or a tunnel. Other students agreed that it could be seen both ways, so the teacher asked if there was a way to change the method so that it would be clear one way or the other. After a few minutes, a student suggested using different colors and a key to the map to explain which color corresponded to each height.

This was an important turning event in the conversation. The problem that one student noticed about another's method led the class as a whole to revise the method. They could have abandoned the method, or moved onto debating the merits of other methods, but at the teacher's suggestion they worked together to modify the concentric shapes strategy. This co-authorship seemed to change the status of the method from a single student's idea to the class's idea, even if not all of the students had yet agreed that this was even a good method. The teacher then polled her students to see how many of them in fact thought this idea was a good idea, and then asked each and every student to go try out this new method and see how it worked. The students did and in the course of doing so several new refinements of the concentric shapes method occurred, including the conventional method in topographical maps where each new line/shape represents a specific change in height (e.g., each circle represents a one-inch change in height).

Example of a Contrastive Conversation

At the beginning of mathematics class, Ms. P poses the problem 42 + 25. The 42 is lined up above the 25 in columns written on the board (as is often shown in textbooks). She asks her second graders to tell her, "What is the problem asking you to do?" The students provide a range of responses. Ms. P focuses in on one student's response, "there are two numbers and you are going to add them up." Following the brief problem discussion Ms. P asks the students to work on solving the problem. They can work alone or with a partner. In sending

them off to solve the problem she reminds them that they can solve the problem in whatever way makes sense to them, that they can use counters or base ten blocks or any other materials around the room. She also reminds them that she will be asking them how they solved the problem. The students work on their solutions and Ms. P moves through the group of students watching, listening and asking questions. If students are finished she asks the student to try and solve it another way or to share with a friend who is also finished. She lets the students work on the problem until they are all about ready to share. She gathers the students together on the rug to share.

Ms. P begins the contrastive conversation by saying, "Who wants to help me solve this problem? How did you solve it?" She calls on two boys who had worked together. One of the boys tells her, "We started here," and points to the board. She repeats, "You started here? Explain to me how you did that exactly." The boys describe their strategy and animate their drawing of the manipulatives they used earlier in the lesson. They drew four "tens sticks" and then two more and said that would be 60. They then drew five "ones cubes" and two more cubes and got seven. Ms. P asks a series of questions about how they got the 7. "How did you get a 7? How did you count those (the 2 and the 5)? You counted them altogether? Where did you start counting?" Through her questioning she learns that the boys can count on from 5, saying "6, 7" and do not need to count starting at 1. The boys then tell her they put the 60 and the 7 together and got 67. She asks, "What did you count first, the tens or the ones?" They respond tens. "The tens, okay." Ms. P then turns to the whole group and asks if anyone solved it a different way. One girl responds that she added the 2 and the 5 and got 7 and then the 4 and the 2 and got 6. Ms. P asks if it is actually a four. The girl says it is a 40. And together they pursue what that means for how she describes her strategy. Ms. P asks for a third solution. Again two boys share. They write vertically "42 + 25 =" They break the 42 into 40 +2 and the 25 into 20 + 5. After three strategies are shared, Ms. P says, "Let me ask you this question, they (referring to the last pair sharing) put their tens and ones together, in what other strategy did someone else put their tens and ones together? The 40 and the 20 and the 2 and the 5? Whisper it to your partner, as a secret." They then engage in a conversation that helps the students see that each strategy breaks the numbers apart into tens and ones. They compare what is written on the board carefully together. The conversation closes with Ms. P saying, "You all did the same thing in different ways. Did you all get the same answer? Yes 67, 67, 67."

WHEN TO HAVE CONSENSUS CONVERSATIONS

In a consensus conversation, the group discusses multiple solutions or ideas about a common problem and comes to a collective reasoned agreement about how the group will proceed for the time being. Consensus conversations can take several different forms depending on what is being discussed and the context in which the discussion occurs. We see consensus conversations as useful for three basic purposes: to come to a reasoned best solution, to settle a conceptual argument between opposing camps, or to create an argument together to make explicit existing ideas that have not been named.

Sometimes one best solution to a collective problem exists that teachers want students to understand. Rather than simply show them the solution, teachers engage the students in a very

open-ended consensus conversation geared toward sense making about the problem and the criteria which solutions need to satisfy. In the mapping example these criteria were about quantifying height without distorting other information shown on the map. In these conversations, students generate many possible solutions to the collective problem and use deductive reasoning to come to an agreement about the best solution or solutions that meet the criteria, which may or may not be explicitly stated but guide the conversation nonetheless. While on the surface the discussion may look like it is about the students' invented solutions, it is in fact about understanding and applying the criteria that embody the big ideas of the lesson. Another example of this type of conversation would be asking students about how they would share a cake fairly among five friends. Students may come up with many ideas of how to split a cake, then come to consensus that fairness should be a guiding criteria in determining solutions. It is therefore not the individual "cake-cutting" strategies that are agreed to, but the criteria of what constitutes a good solution: use the entire cake and make sure the pieces are the same size. We are likely to engage in these types of discussions only when there are clear criteria necessary to adequately solve the problem.

Consensus conversations can also be used to push a fundamental understanding that only some students share. In this case, we are setting up an argument between opposing camps. Students on each side of the issue need to explain their thinking and try to convince the other side of the veracity of their claim. This usually occurs in reference to a property or convention that we want the students to buy into. For example, on the road to understanding the conventional use of the apostrophe, a teacher may push the students' understanding by discussing one child's claim that whenever there is a name followed by an "s", you should put an apostrophe. Besides those students who cannot decide, there will be only two camps on this issue, either students agree with this claim, or they disagree. Students might then spend a period of time garnering evidence to support their side of the issue, until at last someone finds a sentence that says "There are two Lisas in this class." Because it is the plural form of a proper name, rather than a possessive noun, it is counter evidence to the original claim. With this counter evidence, suddenly, the tide turns and the original claim loses support. There may be several of these discussions until the children come to the claim of a possessive apostrophe. Since there is only one right conventional answer to the question of why the apostrophe is being used in this particular way, all reasoning about this issue is done inductively by looking at evidence that already exists in the world. The conversation around the class' consensus creates opportunities for developing understandings about the use of the rules.

Finally, a consensus conversation may be used to make explicit things that the group is already doing implicitly. In this case, the focus is less on generating new ideas or solutions, and more on pushing how far students are willing to buy into or stretch a concept. For example, students may agree that for the specific case 2+3=5, and 3+2=5, but may not have come to any formal, generalized understanding of commutativity—that the order of terms *never* matters in addition problems. The consensus conversation allows students to make generalizations and prove them, allowing students to use their understandings to help them solve future problems. By having a conversation that builds upon a number of accessible examples, students begin to offer broader theories of how the discipline works that deepen their understanding of work they are already doing.

There are five components of every consensus conversation. First, the group must experience a problem that needs to be solved.

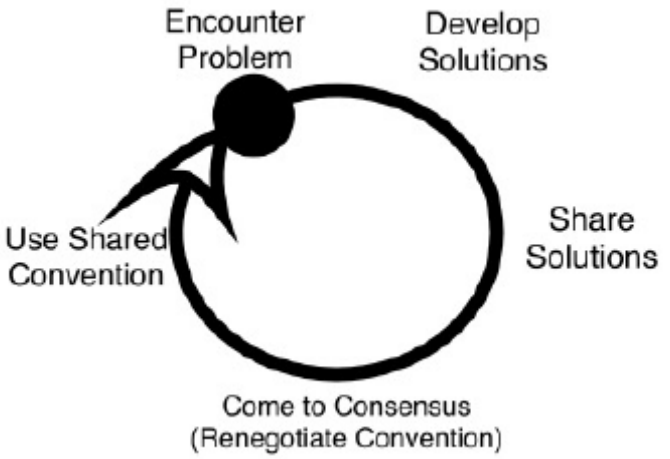

Figure 2. Steps to Consensus Conversation.

This means students must encounter a disequilibrium as they are moving forward with their work, pushing them to need to invent new solutions or understandings. One way teachers create this disequilibrium is by seeding the environment with information that will challenge current conceptions (as was the case with the possessive apostrophe example). Other times teachers create situational constraints which make current solutions or understandings untenable (as was the case in the mapmaking example when students realized they would need to represent height to rebuild their block city). Regardless of what strategy teachers use, the creation of "trouble" with current thinking requires careful planning to encourage the development of new and thoughtful alternatives that will help the group progress.

Second, students develop alternative solutions to the trouble—like the three ways to represent height in the mapping example. During this time, teachers check in with individuals and groups as they are developing new theories or practices. Teachers may also scaffold students' understandings during their local problem solving by asking them questions, making observations, and setting up additional challenges that students' solutions must solve.

Third, students share theories and solutions. The teacher helps students compare and contrast ideas and asks questions that highlight the advantages and drawbacks of each solution. Through this process, the teacher is helping the group to continually redefine the criteria of a successful solution, thus deepening understanding of the discipline.

Fourth, the group comes to a temporary reasoned agreement, allowing one idea to gain collective momentum. This requires that teachers really listen to children's agreements and concerns, providing counter evidence if necessary to push understandings.

Fifth, students have an immediate opportunity to try out their new solutions by engaging in authentic work which requires its use. For example, in the mapping example the teacher had all the students try the concentric shapes method on a new map right after they had collectively decided it was a good method.

It goes without saying that students play an active role in all the steps of consensus conversations. They are the agents by which ideas are brought to the table, refuted, and gain momentum. These are not fast discussions in which the teacher is seeking a student to present

one idea which she can quickly persuade the other students is "right". Rather, in these conversations students grapple with defining the problem and detailing the criteria by which to measure success. In this way, students develop the agency of a practitioner in the field, understanding that current solutions are not "end all, be all" solutions, but rather current best understandings. Therefore, like practitioners they come to agreements that they know they may revisit as understandings of the problem change.

WHEN TO HAVE CONTRASTIVE CONVERSATIONS

Contrastive conversations are not new to many teachers. Contrastive conversations occur when the teacher involves students in sharing their thinking with each other in a public way and then uses what was shared as a way to investigate the similarities and differences across ideas. These conversations may vary in name and form across content areas (contrastive conversations might also be referred to as strategy conversations in mathematics and so on) but they share the core elements and principles that we focus on here. First, a problem is posed or a question asked that allows for multiple approaches to an important content-based idea. Second, students are provided ample time to engage with the problem or issue in a way that makes sense to them. Third, the students share their ideas with the other students in the class. Fourth, the class works together to detail the ideas shared. Fifth, the shared ideas are compared to highlight both similarities and differences. Sixth, students are given an opportunity to try their own or someone else's strategy on a new problem. While there are always subtle aspects of the work that surround these elements, these elements taken together constitute a contrastive conversation.

Contrastive conversations occur when (a) the problem or issue addressed lends itself to detailing a range of responses, (b) the teacher is interested in engaging the students in sense making around a particular idea or (c) students will benefit from detailing their own thinking in relation to others'.

Contrastive conversations are particularly useful when the problem posed or issue addressed lends itself to a range of different ideas or strategies that one's students can access. The content-based issue to be addressed provides openings for students to begin to work on it in their own way and thus, elicits a range of ideas. Often when contrastive conversations don't get off the ground it is due to the problem posed, whether it lends itself to students using what they know to come up with a variety of ways of thinking through the problem or whether it was too easy or too difficult for the students.

Second, contrastive conversations support the development of an idea as students engage together in sense making. Contrastive conversations are not about three students and the teacher. They involve discussion that brings together all the students in the class to make sense of the issue being addressed. Students work together to unpack, often through discussion, the problem itself. They work on detailing their own ideas and comparing the different ideas that are shared. Students engage in individual sense making and then share and develop their ideas as they engage with the class. Contrastive conversations are not just about process. They are in service of learning particular ideas about the content. This requires consistent attention throughout the conversations to the content, both by the teacher and the students.

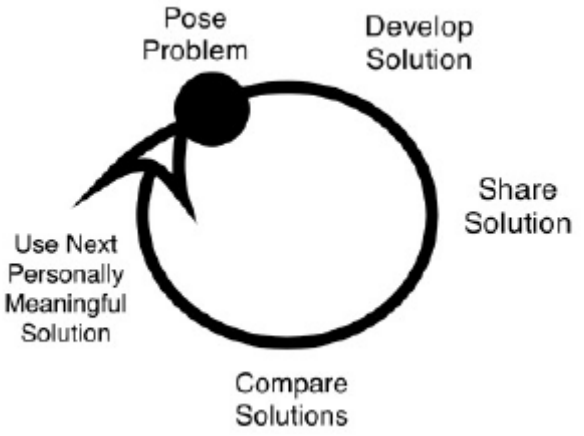

Figure 3. Steps to a contrastive conversation.

Third, contrastive conversations occur so that students can articulate their own thinking and compare their ideas to others, learning more about the content. Asking students to share their thinking means just that. Students publicly describe their ideas in oral and often written form. The teacher and students work together to detail the idea by asking questions or discussing a part of the idea. Typically sharing would not stop with one idea shared. Sharing a range of ideas provides students the opportunity to engage with an idea that might make sense to them and allows for a comparison across ideas. The comparison across ideas is the part of the contrastive conversation that is often skipped. However, this is also the aspect of the conversation that provides the most opportunity to make connections and develop understanding of the underlying content-based idea.

Contrastive conversations begin not with the sharing discussion, but when the problem is posed. The work that occurs by students and the teacher as they unpack the problem and begin to work through their ideas is critical to the success of the contrastive conversation. As can be seen in the example, after the problem is posed the teacher and students work through the problem and document their individual approaches and ideas in ways that they can refer back to when they share their ideas with the class. During a contrastive conversation students need opportunities to not only complete a strategy but they need to be working through how they would talk about their idea, what representations they will use to show what they did, and so on. The teacher can use this time to read the terrain, and find out how students have thought about the problem. The teacher can position students to share and engage students in talking in pairs with each other about their strategy. The teacher can challenge a students' thinking and scaffold movement to a new idea. The teacher can listen to student's explanations and support students in providing detail. This work all occurs as a part of contrastive conversations.

Contrastive conversations are not contrastive conversations without (1) student agency around the strategies, (2) active discussion that involves *all* students, (3) attention to the core content. Throughout the conversations students must maintain ownership over their own ideas. Each student needs to have the opportunity to make sense of the problem in their own way. Thinking through the problem in one's own way first provides access to learning more about the content embedded in the problem. It is difficult to listen to another's idea without

some notion of how to make sense of the problem oneself. It is difficult to ask questions or compare without something to relate it to for oneself. Positioning oneself in relation to a particular idea is what makes the contrastive conversation work.

COMMON FEATURES OF BOTH CONVERSATIONS

In order to make an informed decision about when to have a consensus conversation, a contrastive conversation, or a different type of instructional conversation, we need to fully understand the range of positive learning outcomes and potential challenges that might occur for each type of conversation. In this section, we will examine the potential of both consensus and contrastive conversations in terms of: a) the cognitive consequences to individual students from engaging in the process of these types of conversations; b) the value to individual students related to the products of these types of conversations; c) the emotional and affective potentials of these types of conversations; and d) the effect that these types of conversations have on the classroom community and culture.

Since the process of contrastive and consensus conversations begins in quite similar ways, it is not surprising that many of the benefits to student learning are also shared. Both types of conversations involve students actively constructing solutions, articulating them for the whole class, and comparing and contrasting their ideas. Engaging in this process may contribute to students learning in at least five ways. First, the benefits of actively constructing personally meaningful solutions to complex problems have been shown repeatedly.

Second, all students—even non-presenters—are actively involved in the conversation itself. Students who present and contrast their ideas with their peers articulate and externalize their thinking in ways that makes it visible to themselves and others. Non-presenters—having constructed their own personally meaningful solution—have an orientation towards the other students' presentations that make them active listeners.

Both types of conversations also lead students to compare their solutions to the other students'. This brings us to the third benefit, by comparing solutions students may come to see how their approach differs from other approaches. This provides students with opportunities to be exposed to and closely examine other ways of thinking about the problem. Some of these ideas may be borrowed, or they may simply be an opportunity for the students to rethink and revise their own solution in new and innovative ways.

Fourth, the students invented solutions are, at least at first, likely to be partial, or limited to a specific context. For example, in the discussion of mapping (above) the invented solutions of using shadows to show that an object was tall worked until the students needed to know exactly how tall the object was. Therefore, in comparing her solution to another a student might find that her solution doesn't work in certain circumstances where another method does. This reflection about the limits and generalizability of one's own solution is an effective way to focus a student's attention on the various parts of the problem and often leads to the iterative modification of a student's own ideas and understandings.

Fifth, hand-in-hand with a complete understanding of the problem, the comparison of solutions may lead to a better understanding of what it takes to have an effective and complete solution. That is, in discussing what makes a good solution, the student's attention becomes focused on the criteria by which one judges the effectiveness and adequacy of a

solution. Both understanding the problem and understanding what makes a good solution contribute to a deeper understanding and better solutions.

As in consensus conversations, during contrastive conversations students make their thinking explicit to the group, giving both themselves and others a chance to reflect upon and discuss the presented ideas. Both types of conversation provide students the opportunity to participate in an open exchange of ideas, compare strategies, position themselves in relation to others, and refine their thinking. They also allow students to build common language, and participate actively in the discipline.

Finally, while both consensus and contrastive conversations help students to more clearly understand the problem at hand, they do so in opposite ways. Whereas a consensus conversation aims at narrowing solutions to more tightly define the problem, a contrastive conversation widens solutions to more clearly define the problem. Although students are presenting many different ideas in a contrastive conversation, ultimately the discussion helps students see that the underlying content-based concepts appear in all the ideas shared. These five benefits to learning from contrastive and consensus conversations apply to all the students who are actively engaged in the conversations—both actively presenting and active in more legitimate peripheral roles such as active listening (Lave and Wenger, 1991).

Both consensus and contrastive conversations, however, require a safe and supportive environment where students are not afraid to publicly report their current thinking—even when it is likely that their thinking is "incorrect". Embarrassment and the potential for embarrassment permeates everyday life and often lies at the heart of social organization and our efforts to regulate our own actions (Goffman, 1967). In typical school conversations the focus is on providing the correct answer, and students have developed ways of participating in and framing these types of conversations that minimize their embarrassment. In comparison, consensus and contrastive conversations can be very emotionally vulnerable spaces for children. This means that before having a successful conversation of this type a teacher must lay the groundwork that aids the students in their impression management, or as Goffman (ibid.) calls it "face-work". Students must feel secure in the fact that a wrong answer, or a partially developed idea will not be held against them or diminish their social standing with the teacher and their peers. The students must come to perceive that their contributions to the conversation itself are what is valued and not just the final answer. The way in which face is managed socially—challenges, offers, expressions of thanks etc.—can be almost ritualistic, but very important if one wants to keep students involved in the conversation. As a result, during the conversation teachers must also be reflective of how they are summarizing, revoicing, promoting, or ignoring student contributions—even while they attempt to orchestrate the conversation in a productive direction.

UNIQUE BENEFITS AND CHALLENGES OF CONSENSUS CONVERSATIONS

What is unique about consensus conversations is that at some point the conversation turns a corner from sharing to discussing which solution they all agree to "try out" for their next activity. The additional benefits and challenges of this aspect of consensus conversations occur at the level of individual students.

Table 1. Benefits and Challenges of Consensus and Contrastive Conversations

	Benefits to Students	Challenges for Teachers
Shared Features	Active knowledge construction Legitimate and productive roles for non-presenters Access to new ideas Promotes an understanding of the problem (not just the solution) Helps students understand what constitutes an adequate solution	Negotiating (rather then dictating) the pace and direction of the conversation Creating a safe environment where students feel open to sharing their emerging ideas
Consensus	Coordinate future, joint activity Provide shared reference point Mark progress Leverage desire to belong to push individual change Promote an orientation towards knowledge building	Omitting opportunities to revisit and revise conventions Managing "face" (i.e., who's ideas are promoted, etc.) Ensuring that students do not adopt ideas without understanding them
Contrastive	Provide multiple entry points for students at different levels Opportunities for individualized scaffolding Opportunities for students to learn from one another Promote the belief that there are many corrects paths to a solution	Managing and organizing a large range of ideas into a productive conversation Listening to students without distorting or cleaning up their thinking for them Honoring where students are while at the same time pushing students to continually develop their ideas

A potential benefit to the more directed and critical comparison of ideas in consensus conversations is challenging individual students out of their "comfort zones." The solution chosen as the community's temporary norm, is likely to be beyond the current level of understanding of a few of the students. This may challenge students to go beyond themselves in their struggle to make sense of and use the new solution. It is possible that this would set the stage for fruitful collaborations within a zone of proximal development. However, students do not have to invent the solution in order to participate in a consensus conversation. These types of conversations have legitimate roles for peripheral participants (Lave and Wenger, 1991). As the mapping example shows, it is rare that one student will invent the solution that becomes the consensus without input from other students. Thus there is a legitimate role for students to modify other people's ideas. Additionally, a student does not have to fully understand the solution when it is presented to participate. When the teacher facilitates debates and polls the students for their opinions, it provides a way for students who do not yet understand the solution to question it and/or change it.

This potential pitfall of consensus conversations—that students may feel pressured to adopt a strategy without fully understanding it—is mitigated only if consensus conversations are kept in the context of a longer conversation, where what is today's consensus can be re-opened for discussion in light of new developments, contexts, or changes in student understanding. If consensus conversations remain framed as temporary agreements they

provide multiple openings and multiple ways to participate in the conversation. For students who fully understand the convention, they can participate as full participants, using it, teaching it to others, and further modifying it as needed.

We believe there are also some unique benefits to consensus conversations in terms of the products of consensus conversations. The product in this case is a temporary agreement about what solution the community will use to solve its problems. One of the most pronounced benefits of a temporary agreement of the classroom community is that students can coordinate their joint activity on future problems. If the activities that take place after consensus require students to work together on a shared problem, a shared solution helps them to communicate with and understand each other and make smoother progress towards their shared goal. This is in part because the students can use the shared solution without having to stop to unpack it and to justify its value. Likewise, it acts as a shared reference point for communication in that it allows students to see and talk about the problem in similar ways. This shared reference point for communication can also serve as an informal assessment point. When a student talks about the solution in a novel way, in a way that doesn't make sense, or even uses the solution in an inappropriate way, this can be used as a signal and an opportunity to the teacher and other students to stop and discuss their different understandings.

Due to the temporary nature of a consensus, the current solution is an object that is expected to be modified as the need arises. When students encounter a new context, where the current solution does not make sense, the process of invention, sharing and consensus starts again. Revisiting an existing consensus becomes a perfect opportunity to engage in new creative activities and revisit students' old solutions in an effort to overcome the new difficulties. This aspect of the consensus cycle leads to a new orientation towards knowledge. In contrast to traditional instruction, here the students, and not the teacher or the textbook, invent solutions and make knowledge claims. The students also discover on their own that solutions are often partial, limited, context specific, and available for modification. This gives them a new perspective on the conventions of math, science, and other subjects; the students come to recognize that what is taught was invented much in the same way as their own invented solutions.

We also argue that there exists an emotional value to reaching consensus. First, while understanding a solution is ultimately a personal construction, consensus provides a legitimate active role to students who are not the inventors of an idea. That is, students who do not invent the idea still engage with the idea as critics, as members of the community that freely decide to adopt it, and as co-constructors as they modify the solution over time. In this way all students can claim ownership of an idea that has become the community's convention. Second, that act of coming to a consensus provides temporary closure on the issue, which students can use to mark their progress and accomplishments.

Finally, coming to consensus occurs only in a community as a group. A shared solution allows for students to work together in a joint enterprise, the hallmark of a community (Engestrom; 1987; Lave and Wenger, 1991; Wenger, 1998). Therefore, consensus conversations uniquely leverage the student's desire to be part of a community in a productive way. This works on two levels. First, students' desires to be part of the classroom community motivates them to engage in ideas on the conceptual plane. The mastery of shared ideas marks membership in the community and allows students to successfully interact with their peers. This creates a context where peers are motivated to understand each other's ideas, even those that do not make sense to them. Second, as students' conventions develop they become closer

and closer approximations of the normative disciplinary conventions. When this happens appropriating the classes' solution marks more than membership in the class, it also signals membership into the broader community of the discipline. A student who adopts concentric shapes to represent height on a map can think of herself as a map maker and can understand and use conventional topographic maps. Identification with academic disciplines and larger communities of practice like this can have long term implications for how students engage with ideas and with schooling itself.

UNIQUE BENEFITS AND CHALLENGES OF CONTRASTIVE CONVERSATIONS

The unique benefit of the contrastive conversation rests on the premise that the conversation values individual student's reasoning in relation to the group's reasoning. This creates a setting where students can successfully enter the problem. Since every accurate idea is acceptable in a contrastive conversation, everyone has a place to start. From there, teachers scaffold individual children's understanding by nudging them to explain their ideas to someone else, compare ideas or try the next most sophisticated solution. Unlike a consensus conversation, this individualization allows a student to move from her understanding and adopt the next strategy when it makes sense to her. The class as a group has access to a range of content based ways of considering the problem's solution and an opportunity to make sense of their thinking in relation to others.

Often in contrastive conversations, the teacher will also ask students to come up with multiple ways to approach an idea or problem. Students benefit from being pushed towards understanding by providing access to more shared ideas, and by allowing them to compare their thinking around a particular strategy with the thinking of others.

Contrastive conversations have some important benefits for classroom culture as well. First, they reinforce the value that there is more than one path to the right answer. This allows students to view themselves as problem solvers even if they don't know how to use the most conventional solution. Second, it reinforces a value of explaining one's thinking, which makes the process more explicit to the student himself, and to other students that may use that strategy.

Finally, contrastive conversations have benefits to teachers inasmuch as they help teachers understand children's thinking about the content area, and the trajectory that children's thinking follows. The more a teacher engages students in these discussions and resists the temptation to re-formulate their thinking, the more nuanced the teacher's understanding of student's thinking becomes. As this understanding deepens, teachers can improve their instructional practice by carefully inventing problems that will push children's strategic thinking, and scaffolding individual student understandings.

We have identified two broad types of challenges for teachers in conducting productive contrastive conversations. First, laying a foundation for the whole class discussion raises a number of challenges. These include cataloging students' ideas, planning who to call on, and trying to push students to explore new ways of reasoning and to externalize new strategies. Second, there are challenges associated with the contrastive conversation itself. These challenges center around issues of management—listening to students, letting the students

retain ownership of the ideas, and to some degree letting students control the direction of the conversation.

A productive contrastive conversation requires significant work. Prior to the whole class discussion the teacher supports the students to either articulate their reasoning, or think about the problem in a new way. The teacher checks in with the class to see how they as a whole are thinking about the problem and begins to plan who to call on, in what order, and how to attempt to push the conversation towards new and fertile intellectual ground. It is possible to meet these goals without spending a long amount of time with any one student. In fact, to meet the teacher's goals it is necessary to circulate around the room quickly categorizing students into recognizable strategies. This is also productive for the students as the teacher takes the opportunity to suggest new problem variations, suggest that the student compare their strategies with another student, or share an idea that may help the student see the value of the next most sophisticated strategy.

Knowing what to listen for and having a plan for how the conversation will unfold are also critical. Through the research literature or personal experience with student reasoning, teachers often find that students tend to raise a finite number of somewhat predictable ideas on a topic. For example, in a contrastive conversation around addition of whole numbers teachers find that first grade student responses fall into one of a finite class of strategies: direct modeling, counting strategies, derived fact or recall strategies (Carpenter, Fennema, and Franke, 1997). With experience, teachers quickly come to realize which strategy a student is using based on a few cues either in the way they talk about their strategy or in the ways that they graphically represent it. Moreover, teachers typically find that student explanations are not always clear, efficient or easy to follow. But drawing on their experience and knowing the principles underlying the ideas students are engaged with they will find that student ideas often follow a logical pattern.

When it is time to have the contrastive conversation with the whole class it becomes important to listen to students as they fully articulate their reasoning. One of the most significant challenges to orchestrating a successful contrastive conversation is the inclination for teachers to prematurely think they understand the student's reasoning and rephrase the strategy in such a way that it is no longer recognizable to the student. It is easy to fall into this trap, because as a teacher one must balance the need to efficiently progress through the material with the goal of having every student understand the material. While this is often warranted when working with individual students it is often problematic in the whole class discussions.

A related challenge for teachers is to not cut off the discussion after a few minutes in order to move the conversation where the teacher wants it to go or to simply end the conversation by telling the students the correct strategy. In managing the contrastive conversation there is a tradeoff between trying to involve every student in the conversation and the limited amount of time that can be devoted to slight variations of similar strategies that inevitably arise. This is why the teacher needs to have a good understanding of the range of student ideas before the whole class discussion. Typically she has observed and noted the students' various ideas when she circulated around the classroom while the students were inventing their solutions. The focus of the contrastive conversation should be centered on comparisons of strategies and the elicitation of the rationale behind why the strategy works and makes sense. This certainly requires a range of strategies to be presented on the public floor, but it does not necessarily require that every student present his or her idea. It is

important to remember that because every student has adopted some personally meaningful strategy prior to the conversation, even those who do not present their ideas will be engaged in the discussion identifying with one of the public strategies or contrasting a public strategy with their own private strategy. This sort of active listening or intent participation, although understudied, has been shown to be both common and quite effective ((Rogoff, Paradise, Mejıa Arauz, Correa-Chavez, and Angelillo, 2003).

A challenge for teachers is to walk a fine line between helping students articulate their ideas and changing those ideas to such a degree that the student no longer recognizes them as her own. This means that even though it is important to have a plan for how the conversation will proceed, teachers cannot rigidly adhere to the plan. As we have stated previously one of the benefits of contrastive conversations is that students construct a personally meaningful understanding of the strategy. Part of this meaning construction entails a certain amount of ownership over their reasoning and being given the authority to invent, present, and defend their own ideas. In short, part of the way that they construct personally meaningful understandings is by being allowed to engage in knowledge production (Wells, 1999). A common and often productive move for teachers to make in any discussion is to revoice students' ideas—to make sure other students hear them, to "clean" them up to help other students understand them, or to rephrase them in academic terms or in terms of the normative ideas of the discipline (O'Connor and Michaels, 1996). However, if in cleaning up an idea the idea is changed to the degree that the student no longer feels ownership over it, part of what makes a contrastive conversation an effective learning conversation has been sacrificed for an illusionary sense of efficiency. Likewise if the teacher's revoicing of a strategy is a subtle or not so subtle endorsement of that strategy it can freeze the development of that idea or limit the degree to which students who are not yet ready for it have a chance to fully understand it. It is important to note that for us efficiency can only be gauged in terms of having every student understanding at least one effective strategy, and every student having an opportunity to advance to a more sophisticated strategy if one exists. Ironically, from the student's perspective, it is often the traditional sense of efficiency—how fast and accurate their current strategy is—that pushes students to try out and adopt new ways of thinking.

OPPORTUNITIES FOR TEACHER LEARNING

While the main benefit and rationale for engaging in either a consensus or contrastive conversation is to improve student understandings, we believe that engaging in these conversations also can provide a long term benefit to teachers as well. Consensus and contrastive conversation are both examples of what Pea (1994) termed *transformative communication*. These are conversations that are not predetermined nor scripted. Therefore, they engage the teachers in a genuine intellectual exchange with the students. Anytime one engages in such an exchange, it has the potential for all the parties, including the teacher, to be transformed by participating.

First, as mentioned earlier, these types of conversations require thoughtful planning ahead of time. This planning often is grounded in the conceptual domain and can often help the teacher to gain a deeper knowledge and understanding of the disciplinary content. A prime example of this is when the teacher would prepare for a conversation by considering

what criteria will be used to judge more sophisticated and less sophisticated ideas. Will students be held accountable to the accuracy of their strategy? Is efficiency or generalizabilty important? In considering these types of questions, one is in fact reflecting on the commitments and values of the disciplinary community in relation to this particular concept. Researchers have argued that students develop deeper conceptual understandings of the content and more beliefs about the discipline when classroom discourse mirrors the discourse of the professional community (Lemke, 1990). For example, in mathematics there is a premium on accurate and elegant/efficient strategies. In science there is often a commitment to causal theories that are general in nature, but that may or may not provide exact answers in any particular concrete instance where additional factors come into play (e.g. the two objects of different weights accelerate at the same speed, until wind resistance is a factor). In deciding which criteria the class will critically evaluate their own ideas against, the teacher is engaging with and perhaps coming to understand better the core ideas of the discipline which s/he is teaching.

Second, and perhaps more importantly, instructional conversations such as consensus and contrastive conversations offer a much greater potential to provide teachers with real feedback about the students' thinking. In classroom talk based on transmission models of communication—such as the IRE pattern—students don't have many opportunities to express their thinking, and teachers have very little feedback beyond the number of students who can and cannot answer correctly. As a result teachers do not have access to the ways in which students conceptualize the topic or the ways that their current thinking is coloring or distorting the intended message of the lesson.

Once engaged in the give and take of instructional conversations such as the ones discussed in this paper, one's attention is naturally drawn to the students thinking. In order to engage the student in a productive conversation, the teacher has to listen to and think about where a student is, rather than thinking about where the student should be according to the curriculum guide or someone's expectations (including one's own). This allows teachers to gather knowledge about the details of student thinking. Both during the lesson and afterwards, teachers categorize students' ideas into the known intuitions for that domain, and attempt to devise activities and probing questions that are designed to challenge the specific ways of thinking that this group of students is employing. This is a typical example of what is often called pedagogical content knowledge (Shulman, 1986). We know from the research in mathematics and science education, that teachers who know the details of their students' thinking have students who learn more about the content (diSessa, and Minstrell, 1998; Hatano, and Inagaki, 1991; Jacobs, Franke, Carpenter, Levi, and Battey, 2007).

DISCUSSION

Supporting teachers in making use of instructional conversations requires that we continue to unpack the conversations in ways that make explicit the details surrounding what constitutes the particular type of conversation, what the type of conversation can afford, and the potential limitations. We have begun that process here, building on the work of Cazden (2001) and others, to detail two types of conversations within classrooms. Although we have presented examples from across a number of disciplines, it is not yet clear the degree to which

the benefits and challenges of these two types of conversations will vary with the discipline and topic. Even so, we have laid out some guidelines to help educators choose when these two different types of conversations might be appropriate for a given topic or as a means to develop different kinds of classroom community. Additionally, we have detailed the benefits—to teachers as well as students—that are shared and unique to both contrastive and consensus conversations. To help practitioners who may be interested in engaging in one or the other of these types of instructional conversations, we have also roughly sketched out the steps to each conversation and the important roles for teachers and students. While many other types of instructional conversations offer similar potentials to engage teachers in reflecting about their own practice, students' thinking, and the big ideas of the disciplines that they are trying to teach, we hope that the ways that we have mapped out the choices, rationales, benefits and challenges of consensus and contrastive conversations will provide analytic tools for teachers to begin to engage in these types of reflections on their own.

We see this line of inquiry as both the work of research, as we continue to document and detail the benefits for teachers and students, as well as the work of practice as teachers begin to stretch our notions of what can happen in different instructional conversations. More work in this area, in both directions, is needed. We believe there is a need for research in classroom discourse to grapple with the details and consequences of different forms of classroom discourse and move beyond the broad strokes of argumentation, co-inquiry, knowledge building, and critical discussion. Of particular importance will be to empirically test the validity of the careful theoretical analyses of the type presented here. As our nuanced understanding of the different classroom discourse structures grows, so to will our ability to help teachers with the practical aspects of successfully orchestrating productive instructional conversations.

As we eluded to in the beginning of this paper when we quoted Cazden (2001), understanding the details of classroom conversations also has important implications for creating more equitable learning opportunities for our increasingly diverse classrooms. Because classroom discourse is central to the learning that goes on in elementary school, it is also central to our attempts to make learning opportunities more equitable for our students. There are a number of educators who argue that too often classrooms are mono-cultural—that classroom conversations are rooted in white middle class discourse patterns (Heath, 1998; Lee, 2003; Warren and Rosebury, 1995). A better understanding of current and potential classroom discourse structures is a first step towards creating equitable opportunities for all students to learn and develop. We believe that the close attention to student thinking, which is an important aspect of both contrastive and consensus conversations, is a necessary but not sufficient component of any equitable classroom conversation. Without attending to where individual students are and what they are saying, we don't see how to create conversational opportunities that challenge students to grow into their potential.

However, attending to individual students alone is likely to lead us to overlook persistent patterns of who is learning, when, and how. Work Like Carol Lee's (2003) and Shirley Brice Heath (1998) show that for some students the existing conversational repertoires that they have already mastered do not overlap much with the structure of classroom discourse (e.g., typical patterns like the IRE, or potentially with the more reform minded patterns as presented in this paper). In these situations an important first step is to make the language game of the classroom explicit, and to help the students map their existing ways of participating onto the less familiar academic discourse. Making the language games of the classroom explicit to

students requires that we as educators understand the details and nuances of the discourse structures we employ, what opportunities they afford for student learning, and who is likely to be able to seize those opportunities.

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Chapter 8

DEVELOPING CRITICAL THINKING IS LIKE A JOURNEY

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ABSTRACT

I present five passages in a pedagogical journey that has led from teaching undergraduate science-in-society courses to running a graduate program in critical thinking and reflective practice for teachers and other mid-career professionals. These passages expose conceptual and practical struggles in learning to decenter pedagogy and to provide space and support for students' journeys while they develop as critical thinkers. The key challenge I highlight is to help people make knowledge and practice from insights and experience that they are not prepared, at first, to acknowledge. In a self-exemplifying style, each passage raises some questions for further inquiry or discussion. I aim to stimulate readers to grapple with issues they were not aware they faced and to generate questions beyond those I present.

INTRODUCTION

> The most important parts of any conversation are those that neither party could have imagined before starting.
>
> William Isaacs (1999).

In the mid-1980s I was teaching science in its social context as a new faculty member at a non-traditional undergraduate college. I began an ecology course with a brief review of our place in space before I asked students to map their geographical positions and origins. One student, "K," did not come back to earth with the rest of us, but remained off in her own

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thoughts. Some minutes later she raised her hand: "I always knew the sun, not the earth, was the center of the solar system, but do you mean to say..." K paused, then continued. "I'd never thought about the sun not being the center of the universe." From K's tone, it was clear that she was not simply rehearsing a new piece of knowledge. She was also observing that she had not thought about something she now saw as obvious. What other retrospectively obvious questions, I could see her thinking, had she not been asking? What other reconceptualizations might follow? Such self-questioning pointed her along the path I hoped my students would take as critical thinkers—grappling with issues they had not been aware they faced, generating questions beyond those I had presented, becoming open to reconceptualization, and accepting that their teacher should not be at the center of their learning.

Although I had provided space for K to move forward as a critical thinker, I had done so inadvertedly. How could a teacher foster such critical thinking? It was some years before I became acquainted with the abundant literature on critical thinking, but that literature turns out not to illuminate central conundrum of the K incident (Critical Thinking Across The Curriculum Project 1996). I agree that everyone should have skills and dispositions for scrutinizing the assumptions, reasoning, and evidence brought to bear on an issue by others or by oneself; I see the value of thinking about thinking. But how do students come to see where there are issues to be opened up and in what directions? Moreover, how do they come to identify the issues and directions without relying on some authority? The "answer" I present in this essay is that teachers need to support students as they face inevitable tensions in personal and intellectual development—to support them to undertake journeys that involve risk, open up questions, create more experiences than can be integrated at first sight, require support, and yield personal change.

It might be interesting to analyze the literature to show how the experts tend to focus on the critical thinking goals or standards of clarity, accuracy, perseverance, and so on (Paul et al. 1997). This focus comes at the expense of opening up issues that I have come to see as important about students' processes of development. This essay, however, does not pin down arguments. Instead, seeking consistency of message and expository form, I evoke my own pedagogical journey and exposes questions that remain open for me. This journey has taken me from teaching the undergraduate science-in-society courses mentioned above to running a graduate program in critical thinking and reflective practice for teachers and other mid-career professionals. (A parallel journey in ecological and environmental research is described elsewhere, Taylor 2005a.) I recount five passages in which I expose some of my conceptual and practical struggles in learning to decenter my pedagogy and to provide space and support for students to develop as critical thinkers. Each passage raises some questions and ends with an issue that I leave open for further inquiry or discussion. I hope, moreover, that the passages and questions stimulate you to grapple with issues you were not aware you faced and to generate questions beyond those I present.

Of course, I cannot create for readers the experience of participating in a classroom activity or semester-long process. Nor can readers divert me from the steps ahead already written and inject other considerations. If you could, I expect some of you would slow me down to ask for more detail about the situations I describe or to ask for more explication of my line of thinking in relation to other writers.[2] Indeed, it is one of the central tensions of my

[2] I have chosen not to highlight paradigms and conventions in this essay because only towards the end of the journey described did educational theory begin to become part of my voice. Readers who wish to know my

teaching and writing that I seek to open up questions and to point to greater complexity of relevant considerations even though I know that some of my audience would prefer a tight analysis shaped to address their specific concerns and background. In acknowledgement of these tensions, this essay is accompanied by a web-based forum in which readers can engage or witness the author in conversation.[3] This experiment befits the central pedagogical challenge this essay raises, namely, helping people make knowledge and practice from insights and experience that they are not prepared, at first, to acknowledge.

1. Becoming Aware of the Forces that Hold Us or Release Us

Since childhood star gazing in rural Australia I had known about the sun's marginal place in the Milky Way and I felt some superiority when K admitted that she had not thought about this. To my chagrin, I subsequently discovered my own retrospectively obvious question about our place in space. I was reading Sally Ride's book on the space shuttle to my child, when I came to her description of astronauts regaining weight as they descended (Ride 1986). The idea conveyed was that weightlessness was a result of distance from the earth. Yet the space shuttle orbits only 300 kilometers up where the earth's gravity is still 90% of its strength down on the surface. So I started thinking about how to explain weightlessness correctly in a children's book. What I came up with is this:

Think of swinging an object around on the end of a piece of string. To make it go faster, you have to pull harder; if you do not hold on tight, the object might fly off into the neighbor's yard. Astronauts travel around the earth fast—at 7.5 kilometers per second. They feel weightless because all of the earth's gravitational attraction on them goes to keep them from flying off into space. The earth's pull on the astronauts is like your pulling on the string—but, while you may let go, gravity never stops acting. When the space shuttle slows down on its return to earth, less of gravity's force goes to keeping the astronauts circling the earth and what is left over is experienced as weight regained.

After rehearsing this explanation a few times, another kind of weightlessness occurred to me. The sun's gravitational attraction is keeping me circling around it—at 30 kilometers/second I figured out. On the earth I feel weightless with respect to the sun's gravity, but that force is acting nevertheless. I had never thought about this; I had considered myself a passenger on the earth, which the sun's gravity was keeping in orbit around it. I then realized that I was also zooming around the Milky Way galaxy, not as a passenger in a solar system that the galaxy's gravitational attraction keeps in orbit around it, but directly because the galaxy's gravity was keeping me orbiting around its center. I started to feel woozy thinking of the sun and the rest of the galaxy "paying attention to me" all the time, keeping me circling at enormous speed through space—at over 200 kilometers/second, I soon learned.

intellectual location can read an autobiographical contextualization of my environmental and science studies research, where I am more self-conscious about theoretical positioning, in Taylor 2005.

[3] Email questions and comments to reseeing@googlegroups.com and view http://googlegroups.com/group/reseeing to read what others have said. For example, one reader of the manuscript challenged me to acknowledge the paradigms and conventions that inform my thinking (see note 1) and to undertake more "memory work" to recover the roots of my pedagogical tensions, including why I like to contribute to students having "more experiences than can be integrated at first sight" (see section 2).

I then wondered if every molecule in the galaxy was attracting every molecule of my body every moment. The wooziness increased. Was there some other way to think about gravity? Perhaps a further radical reconceptualization awaits me, involving hyper-wooziness-inducing concepts such as Einsteinian curved space-time.

In recent years I have started courses and workshops on critical thinking by relating the reconceptualizations that occurred to K and then to myself. I usually follow the story with an activity. My goal is to have people respond to the story and bring insights to the surface about how people can generate questions about issues they were not aware they faced. The activity begins, therefore, with a freewriting exercise (Elbow 1981) in which each of us writes for ten minutes starting from this lead off: "When I entertain the idea that I haven't been asking some 'obvious' questions that might have led to radical reconceptualizations, the thoughts/ feelings/ experiences that come to mind include..." After this writing, participants pair up and describe situations in which we "saw something in a fresh way that made us wonder why we previously accepted what we had." We then list on the board short phrases capturing what made the "re-seeing" possible. The factors mentioned differ from one occasion to the next, but they always represent a diverse mix of mental, emotional, situational, and relational items, e.g., "relaxed frame of mind," "annoyed with this culture," "forgetting," "using a different vocabulary," and so on. I have concluded the activity simply by noting the challenge, which is common to many other questions in education, of acknowledging and mobilizing the diversity inherent in any group.

Recently, I have started to wonder whether, now that I have lists from several occasions, the factors could be synthesized into general directions. Would future audiences gain from my cutting through the diversity and presenting the synthesis—or does this run against the grain of facilitating thinking about re-seeing?

2. CRITICAL THINKING AS JOURNEYING

Some years ago I taught for the first time a general course on critical thinking. The students were mostly mid-career teachers and other professionals. This was also the occasion of my first telling the place in space story and running the re-seeing activity. Some of the students construed the story as a science lesson; evidently, I had to clarify the delivery and message. Later in the semester I had a chance to do this when we revisited the activity to practice lesson-plan remodeling. What emerged from the class discussion was that it mattered little to me whether students understood my weightlessness explanation. I only wanted them to puzzle over the general conundrum of how questions that retrospectively seem obvious ever occurred to them and to consider their susceptibility to recurrent reconceptualizations. It was during this clarification process that the image occurred to me that development as a critical thinker is like undertaking a personal journey into unfamiliar or unknown areas. Both involve risk, open up questions, create more experiences than can be integrated at first sight, require support, yield personal change, and so on. This journeying metaphor differs markedly from the conventional philosophical view of critical thinking as scrutinizing the reasoning, assumptions, and evidence behind claims (Ennis 1987, Critical Thinking Across The Curriculum Project 1996). Instead of the usual connotations of "critical" with judgement and

finding fault according to some standards (Williams 1983, 84ff), journeying draws attention to the inter- and intra-personal dimensions of people developing their thinking and practice.

In retrospect, the immediate impetus for my re-seeing critical thinking as journeying seemed to have been the "life-course" of students during that fifteen-week semester. Early in the course many students expressed dependency on my co-instructor and me: "Aren't small group discussions an exercise in 'mutually shared ignorance'?" "Could the class be smaller?—we want more direct interaction with you." "I was never taught this at college—I'm not a critical thinking kind of person." Some students were uncomfortable with the dialogues that their co-instructors would have in front of the class in order to expose tensions among different perspectives. They asked for clear definitions of critical thinking and explicit expectations for the product of each assignment or activity. Their anxieties were most evident when they looked ahead to a new end-of-semester "manifesto" assignment, in which we asked for "a synthesis of elements from the course selected and organized so as to inspire and inform your efforts in extending critical thinking beyond the course." We responded to students' concerns with some mini-lectures, handouts, and a sample manifesto. Yet we also persisted in conducting activities, promoting journaling, and assigning thought-pieces through which students might develop their own working approaches to critical thinking. By mid-semester students who had been quiet or lacked confidence in their critical-thinking abilities started to articulate connections with their work as teachers and professionals.

We had reassured those who worried about the manifesto assignment that they would have something to say, but we were surprised by how true that turned out to be. For example, the student who was not the "critical thinking kind" began her manifesto with perceptive advice:

"If there is one basic rule to critical thinking that I, as a novice, have learned it is

DON'T BE AFRAID!"

She continued: "*Don't be afraid* to ask questions and test ideas, ponder and wonder... *Don't be afraid* to have a voice and use it!... *Don't be afraid* to consider other perspectives... *Don't be afraid* to utilize help..." She finished, "Above all, approach life as an explorer looking to capture all the information possible about the well known, little known and unknown and keep an open mind to what you uncover." Another student wrote a long letter to her seven year old: "To give you a few words of advice, yes, but mostly to remind me of what I believe I should practice in order to assist you with your growth." These and other manifestos displayed admirable self-awareness. In finding their own critical thinking voices the students had taken risks and opened up questions, had experienced more than they were able at first to integrate and had sought support, and ended up seeing themselves differently (Taylor 2001).

In retrospect, I saw that the students' confidence had begun to rise during classes involving various approaches to empathy and listening (Elbow 1986, Gallo 1994, Ross 1994, Stanfield 1997). I suspect that listening well helps students tease out alternative views. Without alternatives in mind, it is difficult to motivate and undertake scrutiny of one's own evidence, assumptions, and logic, or of those of others. Being listened to seems to help students access their intelligence (in a broad sense of the term)—to bring to the surface, reevaluate, and articulate things they already know in some sense (Weissglass 1990). The resulting knowledge seems all the more powerful because it is not externally dictated (Friere

1970, Weissglass 1990). These are conjectures—I look forward to opportunities for more systematic exploration of the ways different people experience listening and being listened to in relation to their critical thinking.

3. UNDERSTANDING BY PLACING THINGS IN TENSION WITH ALTERNATIVES

A colleague recently challenged me by asking why, even though the critical thinking course ended positively, the student had been afraid in the first place. The force of this question led me to another: Had I been afraid about my ability to bridge the gaps between my own thought processes and those of different students? Had I composed mini-lectures and handouts as if to say to students, "I have written down the lessons clearly, now it is your responsibility to understand the material"? Once fear was raised as an issue that teachers should consider, I began to realize that it is a deep one. I want simply to leave this issue stirring in the background while I take up another thought about making lessons explicit.

Whatever I say about the power of students coming to their own reconceptualizations, I still feel tempted to use the more conventional approach for inducing re-seeing, namely, to spell out critiques of dominant views. I have written, for example, about the consequences of using natural selection to explain the evolution of organisms' adaptations to their environment. One consequence has been that the dynamics of the development and ecology of organisms get squeezed out (Taylor 1998). When I taught undergraduates in a program on biology in its social context, I led them through this and other critiques. (This was in the 1990s before I moved into the graduate education program, so my story is going backwards in time here.) During the first few years some students' evaluations claimed my course required students to accept the "dogma according to Taylor." These accusations disappeared, however, when I re-framed the purpose of raising alternative ideas. I started to ask students not to accept the alternative ideas, but to consider them in contrast to standard ideas so as to check that they understood those ideas clearly (Taylor 1995). For example, people often talk about DNA as a "blueprint" "coding for" an organism's traits, as if this molecule directed the rest of the organism's biological processes. I would ask students to explore alternative metaphors for the development of organisms and they came up with ideas such as improvisional dance, cheese making, and a casual conversation in an elevator. After playing around with metaphors that do not connote centralized control, many of the students saw for themselves the need to be more careful or precise about the actual functions of DNA.

The pedagogical shift—from critiquing dominant views to raising alternatives—led me in 1995 to compose the following view of students' developing as critical thinkers:

> In a sense subscribed to by all teachers, critical thinking means that students are bright and engaged, ask questions, and think about the course materials until they understand well-established knowledge and competing approaches. This becomes more significant when students develop their own processes of active inquiry, which they can employ in new situations, beyond the bounds of our particular classes, indeed, beyond their time as students. My sense of critical thinking is, however, more specific; it depends on inquiry being informed by a strong sense of how things could be otherwise. I want students to see that they understand

> things better when they have placed established facts, theories, and practices *in tension with alternatives* (Taylor 1995).

The pivotal pedagogical role of alternatives is evident in the way this paragraph continued:

> Critical thinking at this level should not depend on students rejecting conventional accounts, but they do have to move through uncertainty. Their knowledge is, at least for a time, destabilized; what has been established cannot be taken for granted. Students can no longer expect that if they just wait long enough the teacher will provide complete and tidy conclusions; instead they have to take a great deal of responsibility for their own learning. Anxieties inevitably arise for students when they have to respond to new situations knowing that the teacher will not act as the final arbiter of their success. A high level of critical thinking is possible when students explore such anxieties and gain the confidence to face uncertainty and ambiguity.

Let me make some observations about my own journey before returning to the idea of understanding ideas by placing them in tension with alternatives. Retrospectively, I can see that the journeying metaphor for critical thinking was already forming four years before it occurred to me. It seems that reconceptualization is preceded by a phase in which the person on the journey has, so to speak, shot rolls of film, but the photos have not yet been processed and printed. Indeed, the next paragraph of the 1995 account of critical thinking began:

> There are few models for teaching critical thinking, especially about science... Just as I expect of my students, I have experimented, taken risks, and through experience am building up a set of tools that work for me. Moreover, I have adapted these teaching tools to cope with the different ways that students in each class respond when I invite them to address alternatives and uncertainty, and when I require them to take more responsibility for learning (Taylor 1995).

I now see that writing the statement of my teaching philosophy, from which these excerpts have been drawn, precipitated a phase of self-conscious pedagogical exploration and identity formation. This exploration led to my moving to a graduate education program in the late 1990s and has continued in this position (Taylor 2005b). I had the opportunity in 1999 to participate in a faculty seminar on "Becoming a teacher-researcher." The focus I chose was a graduate course in which students undertake their own research projects directed, usually, towards some educational change. Let me describe my teacher-research because it extends the idea of understanding by placing in tension with alternatives.

In the research course I encourage considerable intra- and interpersonal exploration in defining and refining research direction and questions. An important part of this exploration comes through written and spoken dialogue around written work and successive revisions. For many students, such dialogue and revision are fraught; some strongly resist being weaned away from the familiar system of "produce a product and receive a grade." The specific teacher research began a month into the course with students writing their expectations and concerns in working under the "revise and resubmit" process. In the faculty seminar we digested the students' responses and used them as a basis for brainstorming about qualities of an improved system and experience. We clustered the large post-its on which we had written

suggestions and ended up with five themes: "negotiate power/standards," "horizontal community," "develop autonomy," "acknowledge afftect," and "be here now."

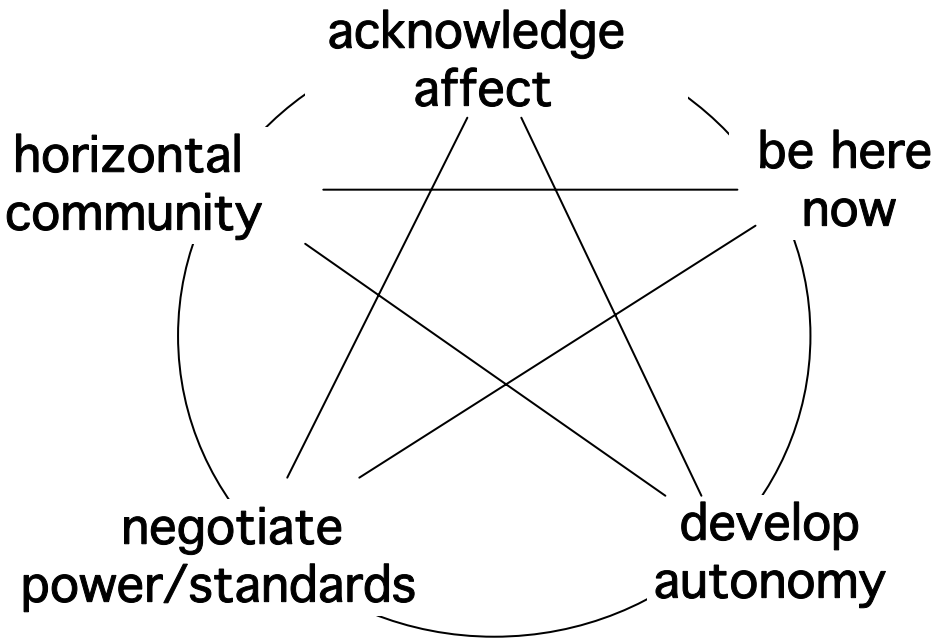

Figure 1. Five themes about improving the experience of dialogue around written work.

Back in class I discussed the students' responses with them and drew attention to the tension among the different themes (see Figure 1). "Develop autonomy" stood for digesting comments and making something for oneself, neither treating comments as dictates nor keeping one's work to oneself to insulate oneself. "Negotiate power/standards," on the other hand, recognized that students made assumptions about my ultimate power over grades translating into expectations that students would take up my suggestions. "Horizontal community" stood for building relationships other than the "vertical" one between professor and student.

During the rest of the research course we continued to refer to these themes and tensions. A substitute was needed for "autonomy" (or, equivalently, "independence") because some students construed this as going their own way and not responding to comments of others, including those of professors. When "taking initiative" was suggested to me by my wife, I realized that it applied to all five themes. I emailed my students: "[The challenge is to] take initiative in building horizontal relationships, in negotiating power/standards, in acknowledging that affect is involved in what you're doing and not doing (and in how others respond to that), in clearing away distractions from other sources (present and past) so you can be here now." A longer phrase soon emerged: "Taking initiative in and through relationships." That is, don't expect to learn or change on one's own. Build relationships with others. Don't expect to learn or change without jostling among the five aspects.

Of course, the "mandala" of themes-in-tension had not specified how to teach and support students to take progressively more initiative. Nevertheless, I believe that it helped the students in that course recognize themselves and take more initiative in their learning

relationships (Taylor 1999). I expect, however, it would be helpful for each new cohort to create their own mandala. I like to present the insights from the original group (sometimes adding "explore difference" as a sixth theme), but I also wonder how much the power of any summary lies in creating it oneself.

4. OPENING UP QUESTIONS

The research project course was a suitable venue for encouraging students to be more self-conscious about learning relationships. In other critical thinking courses I have had less time to explore the tensions captured by the mandala. Like most teachers, I feel the pressure to cover "content," that is, to move through the relevant body of material. (This pressure applies even though my current courses do not cover pre-formulated critiques, but move through a series of activities designed to help students place ideas in tension with alternatives.) Let me introduce a tension in the content side of my teaching (one I also wrestle with in my contributions to environmental research; Taylor 2005a) that extends the theme of the previous passage, namely, that understanding comes by placing things in tension with alternatives.

The tension I have in mind is between attending to complexity and particularity versus presenting simple accounts. On the complex side, in the early 1980s I adopted the anthropologist Eric Wolf's image of structures—in his case, societies or cultures—as contingent outcomes of "intersecting processes" that involve diverse components and span a range of spatial and temporal scales (Wolf 1982, 385-391). Not surprisingly, I was attracted to the research emerging in the late 1980s that explained cases of environmental degradation, such as soil erosion or deforestation, in terms of processes that linked changes in local agro-ecologies, labor supply and the organization of production, and wider political-economic conditions (Watts and Peet 1993). During the same period I was stimulated by sociologists of science who highlighted scientists' heterogeneous linguistic, material, and institutional "resources" and whose concept of scientific work encompassed many activities (Latour 1987; see also citations in Taylor 2005a, 93-133). On the "simple" side, however, I have to recognize the rhetorical power that simple environmental themes have, most notably variants of "Natural resources need to be privatized because resources held in common are inevitably degraded," and "Population growth will lead to environmental degradation." Similarly, simple themes about how science works, such as "Convince others of what is really going on," have more impact in dicussions about science and society than analyses of the specific networks of resources in particular cases.

Instead of resolving the simple-complex tension, I try to render the tension productive, a response that emerged from developing activities for interdisciplinary courses in which material must be accessible to a wide range of students. For example, in environmental courses I have students play out a scenario involving two countries. Each country has the same amount and quality of arable land, population size, level of technical capacity, and 3% annual population growth rate. I ask students to look ahead at the declining land area per household and decide what they would do in that situation. Their answers usually revolve around reducing consumption or using contraception. Then I tell them that country A has a relatively equal land distribution, while country B has a typical 1970s Central American land

distribution: 2% of the people own 60% of the land; 28% own 38%, which leaves just 2% of the land for the poorest 70%. Five generations before anyone is malnourished in A, all of the poorest class in B would already be—unless they act to change their situation. I divide the students into the wealthy, middle, and poor classes of country B and ask them again what they would do. Linking their impending food shortages to inequity in land distribution, the poor often propose taking over the underutilized land of the wealthy. The wealthy, anticipating this possibility, sometimes propose paramilitary operations that target leaders of campaigns for land reform. The middle class suggest investing in factories that employ the land-starved poor, or promoting population control policies for the poor. And so on. Although students do not learn the details of political, economic, or sociological analysis—that would require a course for specialists—the activity teaches them that the crises to which actual people have to respond come well before and in different forms from the crises predicted on the basis of aggregate population growth rates (Taylor 1997).

This simple, two-countries scenario points to the need for more complex analyses of the dynamics among particular people who contribute differentially to environmental problems. As I make explicit to students, the scenario invites us to consider that the analysis of causes and the implications of the analysis would change if uniform units were replaced by unequal units, subject to further differentiation as a result of their linked economic, social, and political dynamics. I call this kind of proposition an "opening up theme"—simple to convey, but always pointing to the greater complexity of particular cases and to further work needed to study them (Taylor 2005a).

Opening up themes are simple to dictate to students and to demonstrate to other teachers. At this stage, however, I am not sure that many students or teachers have added the themes to their toolbox and applied them to open up questions in other areas. I used to fret about this, but now see that I should not expect fast-track reconceptualization. My current, more modest pedagogical rationale is that tools placed in a toolbox may get buried for some time, but can eventually be reached for. Helping this happen I suspect is a matter of patience and persistence—listening to, acknowledging, and supporting the diversity of students' thinking about particularity and complexity.

5. TRANSLOCAL KNOWLEDGE IN PARTICIPATORY SETTINGS

> We did make a terrible lot of mistakes... So we had a little self-criticism, and we said, what we know, the solutions we have, are for the problems that people don't have. And we're trying to solve their problems by saying they have the problems that we have the solutions for. That's academia, so it won't work.
>
> So what we've got to do is to unlearn much of what we've learned, and then try to learn how to learn from the people.
>
> Myles Horton (1983), describing the early days of the Highlander Center

The final passage of this essay concerns a variant of the simple-complex tension. In the previous passages my ideal student or audience member appears to be a person who would be stimulated by my critical thinking activities to seek more *complexity* in their own understandings of the world. A contrasting image, however, is of people who can make good use of more *straightforward knowledge*, as long as that can be brought to the surface. This

tension has run through my environmental research; eventually I came to articulate it in the terms to follow.

I have long been inspired by participatory action researchers, such as Myles Horton, who shape their inquiries through ongoing work with and empowerment of the people most affected by some social issue (Greenwood and Levin 1998, Taylor 2005a). Yet my own environmental research has drawn primarily on specialist skills in quantitative modeling and analysis. For example, in a formative experience at the end of the 1970s, I was contracted by a government agency to undertake a detailed analysis of the economic future of a salt-affected Kerang irrigation region in southeastern Australia. I completed this at a distance—both geographically and institutionally—from those most directly affected by the region's problems. The sponsors homed in on a finding in the final report that confirmed their preconception that the price charged for irrigation water could be increased. They were, however, unable to implement this change and nothing more resulted from the study (Taylor 2005a, 94ff).

In contrast, let me draw some material from the phase of pedagogical exploration since 1995 mentioned earlier. Part of this has involved training in group facilitation with the Canadian Institute of Cultural Affairs (ICA). ICA's techniques have been developed through several decades of "facilitating a culture of participation" in community and institutional development. Their work anticipated and now exemplifies the post-Cold War emphasis on a vigorous civil society, that is, of institutions between the individual and, on one hand, the state and, on the other hand, the large corporation. ICA planning workshops elicit participation in ways that bring insights to the surface and ensure the full range of participants are invested in collaborating to bring the resulting plan to fruition (Burbidge 1997, Spencer 1989, Stanfield 1997).

Such participant "buy-in" was evident, for example, after a community-wide planning process in the West Nipissing region of Ontario, 300 kilometers north of Toronto. In 1992, when the regional Economic Development Corporation (EDC) enlisted ICA to facilitate the process, industry closings had increased the traditionally high unemployment to crisis levels. Although the projects resulting from the planning process are too numerous to detail, an evaluation five years later found that they could not simply check off plans that had been realized. The initial projects had spawned many others and the community now saw itself as responsible for these initiatives and developments, eclipsing the initial catalytic role of the EDC-ICA planning process. Still, the EDC appreciated the importance of that process and initiated a new round of facilitated community planning in 1999 (West Nipissing Economic Development Corporation 1993, 1999; Taylor 2005a, 207-210).

When I learned about the West Nipissing case, I could not help contrasting it with my own experience in the Kerang study. Detailed scientific or social scientific analyses were not needed for West Nipissing residents to build a plan. The plan built instead from straightforward knowledge that the varied community members had been able to express through the facilitated participatory process. The process was repeated, which presumably allowed them to factor in changes and contingencies, such as the start of the North American Free Trade Association and the declining exchange rate of the Canadian dollar. And, most importantly, the ICA-facilitated planning process led the community members to become invested in carrying out their plans and had enhanced their capacity to participate outside of that process in shaping their own future.

A difficult question has been opened up by the contrast between scientifically detailed analysis and participatory planning. Could a role in participatory planning remain for researchers to insert the "translocal," that is, their analysis of dynamics that arise beyond the local region or at a larger scale than the local? (Harvey 1995) For example, if I had moved to the Kerang region and participated directly in shaping its future, I would still have known about the government ministry's policy-making efforts, the data and models used in the economic analysis, and so on. Indeed, the "local" for professional knowledge-makers cannot be as place-based or fixed as it would be for most community members. I wonder what would it mean, then, to take seriously the creativity and capacity-building that seems to follow from well-facilitated participation, yet not to conclude that researchers should "go local" and focus all their efforts on one place.

Although West Nipissing versus Kerang symbolizes a longstanding tension in my research, I have seen something analogous in my teaching when I have tried to extend students' critical thinking into reflective practice. On one hand, experiences such as those recounted in this essay lead me to assume that students know more than they are prepared, at first, to acknowledge. Facilitation training leads me to assume also that students will become more invested in the process and in the outcomes when insights emerge from themselves. On the other hand, when I explicitly adopt a facilitator's role, should I keep quiet if I see that a crucial insight is not emerging? How much will it stifle the group process if I, the teacher, contribute as well? In any case, even if I put on a facilitator's hat and keep quiet, I cannot ensure that I am perceived simply as a non-directive supporter of their process. I cannot completely erase the students' sense of me as a teacher with whom they need to negotiate power and standards. Decentered pedagogy cannot avoid active, charged, and changing relationships among all concerned (Palmer 1998, 74).

CODA

The tension between acting as a facilitator and being more directive is evident not only in my teaching, but in the writing of this essay. In the spirit of the epigraph about dialogue "that neither party could have imagined before starting," I have endeavoured in various ways to keep matters open, even ambiguous. The sequence of passages was intended to evoke a continuing pedagogical journey that "involves risk, opens up questions, creates more experiences than can be integrated at first sight, requires support, and yields personal change." I decided to tease out multiple strands, rather than follow one thread, hoping to allow different readers the chance to choose which strands to pull on during their own journeys. I have exposed tensions; while not the path of maximum comfort, this seemed one way to model a process of keeping tensions active and productive. Yet, notwithstanding these attempts to open conversations, as author, I have necessarily spoken first and set many terms of any discussion that ensues. Rather than play down this as an unavoidable tension, let me present a summary of this essay's themes in both a didactic and a dialogic spirit. The themes to follow need to be addressed, I would propose, in order to provide space and support for others in their critical thinking journeys. At the same time, I hope readers draw me into discussion that leads to new ways of addressing and conceptualizing the challenges I have been opening up.

The central challenge addressed in the essay is that of helping people make knowledge and practice from insights and experience that they are not prepared, at first, to acknowledge. Some related challenges for the teacher/facilitator are to:

a) Help students to generate questions about issues they were not aware they faced.
b) Acknowledge and mobilize the diversity inherent in any group, including the diversity of mental, emotional, situational, and relational factors that people identify as making re-seeing possible.
c) Help students clear mental space so that thoughts about an issue in question can emerge that had been below the surface of their attention
d) Teach students to listen well. (Listening well seemed to help students tease out alternative views. Without alternatives in mind scrutiny of one's own evidence, assumptions and logic, or of those of others is difficult to motivate or carry out; see also point i, below. Being listened to, in turn, seems to help students access their intelligence—to bring to the surface, reevaluate, and articulate things they already know in some sense.)
e) Support students on their journeys into unfamiliar or unknown areas. (Support is needed because these journeys involve risk, open up questions, create more experiences than can be integrated at first sight, and yield personal change.)
f) Encourage students to initiative in and through relationships, which can be thought of in terms of themes that are in some tension with each other: "negotiate power/standards," "horizontal community," "develop autonomy," "acknowledge affect," "be here now," and "explore difference."
g) Address fear felt by students and by oneself as their teacher.
h) Have confidence and patience that students will become more invested in the process and the outcomes when insights emerge from themselves.
i) Raise alternatives. (Critical thinking depends on inquiry being informed by a strong sense of how things could be otherwise. People understand things better when they have placed established facts, theories, and practices *in tension with alternatives*.)
j) Introduce and motivate opening up themes, that is, propositions that are simple to convey, but always point to the greater complexity of particular cases and to further work needed to study those cases.
k) Be patient and persistent about students taking up the alternatives, opening up themes, and other tools and applying them to open up questions in new areas. (Experiment and experience are needed for students—and for teachers—to build up a set of tools that work for them.)
l) Take seriously the creativity and capacity-building that seems to follow from well-facilitated participation, while still allowing space for researchers to insert the "translocal," that is, their analysis of changes that arise beyond the local region and span a larger scale than the local.

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Chapter 9

INQUIRY: TIME WELL INVESTED

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ABSTRACT

Many recent reform recommendations on science teaching have emphasized the need for incorporation of scientific inquiry as a routine part of science instruction. Inquiry is a difficult skill to master for both the science teacher and the science student. Many science teachers, new to teaching by inquiry, are disappointed in their students' abilities to design and carry out sound experiments. Often, they abandon teaching by inquiry for that reason. This chapter is a report of a qualitative study of the skills displayed by a group of graduate students [n=10] in Science Education, all of whom were preservice teachers, as they engaged in long-term inquiry activities with living organisms. The participants' initial experimental designs were dismal, lacking in the essential features associated with quality scientific inquiry. With the passage of time and with mentoring by course instructors, the students became adept at designing and carrying out sound scientific inquiries. We argue that development of inquiry skills, in particular the ability to design and carry out a sound scientific experiment, is a skill that must be developed over time. If time is invested in such an endeavor, the results are often very rewarding. We hope that the information presented in this chapter will help science teachers and science educators realize that time invested in well thought out inquiry activities will help their students to master critical science skills.

INTRODUCTION

In 1859, the British philosopher Herbert Spence characterized science instruction as the passing of "dead facts" to students and noted that there was little to no emphasis on how science may be pertinent to one's daily life (Hurd, 1998). Calls to reform in science instruction have continued at all levels of education. Two major science education reform documents appeared in the 1990s: *Science for All Americans* (AAAS, 1990) and the *National*

Science Education Standards (NRC, 1996). They continue to influence the discussion of how science should best be taught.

Central to modern science education reform recommendations is the declaration that students should be occupied with the same types of activities as professional scientists. Reformists contend there is need for widespread use of inquiry in science classrooms (AAAS, 1990; NSTA, 1996; NRC, 2000). Inquiry based instruction should epitomize the scientist's world (AAAS, 1990; Roth, McGinn and Bowen, 1998). Several types of inquiry are recognized, all of which share basic themes. Those that mimic the work of a professional scientist nearly or identically are known as authentic science or open inquiry (Roth, 1995; Colburn, 2000). During these activities, students derive their own scientific questions for research. They decide their own methods while working within their classroom and/or the larger scientific community, as they come to understand science through their on-going work. These activities differ vastly, in practice and in philosophy, from what some have taken to calling cookbook science in which students follow a set of pre-written instructions and have little to no understanding of the predetermined conclusion (Roth, 1995). It is of note that the cookbook method falls short for science instructors and their students.

Teachers who practice cookbook science often oversimplify lessons and leave out process skills of science altogether. Students tend to misrepresent results in an effort to comply with an expected answer. They do not think and act like a scientist (Fairbrother, Hackling and Cowan, 1997; NRC, 2000; Martin-Hansen, 2002; Barrow, 2006). Teachers cite these habits as points of frustration as they try to implement inquiry in their classrooms (Byers and Fitzgerald, 2002; Dunkhase, 2003).

When inquiry is used in science classrooms, teachers may have a content goal in mind for an inquiry to address. Some inquires are of a shorter duration than is typical in open inquiry. Teachers may provide students with a question or hypothesis for testing. Activities such as these, provided they still allow for some measure of authenticity of process skills, are often called guided inquiry or structured inquiry (Colburn, 2000; Zachos, et al., 2000). In a variation dubbed coupled inquiry students engage in an open-ended experiment after completion of a guided inquiry activity (Dunkhase, 2003). Whatever the form of inquiry, students carry out the same sorts of authentic activities in which a professional scientist may engage.

Inquiry is not common as a method of instruction. Many teachers have resistance regarding its implementation (Eiriksson, 1997; Melear, et al., 2000). One of the objections raised is that inquiry activities require a great deal of time. We hear this alarm repeatedly. Science teachers are often concerned that other aspects of the curriculum may remain unattended if inquiry activities are heavily pursued (Byers and Fitzgerald, 2002; Dunkhase, 2003).

BACKGROUND OF STUDY

The study reported in this chapter tracks a group of science education graduate students who were enrolled in a semester-long course that emphasized learning through inquiry. All participants provided informed consent at the onset of the study. The quality of the experiments the students designed and carried out was monitored. The participants (n=10)

were preservice teachers, enrolled in a public university in the Southeastern United States. All were seeking licensure in some field of science, mostly biology. They ranged in age from 21 to 43 years. They came to the course, *Knowing and Teaching Science: Just Do It*, with impressive amounts of coursework in the sciences. They had completed courses in microbiology, physics, ecology, biology, chemistry, botany and zoology. Many had a bachelor level degree in biology. In *Just Do It*, participants spent most of their time pursuing inquiry-based activities on living organisms. For about the first two-thirds of the course, they experimented with C-Fern®, a cultivated variety of *Ceratopterius richardii*, an easily grown tropical fern (Hickok, et al., 1998). For the remainder of the semester, students experimented with an organism they selected from a list that included annual rye (*Lolium multiflorum*), sunflower (*Helianthus*), wheat (*Triticum*) and other plants. The course was taught by two professors, a genetics professor and a science education professor (the second author) and two doctoral students, one of which was the first author. Additional details of the course are available (Melear, et al., 2000; Lunsford, 2002/2003; Lunsford, Melear and Hickok, 2005).

In our research, we focused primarily on two questions. (1) Will the quality of student generated inquiry-based experiments improve over time? (2) What factors do the research participants attribute to any change in the quality of their experiments observed over time?

METHODS

Qualitative research is ideal for making sense of human interactions. Participants are valued not merely for being there, but also for the insight they provide (Patton, 1990; Peshkin, 2000). With that in mind, the authors selected two qualitative methodologies. These were participant observation and the long interview. Participant observation involves a researcher placing himself within the group to be studied, not merely as one who watches what is going on but also as a partaker in the events (Denzin, 1988). The researcher may revise questions and methods as the story unfolds. She may participate wholly or marginally with the group (Jorgensen, 1989). Any number of data-gathering techniques may be used; a common one is interviewing the participants. McCracken (1988) detailed the long interview protocol. A list of questions and prompts, known as a discussion guide, is often used to steer the conversation. However, participants may discuss anything they wish during the interview. The exchange should be recorded and verbatim transcripts made. It is common for researchers to conduct follow-up interviews, as they look for universal themes among the participants' responses, to help to verify research conclusions (Patton, 1990; McCracken, 1988).

Participant observation also makes use of many data sources (Denzin, 1988). This is known as triangulation and represents a primary means by which qualitative researchers establish validity of their research. The authors' data came from four sources, described below.

LONG INTERVIEWS

Three interviews were held with the participants. A pre-class interview was completed during the first meeting of the participants. A post-class interview, on the last day, was

followed approximately two months later by a concluding interview with six of the ten participants. Others were unavailable. The topic of this interview was emerging themes and conclusions.

STUDENT REFLECTIVE JOURNALS

As part of their course evaluation, participants were required to maintain a reflective journal about experiences in class. They kept computerized copies of their journals and forwarded them to the researchers at the end of the course.

STUDENT LABORATORY INSCRIPTION NOTEBOOKS

In another notebook, students were required to keep copies of all records they made while engaged in inquiry. Such entries are known as inscriptions. They may take the form of narrative statements, tallies, diagrams, graphs or other records of scientific work and thinking (Roth, et al., 1998). Carbon backing between pages allowed a complete copy of the notebooks to be prepared as the students worked. These copies were delivered to the authors at the end of the study.

AUTHORS' NOTES AND REFLECTIVE JOURNALS

Personal notes were maintained in private journals kept throughout the research process. They provided data about the students, the course activities, unfolding research hypotheses and conclusions, as well as emerging methodologies of the researchers.

RESULTS

Course Activities

Students were given 10 milligram samples of C-Fern® spores during the first class meeting. The genetics professor gave minimal instructions and challenged students to refrain from doing literature review about *C. richardii*. He called for students to design experiments to find out more about the organism. On their own, the students formed four work groups. They pursued experiments within their groups, as well as some individual experiments. Most had to do with the life cycle of C-Fern®. It is of note that students were required to write research papers and prepare verbal summaries of their best experiments. The work with C-Fern® is summarized below.

1. Susan, Sara and Basma (all names are pseudonyms) were interested in the effects of freezing temperatures on *C. richardii* spore germination. In addition to other

experiments, they worked with variations of ratios of gametophytes produced in differing spore densities as well as migration of male gametes during fertilization.
2. Alice and Veronica were mostly interested in whether differing densities of spores in a culture would alter the growth rate or form of C-Fern®. Like the above group, they also completed other experiments.
3. Phillip, Richard and Greg considered effects of light exposure of the plant's growth habits and rate. These students also sought explanations for contamination of their C-Fern® cultures with mold. Other experiments were also pursued by this group.
4. Morgan and Ralph were mostly interested in how C-Fern® would respond to culture media of varying salt content. They became so focused on the topic the professor provided them with spores from a salt-tolerant mutant. On their own, and based on data from their inquiry, this group concluded the variety was salt tolerant.

Students completed the remainder of the course under the guidance of the science education professor. They began experimenting with other plants at this time, with the goal of designing an inquiry-based lesson suitable for students in grades seven through 12. Lessons were presented orally in class. The experiments are summarized below.

1. Basma, Sara and Richard used *Helianthus* as their research organism. They did one experiment on the effects of extreme temperatures on germination. In a second inquiry, the students positioned the apex of the seeds in different orientations and compared germination times.
2. Morgan and Ralph persisted with the theme of salt tolerance in plants but shifted to *L. multiflorum* and *Triticum.* They watered groups of both plants with solutions of varying concentrations of sodium chloride.
3. Susan, Phillip and Greg centered their work on the topic of acid rain. They grew mustard plants (family Brassicaceae) with sulfuric acid solutions of varying pH levels and tracked the plants' growth.
4. Veronica and Alice watered seedlings of *L. multiflorum* with varying concentrations of urea solutions. They studied variations in growth of roots and aerial plant structures.

HOW EXPERIMENTS WERE EVALUATED

The authors' research design was modified early in the process. The original plan was to ask the students to verbally describe an experimental design during the pre-class and post-class interviews. The students did fairly well with these questions during the pre-class interview. Some students verbally described sound experiments, but often with small sample sizes. Only one student failed to mention or imply the need for an experimental control. One participant, Ralph, seemed to be a bit puzzled by the authors asking such elementary questions to a graduate student who held a degree in science.

> Interviewer: I am going to show you some seeds from a popular decorative plant. How would you design an experiment to determine whether natural light or

> artificial light would cause a better growth rate of these plants?
>
> Ralph: Oh, you certainly don't want me to go through things like…Do you want everything from the same soil, same moisture and so forth? Are you going to put one under UV light?

A second student, Basma, appeared puzzled as well, but in a different way. She laughed about trying to remember a concept she studied as a child.

> Interviewer: What is the scientific method?
>
> Basma: Ooh (laughter). Those were the ones we did…like in elementary school? And in middle school there were seven… which I can not remember off the top of my head.

Basma went on to articulate a reasonable experimental design that could address the natural versus artificial light question. However, as Basma and her classmates started work on their actual experiments, a startling pattern emerged. There was a massive discrepancy between what the participants said they new about experimental design and how they actually set up and carried out their experiments. Therefore the authors decided to shift their analysis from verbal descriptions to the participants' actual performance.

REVIEW OF POSITIVISM

Most scientists operate within a positivist/neo positivist framework. A goal of this school of thought is to discover or verify reality by means of controlled experiments (Guba, 1995). Experiments completed by the participants were evaluated within this framework. There are, of course, no rigid rules about sample size and statistical tests. It is largely a matter of consensus of opinion and the presentation of sound scientific arguments. A good experiment should have a specific, well stated question and a hypothesis that may be empirically tested. A control group should be included for comparison. The larger the sample size, the better. Experiments should be repeated; controls and experimental groups replicated, and conclusions must be based on outcomes. For our purposes, the experiment should yield useful results such as being the basis for a student-made research paper or verbal presentation, or serving as the basis for a new experiment.

STUDENT PERFORMANCE OVER TIME

Regarding our first research question, we compared three experiments in which each participant was involved. The first experiment is defined as the earliest entry in the laboratory notebook which the participants explicitly referred to as an experiment or investigation. The

second experiment is the set of entries immediately following. The final experiment is the last one recorded in the laboratory notebook. In considering evidence from the groups, the reader should note that at about week ten of the course, two groups mutually agreed to change one member each.

Alice and Veronica

These students began an "experiment" with at least seven explicitly stated research questions. Some questions were very open-ended and problematic in the sense that they could not have been used to directly lead to experimentation. The students lacked any control group for comparison and the experiment(s) was/were ultimately abandoned. The second experiment was more promising with one clearly stated question, a replicated control and 18 experimental replicates. The two students used the results from this experiment to expand into a third experiment, not discussed here. The final experiment improved even more and was used as the basis for the inquiry lesson. Table 1 compares the features of the three experiments.

Table 1. Comparison of Alice and Veronica's Experiments

Experiment	Question	Control	Operational Definitions	Sample Size and Replicates	Conclusions
First	7 stated, some very open ended	None stated or implied	None stated	8 plates with many organisms, but no groups or separate treatments	None stated or implied
Second	1 clearly stated	Present and replicated twice	Clearly defined "growth form"	20 plates total with 18 experimental replicates and two control replicates	Reported differences based on comparison of experimental and control groups
Final	1 clearly stated	Present and replicated nine times	Clearly defined "growth" and "measure"	69 plants total, 10 in each of 6 experimental groups with 9 control replicates	Reported differences based on comparison of experimental groups with each other and with control groups

Ralph and Morgan

These students began an "experiment" with no explicitly stated research question and no control. This experiment was quickly abandoned. Two subsequent experiments improved dramatically. The participants correctly identified a second unknown genetic variant of C-Fern® as being salt tolerant during their second experiment. The third experiment was used as the basis for the students' inquiry lesson and involved salt tolerance in *Triticum* and *L. multiflorum*. The comparison between the three experiments is summarized in Table 2.

Table 2. Comparison of Ralph and Morgan's Experiments

Experiment	Question	Control	Operational Definitions	Sample Size and Replicates	Conclusions
First	None explicitly stated	None stated or implied	None stated	5 plates with many organisms, but no separate treatments	None stated or implied, did record drawings of organisms
Second	1 clearly stated	Present and replicated three times	Clearly defined "growth" and "region measured"	12 plates total with multiple organisms in each plate, 3 plates in each of 3 experimental groups with 1 control per group	Reported differences based on comparison of experimental groups with each other and with control groups
Final	1 clearly stated	Present and replicated ten times	Clearly defined "growth" and "region measured"	40 pots total with 10 plants per pot, 3 experimental groups and 1 control group	Reported differences based on comparison of experimental groups with each other and with control groups

Basma, Sara and Susan

These students eventually swapped a group member with Phillip, Greg and Richard. The first experiment completed by Basma, Sara and Susan had a control but no explicitly stated research question. They had two replicates of each of three groups and eventually abandoned this experiment. In the second experiment, they had a clearly stated question and increased their replication to three times. The experiment showed clear results. Basma, Sara and Richard joined to complete the final experiment. They reported to the authors that they had to "make do" with a smaller sample size than preferred due to time constraints and problems encountered growing plants for use in the experiment. They used the experiment as a basis for their inquiry lesson and identified water as being a variable they neglected to adequately control. These experiments are summarized in Table 3.

Table 3. Comparison of Basma, Sara and Susan's Experiments

Experiment	Question	Control	Operational Definitions	Sample Size and Replicates	Conclusions
First	None explicitly stated	Present	None stated	6 plates with many organisms, 2 plates in each of 3 groups	None stated or implied, did record drawings of organisms
Second	1 clearly stated	Present	Clearly defined "germination "	6 plates with many organisms in each, three plates in each of two groups	Reported differences based on comparison of experimental groups with control group
Final [1]	1 clearly stated	Present and replicated 5 times	Clearly defined "growth, " "hot and cold" and "region measured"	15 plants total, 5 in each experimental group and 5 in control group	Reported differences based on comparison of experimental groups with each other and with control group

[1] Note: Susan left the group and Richard joined by this time.

Phillip, Greg and Richard

These students eventually swapped a group member with Basma, Sara and Susan. The first experiment completed by Phillip, Greg and Richard had a research question that was problematic because it was too open ended and did not lead to a testable hypothesis. They did not have a control. These students reported the experiment as "inconclusive" but did state that they wanted to replicate the experiment with better control. They made no further attempt. The second experiment had a more scientifically sound research question but still no control. They used the results as the basis for further experimentation, not described herein. Susan joined Phillip and Greg for the final experiment. A control was present and replicated four times. They used the experiment as the basis for their inquiry lesson. Table 4 shows a summary.

Table 4. Comparison of Phillip, Greg and Richard's Experiments

Experiment	Question	Control	Operational Definitions	Sample Size and Replicates	Conclusions
First	1 stated but too open ended for a testable hypothesis	None	Clearly defined "contaminate "	5 plates with many organisms in each, each plate with a different treatment	None stated or implied, did record their wish to replicate the experiment with better control
Second	1 clearly stated	None	Clearly defined "growth form"	6 plates with 10 spores each	Reported percentages and ratios of two different growth forms
Final [2]	1 clearly stated	Present and replicated 4 times	Clearly defined "germination, " "pH" and "region measured"	16 plants total, 4 in each of 3 experimental groups and 4 control replicates	Reported differences based on comparison of experimental groups with each other and with control group

[2] Note: Richard left the group and Susan joined by this time.

Participants' Reports on Performance

At the end of this study, students were asked to identify factors they believed contributed to the improvement shown in their experiments. It is a generally accepted notion that practicing most any task fosters competence. However, participants had things to say regarding this issue that suggest an additional level of complexity. Figure 1 provides a summary of the common themes brought out by the participants. Specific comments shown below were extracted from interviews and journals.

> Susan: For some reason students get in the mode of wanting to know the right answers. I think they get away from asking questions and being curious. That's just the way school is. So that drives the good student away from questioning. So once we got in that mode of asking questions it became a little easier.
>
> Sara: It got easier because we were getting into that frame of mind. I think inquiry, open inquiry, is almost an acquired taste. Because I think you kind of have to train your mind to think that way. Even in my undergraduate labs we were given that cookie cutter lab and we went through it. We got the right answer and we left. So you have to train your mind.
>
> Greg: Well, you just start thinking about things and they build upon each other as time goes on. You start to wonder about other things.
>
> Richard: I think everybody's confidence has really improved. In the other courses that I've had…it's been a step by step procedure and the answer is already given to you if you look a page further in the lab manual. You know, and if you missed step one you have to start…back over or you're not gonna have the end result that is expected. I don't think that allows a student to think on his or her own. It is easy to see that we have become much more critical of the experiments we have discussed.
>
> Basma: Actually I think I have [the scientific method] straight now because of this course. And I know that you have to develop an experiment and have a control and a hypothesis because without those you really don't have an experiment.
>
> Morgan: I got a chance to do it hands-on, personally. It will be easier to remember next time. Maybe next time I won't have to have somebody looking over my shoulder to make sure I do everything right.
>
> Ralph: I don't think my viewpoint of the scientific method has changed. What might have changed though is the specifics and the methodology… becoming more focused and putting things together in some sort of logical order.

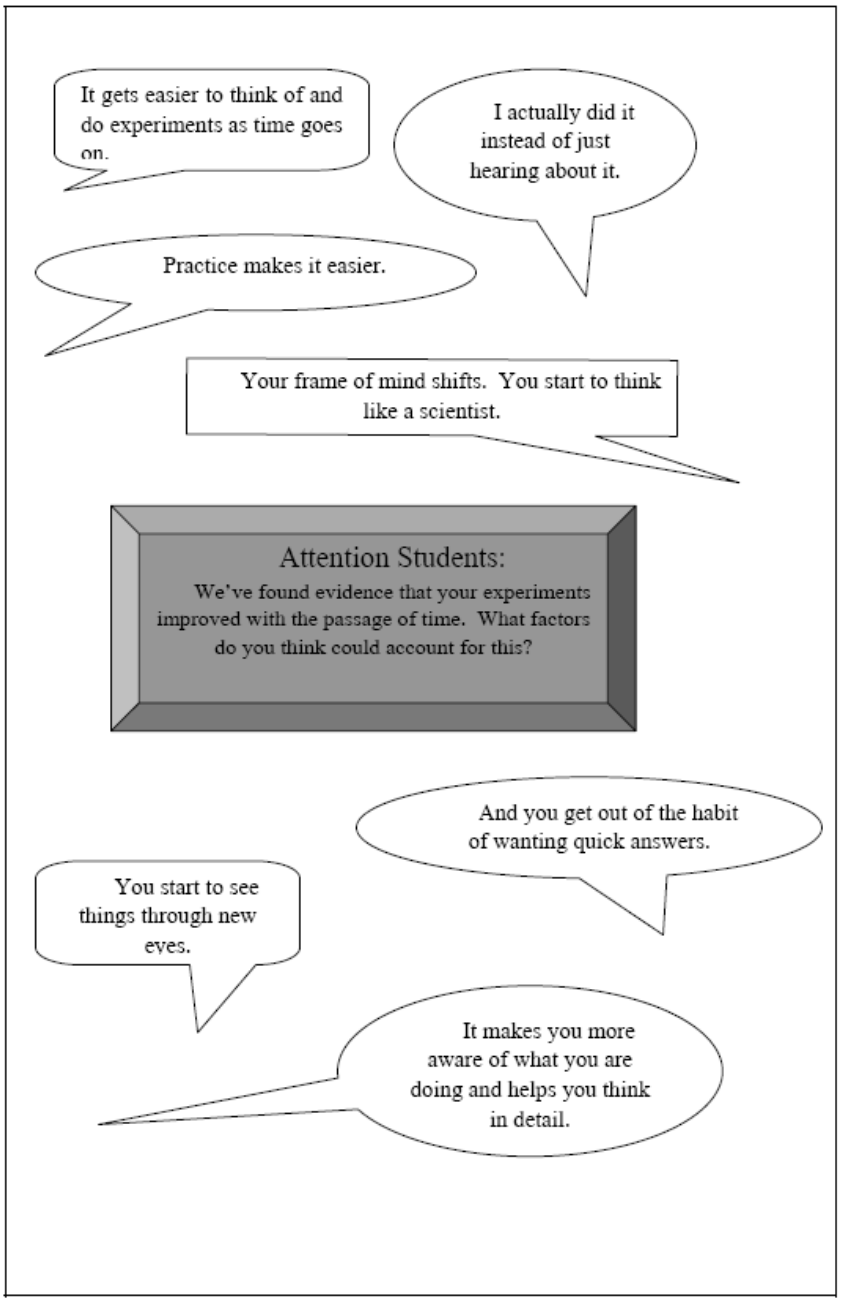

Figure 1. Summary of Participant Comments.

CONCLUSION

While we want to avoid putting too fine a point on the matter, critical is the fact that a group of students, most of whom held bachelor level degrees in biology, failed in their earliest attempts to design and carry out a simple experiment. They produced nothing close to

what could be regarded as valid scientific inquiry. Students in this study were able to verbalize a fairly well articulated notion of the scientific method and of an experiment but initially failed to demonstrate ability to apply this notion in an authentic context. Referring to Tables 1 through 4, one can see that none of the students had a clearly stated, testable question for their first experiments. Just one group had a control. No usable conclusions were generated from any of the initial inquiries. Our first question, whether the experiments would improve over time, was clearly answered in the affirmative. The results do not demonstrate immense perfection of scientific skills, but noteworthy improvements in all groups did occur. Participants became much more skillful in thinking of, designing and carrying out inquiries with the passage of time. Some experiments had a very sound design. All of this provides support of continuing calls for students at all levels of education to be exposed to scientific inquiry, to facilitate development of process skills (AAAS, 1990; NSTA, 1996; NRC, 2000).

Our findings imply that students came to *Just Do It* with little to no appreciation of what Enger and Yager (1998) called the Process and Nature of Science Domains of scientific learning. These aspects of science literacy focus on how scientists do their work and they evaluate their work and the work of their peers. Our study also suggests that concepts inherent in these domains were not embodied in the participants prior to their extended experiences with inquiry. The students spoke of how their inquiry tasks were different from previous science course work and how the experience helped them understand processes and skills involved in actual scientific practice. They used phrases like cookie cutter, cook book and recipe to describe their former laboratory experiences. Figure 1 supports the notion that the participants' frame of thinking shifted as their skills with inquiry increased. In short, actually working like a scientist (and with a scientist) helps one to become a better scientist. Students do not typically encounter inquiry-based tasks until they reach graduate school (Roth, 1995). Is it any wonder that teachers get frustrated, and become obsessed, with their students' shortcomings as they try to teach by inquiry?

Our data suggest that investing time in the classroom to improve inquiry skills, and therefore improve scientific process skills, will produce valuable returns. We encourage teachers, at all levels of education, to expand their use of inquiry rather than reduce it due to fears about poor student performance and time shortages. We are hopeful that inquiry will not become (or remain) merely a one-time exercise for students, but that it will emerge as a routine part of science instruction. In response to the issue of time, it should be noted that inquiry may serve to establish deep, meaningful understanding of various types of science content as well as process skills. By way of inquiry, students in *Just Do It* were exposed to a plethora of science content. Some topics in the list were not explicitly discussed in this paper. Examples of science content studied within the context of inquiry by our participants include (but were not limited to) graphing of data, life cycles of organisms, preparation of chemical solutions, use of the microscope, use of various measurement devices and other laboratory equipment, pH, genetic variation among organisms, mathematical calculations, writing and other forms of scientific communication, adaptations of organisms to their environment, alternation of generations in plants, chemical signals of living organisms and many other content topics. It appears, then, that inquiry may actually bank and streamline instructional time rather than inefficiently consume it.

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Chapter 10

INTENSIVE SECOND LANGUAGE INSTRUCTION FOR INTERNATIONAL TEACHING ASSISTANTS: HOW MUCH AND WHAT KIND IS EFFECTIVE?

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ABSTRACT

Second language instructional programs in academic settings take many forms in terms of length and intensity. Whether a program is intensive (four or more hours per day, five days per week) or conventional (one hour three or four days per week) may be determined by programmatic needs. Instructional formats may also be shaped by assumptions about the nature of the content being learned. A second language, for example, may be seen as a body of content to be mastered, rather than something requiring extensive opportunities for input, practice, and use. Learners may be seen as needing only to learn *about* language with the result that contact hours set aside for instruction are seen as reducible. Time on task needed for input, practice, and use of these features of language may be given short shrift. Empirical investigations are needed to learn how much instruction in terms of length and intensity is effective in developing second language learning. The current study explores this issue in the context of a three-week intensive English as a second language program for newly arrived international teaching assistants (ITAs) at a research university in the southwest U.S. The current six-hour-per-day, five-days-per-week late-summer program was intended to improve ITAs' pronunciation (word stress) and intelligibility (discourse competence), and classroom communication skills (compensation of communicative code using visuals, repetitions, etc.). Using a sample of $N = 18$ ITAs, a statistical model was developed to test whether a third week of intensive instruction in word stress, discourse competence, compensation skills, and an overall rating significantly and meaningfully improved ITAs' skills in those areas in a teaching simulation task. Results suggested that a third week of intensive instruction contributed to significantly and meaningfully higher scores in the four areas of ITAs' classroom communication.

Second language instructional programs in academic settings take many forms in terms of length and intensity (Kaufman and Brownworth, 2006). Whether a program is

intensive (five or more hours of language instruction per day) or more conventional (one hour five times a week or ninety minutes twice a week) may be determined by programmatic needs (availability of classroom space or funding, or length of time allowed by a given academic semester or term). Instructional formats may also be shaped by commonly held, perhaps undiscussed, assumptions about the nature of the content (language) being learned, and the place of that content in perception of student needs. A second language, for example, may be seen as a body of content to be mastered, rather than something requiring extensive opportunities for input, practice, and use. Learners with specialized needs, such as upper intermediate and advanced learners who must improve their pronunciation (word stress) and intelligibility (discourse competence) for professional purposes, may be seen as needing only to learn *about* pronunciation and intelligibility for future use, with the result that contact hours set aside for instruction are seen as reducible. Time on task needed for input, practice, and use of these features of language may be given short shrift. Empirical investigations are needed on how much instruction (with attendant practice and use opportunities) in terms of length and intensity is effective in developing second language learning as measured by current assessments of language use.

The current study explores this issue in the context of a three week intensive English as a second language program for newly arrived international teaching assistants (ITAs) at a U.S. university. ITAs are Chinese, Korean, Indian, etc. graduate students who will be supported as instructors in undergraduate physics, math, chemistry, etc. classes in their subject area, in their second language (English). The current six-hours-per-day, five-days-per-week late-summer program portrayed in this report is intended to improve ITAs' pronunciation (word stress) and intelligibility (discourse competence), and classroom communication skills (compensation of communicative code using visuals, repetitions, etc.) prior to the start of the fall academic semester. For programmatic reasons, a shorter, one- or two-week intensive program was suggested, which raised concern as to whether ITAs would improve as much as needed in the shorter suggested time frame. Fortunately, assessments of ITAs' performance were done throughout the workshop, which allowed investigation of their improvement at various points. The purpose of this report is to demonstrate the use of a statistical model which estimated 18 ITAs' improvement on a similar measure at two different points in the workshop (the 8th and the 16th days), and to discuss the results in light of the duration, intensity, and type of instruction and learner practice known to have taken place prior to each measurement. An additional purpose was to help those who run such intensive programs make reasoned efforts to maintain or increase the number of contact hours needed for second language improvement.

Applied linguistics is in many respects an interdisciplinary field, drawing from research traditions in psychology and education (in additional to theoretical linguistics). Thus the following literature review explores relevant research from these fields, particularly to forge connections between current (if unexamined) models of intensive ITA preparation programs and key related psychological and educational concepts such as duration (length) and intensity (frequency of instruction or practice). We see two other concepts, time on task and practice, as related to duration and intensity, in that time on task and practice refer to what happens in classrooms for particular amounts of time within a program (duration) and in spaced or massed conditions on a given day of classes (intensity).

EFFECTS OF DURATION AND INTENSITY ON LEARNING

In their review of the literature on the effect of duration and intensity on human learning, Dempster and Farris (1990) begin with an 1885 publication by Ebbinghaus and outline a list of continuous publications to the present. In particular, Dempster and Farris (1990) are interested in the spacing effect, which suggests that intervals of time between instruction and practice are more effective than instruction or practice which takes place all at one time. While the spacing effect will discussed at more length below, it is mentioned here because for Dempster and Farris (1990), it is simply assumed that learning takes time. Walberg (1988), in a synthesis of research on time and learning, concludes that key variables in learning are time (what we construe as duration in this paper) and what he calls "devoted effort" (what we believe to be practice). Often only "an extra hour or two per day may enable beginners to attain results far beyond unpracticed adults in many fields" (Walberg 1988, p. 77). Time is indeed required for learning.

DURATION AND INTENSITY DEFINED

For any given amount of material to be learned, instruction or practice can be characterized as having different intensities, sometimes referred to as massed or spaced (Dempster, 1989). A massed presentation can be defined as a single, continuous presentation of information, which could be presumed to have greater intensity. For example, if a vocabulary list is to be learned and one class study period of, say, 30 minutes, is given over to that purpose, a massed presentation would use the entire 30 minutes. A spaced presentation, on the other hand, would be the same amount of time, in this case 30 minutes, but with space in the form of time or intervening events between shorter presentations. A spaced presentation, in the example just given, might be three study sessions of 10 minutes each separated by time, and can be said to be less intense (yet more effective). The time between spaced presentations might be minutes, hours, days, or longer. The beneficial results of intervening time between study is called the spacing effect. Dempster and Farris (1990) define the spacing effect as the tendency for spaced presentations to achieve better results than massed presentations due to greater efforts on the parts of students to retrieve information repeatedly (and thus increasing linkages to long term memory).

In reality, few scholars in formal education settings specifically define duration as we have construed it here as a variable in their inquiries. Anastasi (2007), in discussing the duration of semester-long university courses in undergraduate psychology as compared to shorter summer courses, defined a regular long semester as being 16 weeks long, but does not specify the length (duration) of a summer course. Anastasi raises the issue of intensity by implication when he notes: "courses include the same number of contact hours with students and cover the same amount of information as a regular semester course," (p.19) (suggesting a massed condition) and then poses the question of whether more intensive summer courses are as conducive to student achievement. However, intensity, as we have construed it here, is not defined as a variable in any detail in many educational settings. Gorsuch, Stevens, and Brouillette (2003) in discussing an International Teaching Assistant (ITA) summer workshop, defined "short" (duration) as less than one month, and defined "intensive" as four or more

hours of instruction five days per week. However, no justification for these definitions were given. As will be seen below, there is an odd silence on the issue of intensity in that ITA preparation programs are often simply described as being a certain length (duration) with no description of the intensity and spacing of class meetings, presentation of information, or practice opportunities.

TIME ON TASK AND LEARNING

Fredrick and Walberg (1980) conducted a meta-analysis and found a modest but constant correlation between time on task and learning achievement. As we noted above, time on task has more to do with what happens in classrooms, as opposed to overall models of total course length, as in Fredrick and Walberg (1980, p. 190) who define time on task as "participation" and find that "about 20 percent of the variation of achievement or gain in individuals is accounted for by participation measures." Dempster (1989, p. 322) points out an important connection between spaced repetitions (practice) and time on task: "recall that distributed reviews and tests have been found to be more 'attention grabbing' than similar massed events…thus spaced repetitions are likely to promote student time-on-task, a highly valued classroom behavior."

Dempster (1989) further discusses time on task by emphasizing the time or space between periods of work on the task which he called the spacing effect. Specifically, "the spacing effect refers to the finding that for a given amount of study time, spaced presentations yield significantly better learning than do presentations that are massed more closely together in time" (p. 309). In other words, it is better to read two texts with space, say 48 hours, between them then, say a few minutes between readings. While the spacing effect is a thoroughly studied psychological phenomenon Dempster (1989) also noted that the findings of research on the spacing effect have not been applied by curriculum specialists to the classroom (see also Weigold, 2008).

INTENSITY AND PRACTICE IN HIGHER EDUCATION

Sprague and Nyquist (1991), teaching assistant (TA) development specialists working in higher education, describe three models of TA development: Development of competence, professional development, and teacher development. Their findings are that TA development has recognizable phases of development, and experience is required to move from one phase of development to another, but no comment is offered on how long this development takes, nor in what manner this experiential development should take place, nor on the role of TA practice opportunities.

Parrett (1987) reviewed 36 international teaching assistant (ITA) programs over a ten-year period from 1976 to 1986 and characterized them as pre-service workshops, in-service workshops, and combinations of the two. She found wide variation in reported duration and intensity but meager reporting on ITA practice opportunities within those programs. In terms of intensity, seven of the thirty-six programs reported pre-service workshops lasting from a few days to two weeks; 14 programs reported semester-long in-service workshops lasting

from one to three hours per week; and 15 programs reported combination pre-service workshops lasting from a few days to two weeks and courses lasting from one hour per week to three hours per week. In terms of practice, 10 programs did not provide ITA practice opportunities. Rather, they focused on dissemination of content. The remaining programs reported providing ITA practice opportunities on topics such as syllabuses, lesson plans, and textbook selection, but the type of practice given was not explained, whether ITA role-plays, demonstrations, or small group discussions. In addition, ten programs provided sessions in which they lectured on how to lecture, but none provided ITAs with practice giving lectures. Finally, nine programs included sessions in which they discussed using media and creating visuals, but again none provided ITAs with practice.

One report in higher education does recount consciously shifting instruction towards a model of spaced instruction and practice in response to constraints on course duration: Mitchell and de Jong (1994), working in engineering education, studied the effect of intensity in bridging courses with high school students coming to engineering school with varying degrees of academic preparation in chemistry and physics. The faculty concluded they needed bridging courses in which two years of chemistry and physics had to be covered in 13 weeks. To accommodate this accelerated course intensity, the faculty members consulted theories on learning and instruction and came to some conclusions which powered the design of their intensive courses, including most notably not having students take notes. Rather, students were provided with notes and class time was instead focused on 'thinking tasks' which required them to process the information. Another emphasis was that topics were broken into small sections which allowed the topics to be revisited, which sounds much like a recognition of the spacing effect (e.g., Dempster, 1989; Dempster and Farris, 1990). The authors noted that the majority of students wished to continue taking bridging classes while being very skeptical at the outset of the program.

THE EFFECT OF PRACTICE ON PERFORMANCE AND RETENTION

Ericsson, Krampe, and Tesch-Romer. (1993) countered the commonly held belief that high level performances can be accounted for by talent or innate qualities that are genetically transmitted. They noted that superior performances are "domain specific," meaning that an expert in one field is not necessarily an expert in another field. That is, a great musician shows no greater rates of learning, for example, how to type, than an average person. Rather, Ericsson et al's research with musicians suggested that exceptional performances are achieved through extended and deliberate practice which they defined not as repetition, but as structured activity with the explicit goal of improving performance. Practice opportunities have to be tests, or some variation of the task which "required effortful reorganization of the skill" (p. 365). We feel such research is key to understanding: 1) the importance of practice in learning complex skills, and 2) the reasons why so many lay people, and educators and administrators, do not necessarily account for practice opportunities in successfully learning a complex skill.

Dempster (1993) noted that U.S. schools have curricula that are expanding in size and coverage, and posited that several assumptions are being made including that more curriculum content is better than less content, that most students can learn quickly, and that

once a student has demonstrated learning, further practice is unnecessary. Dempster (1993) challenged these assumptions, and argued for less curriculum material studied in more depth. Key to this argument is the role of practice, which far from stifling creativity, actually helps students learn. He noted that when too much information is presented with insufficient practice, newly covered material interferes with already known information. The opposite can happen as well, where previously learned material interferes with material being currently learned. He argued that practice may reduce the effects of interference or result in better learning.

In a rare study on second language learning and practice, Bloom and Shuell (1981) explored the effects of massed and distributed practice on high school students studying French in regular classroom settings. Two groups were randomly assigned: A distributed practice group who learned 20 pairs of French/English words for ten minutes each on three days, and a massed practice group who learned 20 pairs of French/English words for three successive ten minute periods at the same time. On the initial post-test, students from the two groups remembered about the same number of words. But one week later on a delayed post-test, students who did distributed practice remembered five more words out of the twenty than did the massed practice student group. Bloom and Shuell (1981) suggested that students with distributed practice learned the same amount in the same amount of time as the students with massed practice, but dramatically increased the number of words remembered seven days later because they had more practice remembering. More practice remembering may account for increased memory. It may be that distributed practice allows more practice remembering.

Karpicke and Roediger (2007), working in psychology, investigated two phenomena which they refer to as the testing effect and spacing effect, both of which are thought to be central mechanisms in establishing links between practice and long term retention. While the spacing effect has been discussed above, Karpicke and Roediger added discussion on the testing effect, which is the use of tests to increase retention (similar to Ericsson, Krampe, and Tesch-Romer's (1993) assertion that task variation is necessary for effective practice). In a series of three experiments, they compared the effects of expanding retrieval in the form of tests (increasing the time between practice events) and equally spaced retrieval in the form of tests (equal time between practice events) and consistently found that although equally spaced test-based retrieval seems to be more effective, it was the first and subsequent tests that made the difference. Specifically, delaying the first test was key because the delay ensured that retrieval was from long term memory rather than short term memory. A second key characteristic was making the test difficult which ensured effort, which seems to establish memory pathways.

DURATION, INTENSITY, AND PRACTICE IN ITA AND TA EDUCATION

Here we examine the literature describing ITA and TA programs in higher education and how they characterize duration, intensity, and practice. This is important to establish assumptions held in the field, whether explicit or implicit, on the role of duration, intensity, and practice in the learning of teaching skills, and more importantly, developing the use of a second language to teach. Through this review, we might learn what motivates teacher

educators and administrators to make their ITA and TA courses as long as they do (duration), and in the style they do (intensity and provision of practice opportunities).

Smith (1994), an ITA educator, classified ITA programs as either pre-service or in-service. Pre-service are described as being a week or more in duration, and are cast as orientation programs, or semester courses. In-service programs are more rare because they occur while the ITA is teaching. Smith (1994) argued that both types of programs must provide adequate time to acquire the necessary language and teaching skills, but the time requirement (duration) is not defined or discussed. Referring to practice, Smith (1994) noted that the ITA field has gone beyond an early stage of curricular development and advocates more current methodologies for practice in the spoken language, listening comprehension, interactive classroom teaching techniques, and practice in language labs with native speaker partners, but in this seminal ITA article practice was not defined, nor were examples provided. In fact, it is relatively rare for TA and ITA program literature to describe all three categories; many programs describe one or even none of these categories. For example, Ford, Gappa, Wendorff and Wright (1991) described an ITA institute at the University of Nebraska in which duration, intensity, and practice were not discussed. Civikly and Muchisky (1991) described a program at the University of New Mexico in which ITAs met weekly for a semester and deal with topical issues such as cheating and giving directions, but it is not clear how language use practice was construed. Constantinides (1987) described a five day intensive program at the University of Wyoming, but did not describe what constitutes practice.

Duration in ITA programs seems to be construed as intensive, protracted, or short. Intensive programs are measured in weeks (Constantinides, 1987), protracted programs are measured in semesters (Hiiemae, Lambert, and Hayes, 1991), and short programs are measured in days or hours (Burkett and Dion, 1991). Of the six intensive programs reviewed here, two are one week in duration (Constantinides, 1987; Ross, 2006), three are two weeks long (Cotsonas, 2006; Hiiemae, et al,1991; Pineiro, 2006), and one (Gorsuch et al, 2003) is three weeks long. Most of these intensive courses are held in the month before the fall semester with some programs repeated in even more abbreviated form before the spring semester.

Protracted courses are by definition at least one semester in duration, and are conducted as a regular for credit courses (Gorsuch et al, 2003) or non-credit courses (Ross, 2006). They can be a single course (Burkett and Dion, 1991) or a series of separate courses (Ross, 2006) to assist ITAs on various problem areas. If a single course, it can meet one for just one semester (Burkett and Dion, 1991) or for two semesters (Benassi and Fernald, 1991).

Courses that are short in duration, measured in days (or hours) rather than weeks or semesters, are not commonly found in published reports. It may be that many schools have multiple, decentralized courses available to TAs. For example, Temple, Issac, Adams, Haughland, Engelstoft, and Garcia (2003) note that at their university there are a variety of courses for TA and ITAs: TA orientation sessions, credit bearing teacher training courses through a Teaching Center, an “Instructional Skills Workshop,” and seminars. In biology they saw the utility of having a two-hour workshop to introduce the department to incoming TAs and orientate them to anticipated teaching problems. In a similar way Wulff, Nyquist, and Abbott (1991) describe a half-day campus-wide TA orientation.

Intensity, the specification of how many hours per day are spent in instruction, or whether class instruction or practice opportunities is massed or spaced, is rarely reported. It seems

enough to state the number of days a program covers. Pineiro (2006) reports that in her ten-day program of 50 hours, 30 hours were given to instruction. Of the programs reviewed here, only one, Gorsuch et al (2003) specifically reports that her three-week intensive course met five days per week for seven hours per day.

Practice is what students are directed to do in order for them to learn. Of course, all language programs include practice, but few spend much time detailing what they actually do. For example, Ambrose (1991) has an implicit awareness of teaching as a skill requiring development over time, as the program at Carnegie Mellon University takes place with sessions throughout the three or four year teaching career of the TAs. Myers and Plakans (1991) and Ross (2006) both list practice as an integral part of their programs. For example, Ross (2006, p. 98) lists nine components of her workshop including two specifically aimed at practice, first-day-of-class practice and microteaching practice, but does not fully describe or give the time allotted to practice. Finally, Cotsonas (2006) and Gorsuch et al (2003) list practice sessions, show their location in the syllabus, and describe them somewhat. For example, Cotsonas (2006, p. 112) describes microteaching, a common type of practice in many ITA programs, in terms of videotaping and feedback sessions.

PURPOSE AND RESEARCH QUESTIONS

Given the lack of attention paid to duration, intensity, and practice in education in general and ITA development in particular at the programmatic level, we felt it was important to bring these issues to the fore. In order to do this, we decided to create a strong account of the duration of a specific ITA preparation program, and the intensity and role of instruction and practice within that program. We wished to juxtapose this account with a statistical model which estimated 18 ITAs' improvement on a similar measure at two different points in the workshop (the 8th and the 16th days), and to discuss the results in light of instruction and learner practice taking place in the program.

1. Overall, do ITAs improve on a performance test given on the 8th day (beginning of the second week) of a workshop to the performance test given on the 16th day (middle of the third week) of the workshop?
2. Do ITAs improve during the same time frame on specific performance test criteria which are explicitly related to instructional content of the workshop?

METHOD

Participants

Participants were eighteen international teaching assistant (ITA candidates) from China, Korea, India, and Turkey. Four were women, and fourteen were men. All were in their mid-20s, and had just arrived at the university for graduate study in chemistry, biology, math, and restaurant and hospitality studies.

Materials

Two areas of "Materials" are discussed here: The ITA Performance Test, and the ITA Workshop Timeline. The ITA Performance Test (Appendix A) has been under continuous development since 2000 (Gorsuch, 2006). The current version includes 12 criteria that ITAs are scored on while they give a 10-minute teaching simulation in which they must define a term or describe a process in their field, and field questions from undergraduate students and fellow ITAs in the audience. Two and sometimes three raters sit in the back to complete their ratings. The raters have at least an M.A. in TESOL or Applied Linguistics and have undergone rater training on the instrument using videotapes of teaching simulations from earlier workshop. The 12 criteria in the current ITA Performance Test are: *word stress, vowel clarity, consonant clarity, spoken grammar and usage, speech flow, discourse competence, handling of questions, examples,* and *detection and repair of communication breakdowns* under the heading Linguistic Skills; *compensation* and *eye contact* under the heading Classroom Communication Skills; and *overall*. Of these twelve, *word stress, discourse competence, compensation* and *overall* are of particular interest. Definitions and targets (standards) for the four criteria are given in Table 1 below:

Table 1. Criteria definitions and standards for the ITA Performance Test

Criteria	Definition	Standard Descriptor
word stress	The ability of an ITA to use higher pitch, louder volume, or longer vowel length on the appropriate syllable of key words in utterances (expectation, similar).	4: ITA makes a few errors, but comprehension is not impeded.
discourse competence	An ITA's ability to use classroom specific ments, etc. that express transition, sequence, etc. first, second, then, I have an announcement, an important concept is, to review, on a different topic, now I want to move on to, etc.	4: ITA uses basic discourse markers most of the time. Listeners are generally able to follow the ITA's line of thinking.
compensation	An ITA's ability to use strategies to underscore and supplement ITA's intended message; e.g., use of visual cues (black-board and OHP), verbal repetition, and recycling of key words, phrases, and sentences.	4: ITA uses basic compensation skills which generally enhance listener comprehension. ITA uses the blackboard, OHP, etc., when appropriate to use or introduce a term, and/orrepeats and recycles verbal cues adequately
overall	Would you want this candidate as your teacher?	4: ITA is generally comprehensible. ITA shows a general ability to communicate in the English language in classroom situations..

On all 12 criteria, including the four focused on above, the standard to which ITAs are held is "4" on a five-point scale. Thus, when raters award an ITA a "3" or "2" on criteria, their performance is below standard.

The ITA Summer Workshop Timeline can be found below in Table 2:

Table 2. ITA Summer Workshop Timeline

Day 1 M Oral interviews	Day 2 T Classroom observations; Language focus	Day 3 W Classroom communication; Language focus	Day 4 R Classroom communication; Language focus	Day 5 F Classroom communication; Language focus	Day 6 20.58 hours	Day 7
Day 8 M ITA Performance Test, Occasion 1 37.91 hours	Day 9 T SPEAK Test	Day 10 W ITA Performance Test and. feedback	Day 11 R Classroom communication; Language focus	Day 12 F Classroom communication; Language focus	Day 13 37.91 hours	Day 14
Day 15 M Classroom communication; Language focus	Day 16 T ITA Performance Test, Occasion 2 44.16 hours	Day 17 W Guest talk; ACT Tests	Day 18 R Workshop summary and evaluation	Day 19 F Decisions	Day 20 49.08 hours	Day 21

Each day is numbered. Note Occasion 1 of the ITA Performance Test on Day 8 (the beginning of the second week) and Occasion 2 on Day 16 (middle of the third week). Classes were held only on weekdays. At the end of each week of classes, the estimated number of hours of instruction are listed. Thus, by the end of the workshop (Day 20), ITAs had nearly 50 hours of instruction. By the time of Occasion 1 of the ITA Performance Test, ITAs had had 20.58 hours of instruction. For Occasion 2, they had had 44.16 hours of instruction. By "instruction" we mean not only direct instruction, which takes up relatively little class time, but also guided opportunities for practice in the form of pair- and small-group work, and whole class presentations and feedback. On Saturdays and Sundays, ITAs have more language practice opportunities in that they are roomed with a person in their field, yet who does not share their first language. Further, instructors noted informally that they had much contact with ITAs outside of class. One instructor reported spending up to three hours per week with ITAs, counseling them on their presentations, helping them open bank accounts, and otherwise communicating with them face-to-face.

A content analysis of the main types of classes, "language focus" and "classroom communication" was done by perusing a detailed schedule kept by the workshop director. The content analysis revealed that the bulk of "language focus" classes were taken up in activities designed to raise ITAs' awareness of word stress issues, and improve their performance in this all-important area. Gorsuch et al (2003) described the learning model of the language focus sessions which informs the current workshop: "each group would have moved three times [in one afternoon] and had three different sessions with different instructors all focusing on the same general content and skills domain" (p. 61). On a given day, one session might focus on word stress while working in the language lab for individual practice and private feedback, a second session would focus on word stress but would use a specialized text with video for visual and aural input, and a third session would focus on word stress as used to give presentations in a classroom (pp. 61-62).

The same content analysis revealed that "classroom communication" classes focused on improving ITAs' ability to use compensation strategies, such as writing key words on the board, and increasing their use of explicit discourse markers. Thus, it was surmised that ITAs would likely improve in those areas. Further, it was assumed that rater training for the ITA Performance Test would adequately ensure that the instrument (Appendix A) would be reflect

changes in ITAs' performances in those areas (*word stress, discourse competence, compensation*).

PROCEDURE

During the three-week workshop held last summer, two videotaped and rated performance assessments were administered, one on the eighth day of the workshop and the second videotaped presentation on the sixteenth day of the workshop. Two raters rated the eighteen ITAs' performances on all eleven criteria of the ITA Performance Test (see Materials section above) on the first occasion of the test, and the same raters rated the same ITAs on the second occasion of the test. While ITAs gave simulated teaching sessions on two different topics for the first and second videotaped assessments, they chose their own topics within their disciplines, and were counseled on selecting topics that were teachable in ten minutes, and which they were likely to have to teach to U.S. freshmen.

At the same time, the authors created a timeline of the workshop, and using a detailed schedule (see Table 2 above) calculated how much instruction, and on what areas (word stress, discourse competence, compensation), took place prior to each videotaped assessment. They confirmed their timeline and calculations through informal interviews with instructors. This step was important, in order to create a theoretical basis for the statistical model discussed below in the Analysis section.

ANALYSES

To check the reliability of the data used in the repeated measures ANOVA model, interrater reliability for the two raters A and B for both the first and second performance assessments were calculated on the four criteria of interest: word stress, discourse competence, compensation, and overall. See Table 3 below.

Table 3. Interrater Reliabilities

Interrater Reliabilities	Word Stress	Discourse Competence	Compensation	Overall
Pre-test				
Rater A and B	.85	.94	.75	.94
Post-test				
Rater A and B	.73	.72	.66	1.00

With the lowest level of agreement at $r = .66$, interrater reliability on all four criteria was sufficient to be used as variables in the repeated measures ANOVA model.

To answer RQs #1 and #2, two steps were taken. First, descriptive statistics for the 18 ITAs on the first occasion (8^{th} day test) and second occasion (16^{th} day test) for all four criteria were calculated. Second, a repeated measures ANOVA model was constructed. The

dependent variable was the average of the Rater A and Rater B's ratings on a one to five point scale. Since the scale was the same for the four criteria of interest on the ITA Performance Test, it could be treated as a single dependent variable. The model had two independent variables: *occasion* and *criteria*. The variable of occasion would show whether ITAs had improved on all criteria from the first videotaped presentation to the second videotaped presentation. The variable of criteria (*word stress, discourse competence, compensation,* and *overall* on the ITA Performance Test) would show whether there were differences, either on the pre-test, or on the post-test, in ITAs' performances on the four criteria. This would show whether, at either the time of the first videotaped presentation or the second videotaped presentation, ITAs' ratings on the criteria were different from each other. For example, is the ITAs' average rating on *word stress* better or worse than their average rating on *compensation*?

While this may not be seem important when viewing the first or second videotaped presentation ratings alone, it becomes important when considering whether ITAs' ratings change differentially over time from the first to the second videotaped presentation. If ITAs' ratings on *word stress* increase more over time than their ratings on *compensation* , and if it can be shown on the workshop timeline and content analysis that much instruction and many practice opportunities were given on *word stress,* it may show that *word stress* portions of the workshop influenced ITAs' development in that area of their language ability. This interaction effect planned on the *occasion* and *criteria* variables might suggest an empirical underscoring to the data (workshop timeline and content analysis) showing the duration and intensity of coverage and practice opportunities for specific areas of ITAs' communication abilities.

Finally, effect sizes were calculated. This would show the amount of variance in ITA candidates' improvement accounted for by the two variables of *occasion* and *criteria*. When these effect sizes are examined and interpreted in light of the number of hours and type of instruction known to have taken place at the time the data from the two videotaped presentations were collected, it may suggest (or not) that a partial *third* week of intensive instruction contributed to positive outcomes for the ITAs.

RESULTS

In terms of RQ #1, the descriptive statistics comparing the first and second occasions of the ITA Performance Test suggest that ITAs improved in the four areas of word stress, discourse competence, compensation, and overall. See Table 4 below.

On the first occasion of the test on the 8th day of the workshop, ITAs averaged a rating of 2.94 for *word stress* on a five point scale. By the time the test of the 16th day (second occasion) ITAs had improved on average to 3.5, an increase of over half a point. For *discourse competence*, ITAs improved from 3.53 on the first occasion to 3.89; and for *compensation*, ITAs improved from 3.39 for the first occasion to 3.83 on the second occasion. On the overall criteria, ITAs improved from 3.28 on the first occasion to 3.72 on the second occasion, an increase of nearly half a point on a five point scale. On all criteria taken together, the increases from the first to the second occasion were statistically significant ($F = 24.290$, $df = 1$, $p < .0001$). Effect size eta squared was .588, indicating that 58.8% of the variance seen in

the increases were due to the variable of *occasion*. In other words, simply the fact that the two measurements taken five class days apart accounts for much of the increase in ITAs' performance. This begs the question of what went on in the five class days of instruction and practice opportunities (and the two days off on weekends) that brought about the improvement.

Table 4. Descriptive Statistics for First and Second Occasion of the ITA Performance Test

Criteria	First Occasion (8th day of the workshop)		Second Occasion (16th day of the workshop	
	M	*SD*	*M*	*SD*
Word stress	2.94	.59	3.5	.45
Discourse competence	3.53	.72	3.89	.40
Compensation	3.39	.58	3.83	.42
Overall	3.28	.69	3.72	.46

In terms of RQ #2, the descriptive statistics given in Table 4 above suggest that ITAs' performances on the criteria on the first occasion of the ITA Performance Test were quite different. For example, ITAs got a mere 2.94 average rating on *word stress*, while they got a much higher $M = 3.53$ on *discourse competence*, a difference of .59 points on a five point scale. ITAs were apparently better at *discourse competence* aspects of their presentations, than they were with *word stress*. Mean scores for *compensation* (3.39) and *overall* (3.28) were also higher than the *word stress* rating. The same pattern follows with the second occasion of the ITA Performance Test with ITAs getting a mean score of 3.5 on *word stress* and then higher ratings on *discourse competence* (3.89), *compensation* (3.83), and *overall* (3.72). Even though ITAs improved on *word stress* from 2.94 on occasion one to 3.5 on occasion two, ITAs also improved on the other three criteria accordingly. Apparently, the instruction and practice opportunities afforded by the five day period between the first and second occasions benefited ITAs on all criteria: *word stress*, *discourse competence*, *compensation*, and *overall*. The ANOVA results underscored the findings from the descriptive statistics in Table 4. Differences in ITA means on the four criteria in the first and second occasions of the tests were statistically significant ($F = 11.351$, $df = 3$, $p < .0001$) with an eta squared effect size of .694. Interestingly, the interaction between *occasion* and *criteria* was not significant ($p = .753$), suggesting that ITAs' increases in performance on any one of the criteria was not disproportionate. In other words, ITAs did not improve more on any one of the criteria—they were simply better on some criteria than on others, and remained that way.

DISCUSSION

We were struck by the number of times that pragmatic issues such as cost and degree completion time, rather than robust theoretical understandings of human learning, were named in the literature as main considerations when determining the duration of TA and ITA

development programs. Constantinides (1987) stated that longer programs are necessary for ITAs to fully develop their abilities to teach in the second language but noted: "such a program is costly" (p. 278). Ambrose (1991, p. 159) noted that TA training "should not delay progress toward the [TA's] degree beyond normal time limits." Temple, Isaac, Adams, Haughland, Engelstoft, and Garcia (2003) noted that a two hour biology TA orientation was constrained by budget. At the university where this study took place, ITA complaints about having to be at the university four weeks before the start in classes in August (and unpaid until October 1 due to state funding legislation), initiated official inquiries into whether the current three-week workshop ought to be shortened.

At the very least, our results suggest that shortening the workshop is probably not the best remedy for what are pragmatic concerns, and would not be worth the potential loss of the robust learning and improvement that seems to take place in the current workshop. Looking at the overall results of first and second ITA Performance Tests given on the 8th and 16th days of the workshop alone suggests that three ITA candidates of the eighteen would not have been approved to teach if they had only been given the first test on the eighth day, whereas by the 18th day (and the second test), their skills were sufficient on a number of measures to be approved to teach. This may not seem like an astounding number, but considering the wide variety of spoken language levels at the outset of the workshop (with some of the eighteen ITAs getting "2s"--nearly nonfunctional levels--on the ITA Performance Test), all the ITAs came a long way (see also Table 4 above). We believe the workshop, with its current duration of three weeks, and intensive practice with repeated opportunities for improvement of crucial second language and classroom communication skills, should be continued. Certainly, our results support it, and so do theories on spaced learning, long-term memory retrieval, the role of practice in improving performance, and the importance of time on task in human learning. We believe the workshop design reflects these theories.

We believe that further research on intensive learning programs in higher education, whether for TAs, ITAs, or undergraduate psychology or engineering students, should be undertaken with a special focus on adequately documenting the types of information presentation and practice taking place. Mitchell and de Jong (1994) came close when documenting a redesign of their pre-engineering physics and chemistry courses in the face of constraints on duration. Note taking was reduced, and time on task on "thinking tasks" was increased, along with opportunities for students to revisit topics multiple times (p. 170). We suspect the norm in conventional higher education curricula is to promote a topical, one-off approach to content and to offer little in the way of review or practice opportunities in class. Perhaps practice is seen as something that students should attend to on their own time. Clearly, further research is needed.

CONCLUSION

In this report, we explored the effectiveness of an intensive three-week ITA preparation program through statistical means by focusing on repeated performance measures taken of ITA candidates on the 8th and 16th days of the workshop. We felt, however, that statistics alone were not enough and so documented the instruction and practice opportunities ITA candidates engaged in during the workshop. Our robust results led us to an exploration of

psychological and educational theories which might explain our findings. We found that despite years of research suggesting that longer amounts of instruction (duration), different types of intensity (spaced instruction over massed instruction), and repeated and meaningful practice were necessary for effective learning in many domains, these findings are largely ignored in ITA and TA education. We call for a larger role of these theories in informing ITA development program design.

APPENDIX A

ITA Performance Test V.6
Texas Tech University
ITA Name: _____ Date: _____

Rater: _____ Time: _____ Room#: _____

Linguistic Skills
1. word stress (*expectation, similar*)
Target: 4 ITA makes a few errors, but comprehension is not impeded.

1	2	3	4	5	Problematic field specific terms or expressions:
Low			*	High	

2. vowel clarity (a,e,i,o,u, diphthongs)
Target: 4 ITA makes a few errors, but comprehension is not impeded.

1	2	3	4	5	Problematic field specific terms or expressions:
Low			*	High	

3. consonant clarity (t, s, z, b, v, sh, th, zh, etc.)
Target: 4 ITA makes a few errors, but comprehension is not impeded.

1	2	3	4	5	Problematic field specific terms or expressions:
Low			*	High	

4. spoken grammar and usage
Target: 4 ITA makes a few errors, but comprehension is not impeded.

1	2	3	4	5	Problematic sentences, expressions, phrases:
Low			*	High	

5. speech flow
Target: 4 ITA seems to speak fairly easily. There are a few unnatural thought groupings and pauses, a few incomplete sentences/phrases, a few false starts, but comprehension is not impeded.

1	2	3	4	5	Specific problems:
Low			*	High	

Linguistic Skills (continued)
6. discourse competence (classroom specific language used in explanations, announcements, etc. that express transition, sequence, etc. *first, second, then, I have an announcement, an important concept is, to review, on a different topic, now I want to move on to,* etc.)
Target: 4 ITA uses basic discourse markers most of the time. Listeners are generally able to follow the ITA's line of thinking.

1	2	3	4	5	Specific problems:
Low			*	High	

7. handling of questions (use of language to negotiate questions and answers, and clarify question meaning)
Target: 4 ITA is generally able to respond to questions by acknowledging the question, confirming understanding by repeating or paraphrasing the question, asking for clarification where necessary, and confirming listener comprehension of the ITA's answer.

1	2	3	4	5	Specific problems:
Low			*	High	

8. examples (use of language to create effective examples to explain field specific concepts)
Target: 4 ITA makes adequate attempts to make content relevant to students by using examples, analogies, or stories that are relevant to students' experiences.

1	2	3	4	5	Specific problems:
Low			*	High	

9. detection and repair of communication breakdowns (use of language to detect listener non-comprehension, and use of clarification sequences to repair breakdowns in communication)
Target: 4 ITA demonstrates general awareness of listener comprehension using comprehension checks with adequate wait time, and other verbal strategies such as *You look like you have a question*, etc. ITA demonstrates, where appropriate, the basic ability to use clarification requests to repair communication breakdowns.

1	2	3	4	5	Specific problems:
Low			*	High	

Classroom Communication Skills

10. compensation (use of strategies to underscore and supplement ITA's intended message; e.g., use of visual cues (blackboard and OHP; verbal repetition and recycling of key words, phrases, and sentences)

Target: 4 ITA uses basic compensation skills which generally enhance listener comprehension. ITA uses the blackboard, OHP, etc., when appropriate to use or introduce a term, and/or repeats and recycles verbal cues adequately.

1	2	3	4	5	Specific problems:
Low			*	High	

11. eye contact (ITA maintains eye contact with a variety of listeners, faces listeners while explaining items written on the blackboard)

Target: 4 ITA maintains adequate eye contact, looking at a variety of listeners, in such a manner as to express openness and awareness of listeners. ITA faces listeners while explaining terms, illustrations, etc. on the blackboard.

1	2	3	4	5	Specific problems:
Low			*	High	

Overall

12. Overall, how comprehensible is the ITA? Would you want this candidate as a teacher?

*Target***:** 4 ITA is generally comprehensible. ITA shows a general ability to communicate in the English language in classroom situations.

1	2	3	4	5	Specific problems:
Low			*	High	

Additional Items

What helped or hindered your comprehension of the ITA's presentation? (i.e., use of humor, rate of speech too slow or too fast, voice volume, speech mannerisms, etc.)

Points that Helped *Points that Hindered*

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Chapter 11

HOW TO TEACH DYNAMIC THINKING WITH CONCEPT MAPS

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ABSTRACT

Concept Map (CMap) is a graphical knowledge representation system, which has received growing popularity as a teaching and evaluation tool. In CMaps knowledge is represented by linking concepts to one another and specifying the nature of their relationship on the link. A pair of concepts connected with a linking phrase is called proposition.

In general, knowledge is organized by relating different concepts to one another. We argue that there are two types of conceptual relationships: static and dynamic. The static relationship organizes knowledge by grouping similar items under the same concept and noting the belongingness of the concept to a more abstract construct as a super-ordinate or identifying its own sub-categories. For example, category "chair" is a part of a super-ordinate category "furniture" and may have sub-categories of "lawn chair" and "dining room chair." In addition, static meaningful relationships could be based on intersecting two constructs from different domains. For example, "design" and "chair" may be intersected by noting that "chair" requires "design." Organization of knowledge based on static relationships often results in hierarchical arrangement of concepts, which is very typical of most Concept Maps.

On the other hand, the dynamic relationships reflect how change in one concept affects another concept. The emphasis is on showing the functional interdependency between concepts. For example, "increase in the amount of gasoline consumption" results in "increase in the level of carbon dioxide in the environment." The dynamic relationships have played an important role in the advancement of physical sciences. For example, Newton invented calculus as a representation system for dynamic relationships. Similarly, we argue that Concept Maps need the capability for representing dynamic relationships.

However, CMap, in its traditional form, primarily encourages static thinking. In this chapter we, on one hand, bring attention to this tendency and, on the other hand, discuss

the strategies teachers can use to encourage dynamic thinking with Concept Maps. These strategies include:

- imposing a cyclic map structure instead of hierarchical arrangement of concepts,
- quantifying the root concept of the map instead of a static category, and
- reformulating the focus question of the map from "what" to "how."

We discuss theoretical issues and empirical evidence in support of the proposed strategies.

ABBREVIATIONS

Cq - Cyclic Quantified condition
Cn - Cyclic Non-quantified condition
CLq - Cross-Link Quantified condition
CLn - Cross-Link Non-quantified condition
Tq - Tree Quantified condition
Tn - Tree Non-quantified condition
HQ – "How" focus question condition
WQ - "What" focus question condition
-- - no significant difference (based on 0.01 significance level)

INTRODUCTION

Educators' aspiration to improve the quality of teaching and learning has led to a continuous search for new teaching and evaluation methods and new ways to engage students in the learning process. As a result, the use of tools and technology to represent and communicate knowledge has grown steadily in educational setting. One technology that has received significant academic and practitioner attention is the Concept Map (CMap), which allows representing and organizing domain-specific knowledge in graphical form. Joseph Novak and his colleagues developed Concept Maps in the early 1970s, while they were studying science concept learning in children (Novak and Gowin, 1984). Since then, CMaps have been used in elementary and higher education as a means of teaching new material, evaluating students' learning, and as self-study aids.

The CMap has constructivist epistemological underpinnings and it is rooted in D. Ausubel's (1968) theory of learning (Novak 1998), which emphasized the difference between meaningful and rote learning. Ausubel argued that meaningful learning builds one's cognitive structure, by assimilating new concepts into the learner's existing conceptual structure. Novak (1998) described concept mapping as a major methodological tool for implementing Ausubel's assimilation theory of meaningful learning. CMap's theoretical foundation in the learning theory makes it an attractive tool for educational setting. Utilizing the CMap in the classroom is seen as having a potential for facilitating meaningful learning and improving the quality of education.

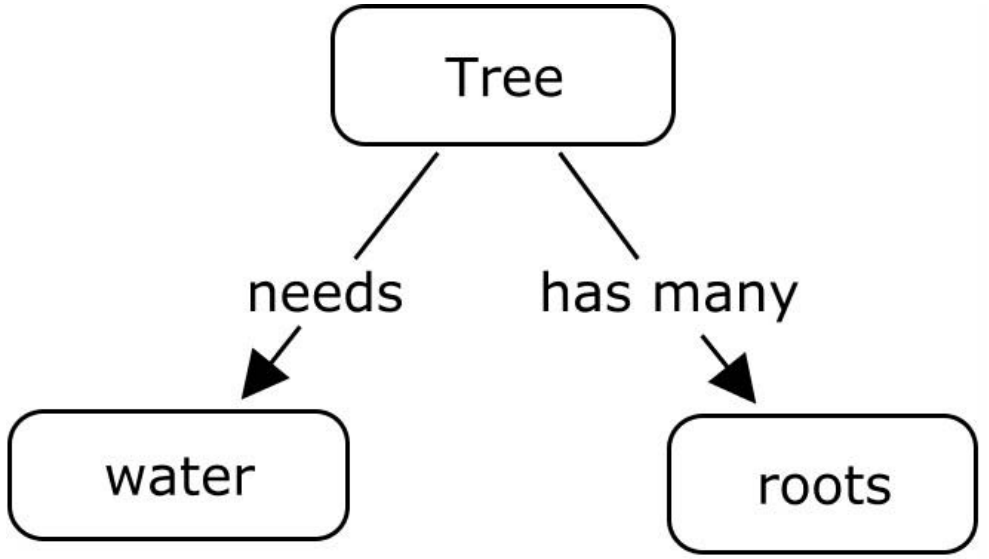


Figure 1. Example of a simple CMap.

What is a Concept Map?

A concept map is a graphical representation of an individual's knowledge of a given domain. CMap's graphical representation consists of a two-dimensional diagram where concepts written in boxes are connected to one another by arrows denoting relationships between them. A CMap can capture interrelationships among several concepts in a single map, and, thus, it can be an efficient way of representing complex knowledge. CMap representation has several characteristic properties: construction and representation of meaningful propositions, hierarchical organization, creative cross-links, and focus question, all of which are briefly discussed below.

CMaps are comprised of boxes connected with labeled arcs. Words or phrases that denote concepts are put inside the boxes, and relationships between concepts are specified on each arc using a linking phrase. Concepts are defined as "perceived regularities in events or objects, or records of events or objects, designated by a label" (Novak, 1998, p.21). For example, Figure 1 shows a simple example of a CMap representing knowledge about the concept "tree" with two links.

The concept of "tree" and the concept of "roots" are linked together by the linking phrase "has many," thus forming a proposition read as "(a) tree has many roots." Propositions in CMaps contain two or more concepts connected with a linking phrase, which are read in the direction of the arrow. Propositions form meaningful statements and are a unique feature of CMaps in comparison to other graphical knowledge representation schemes. Needless to say, the concept "tree" has many other properties, thus a CMap representing knowledge about trees may have many concepts and many linking phrases. Figure 2 shows a Concept Map about Concept Maps from Novak and Cañas (2006).

In CMaps, complex conceptual relationships are organized in a hierarchical fashion whereby general concepts are specified in terms of more detailed concepts. Novak (1998) highlighted the importance of hierarchical structure in concept mapping, which is based on the view of hierarchical organization of human knowledge. Based on this principle, CMaps should have more inclusive, general concepts at the top of the hierarchy with progressively reducing generality at the lower levels, which consist of less inclusive, more specific concepts. As a result, CMaps are often read from top to bottom. With such organization, novel relationships between concepts in different parts of the map could be identified, forming cross-links. Cross-links are a special case of propositions, and their identification is associated with creativity.

Each map is constructed to answer a specific question, called focus question, which provides context for the map in determining the meaning of the concepts and their hierarchical relationships. Focus question largely determines the selection of the concepts and relationships to be included in the map and allows keeping the map "focused" on the topic.

Several software packages have been developed to create CMap-like graphs. For a review and comparison, see Coffey et al. (2003). Some software packages like CMapTools (Cañas et al., 2004) provide not only a convenient user-friendly interface for creation and storage of CMaps, but also a collaborative environment for construction of CMaps by several users via the Internet (or a local network). The development of CMap software packages has contributed to rapid adoption of this tool in business, government and educational settings.

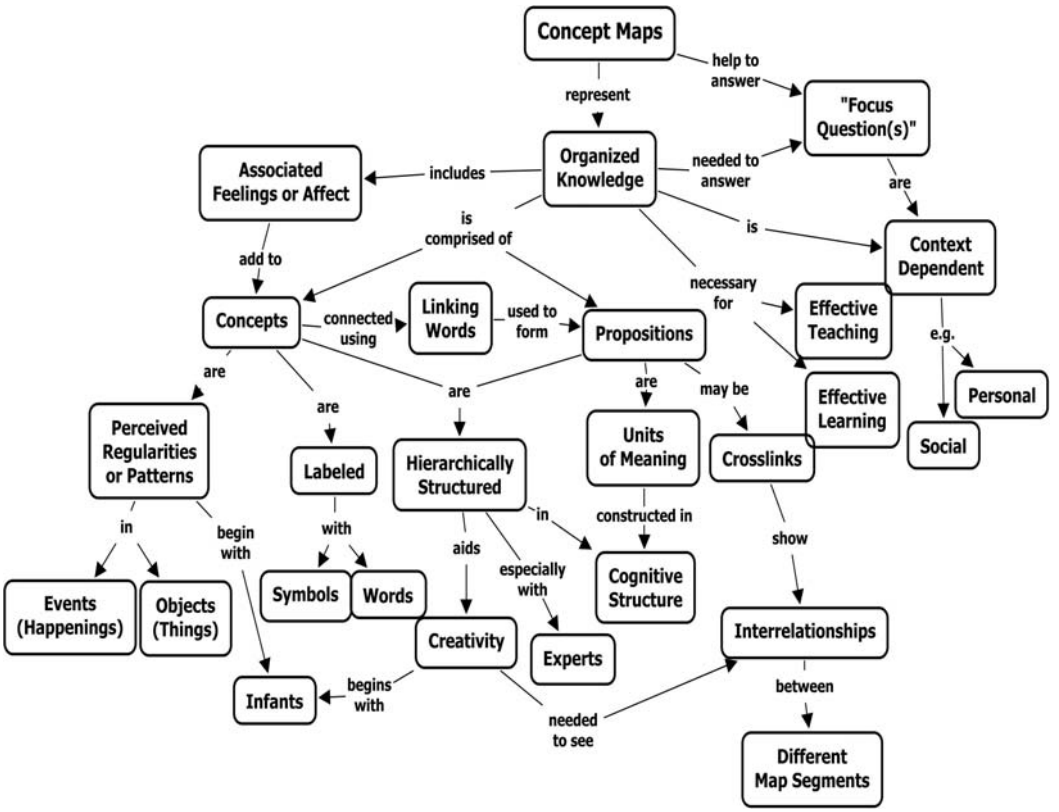


Figure 2. Concept Map about Concept Maps (Novak and Cañas, 2006).

CMap in Education

Although CMaps have been used in a variety of domains, the widest application of this tool remains in educational setting. CMaps have been used as a way of presenting new material and summarizing information at the end of a unit for students, as individual study tool, and for evaluating students' knowledge. There is a substantial body of research investigating CMaps' application in education. Several researchers have reported positive effects of the use of CMaps as knowledge organizers during the learning of new topics (Daley, 2004; Markow and Lonning, 1998; Edmondson, 1995). For example, Willerman and MacHarg (1991) reported significant increases in performance in a group of grade eight students that used CMaps while learning a science unit compared to a group that did not use CMaps. Anderson et al. (2000) used CMaps and an interview methodology to study the learning process by tracking changes in students' understanding of the scientific concept of magnetism. Soyibo (1995) used concept mapping to identify differences in the presentation of the topic of respiration in six different biology textbooks. Hall, Dansereau, and Skaggs (1992) reported a significant difference in the recall of material for a particular subject domain presented in the form of a CMap when compared to an ordinary text presentation. Lambiotte and Dansereau (1992) found a significant increase in recall of material for CMaps, compared to outlines or lists, when students had little prior knowledge of a topic. Markow and Lonning (1998) reported a strong positive attitude toward the use of CMaps among students in college chemistry laboratories; however no differences were found in performance on multiple choice assessment tests between the experimental and control groups.

Various researchers have examined the use of CMaps for the evaluation of student knowledge (e.g., Ali and Ismail, 2004, Roberts, 1999; Williams, 1998). Williams (1998) and Markham and Mintzes (1994) compared CMaps constructed by novices to those made by experts. Both studies reported significant differences in the CMaps of experts and novices. Markham and Mintzes (1994) argued that CMaps are able to capture differences in the knowledge and understanding of the subject matter, and that they can be used as a knowledge evaluation tool. Hoeft et al. (2003) described a software tool, TPL – KATS, that automates knowledge assessment demonstrated in CMap form. CMap form of knowledge representation extracts and emphasizes concepts and relationships between them. Conceptual relationships depicted in a CMap might not be as explicit in other forms of representation of the same topic, e.g. in a paragraph of text. This explicit graphical representation of conceptual relationships in CMap allows for an efficient identification of students' misconceptions.

Generally, there is agreement among researchers regarding the potential use of CMaps as an evaluation tool, particularly with respect to the use of CMaps to identify areas of students' misunderstanding (e.g., Kinchin, 2000; Roberts, 1999). However, some authors warn against the lack of reliability and validity in concept mapping techniques and scoring practices (e.g., Ruiz-Primo, 2004; Ruiz-Primo and Shavelson, 1996), suggesting more research is required before CMaps can be used for the formal assessment of student knowledge.

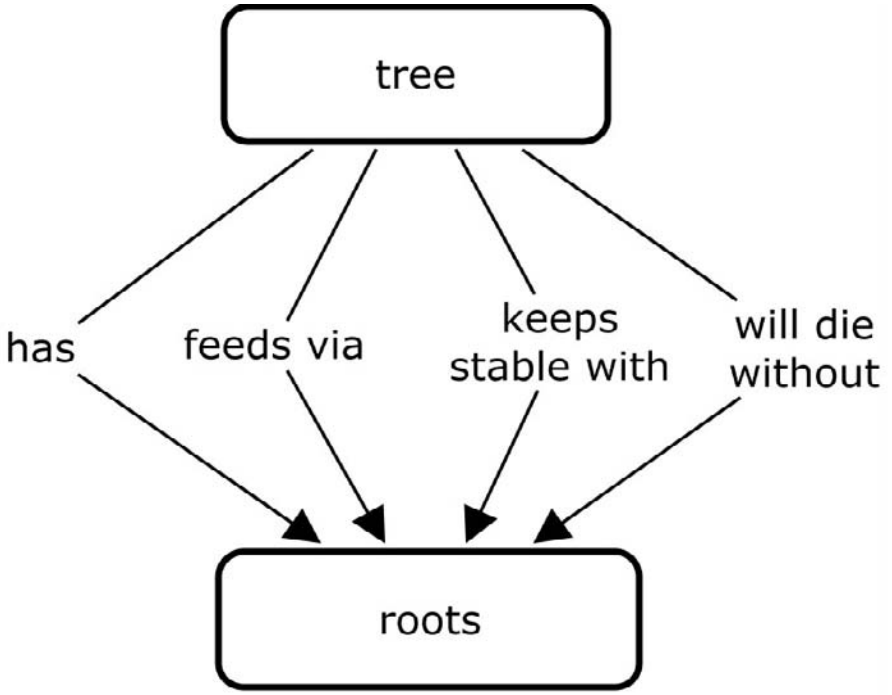


Figure 3. An example of possible relationships from the concept “tree” to the concept “roots”.

CONCEPTUAL RELATIONSHIPS

The unit of meaning in a CMap is a proposition, which consists of two concepts linked in a specified directional relationship. It is worth noting that a set of possible relationships between a given pair of concepts exists; however, typically, only one of them is represented in a CMap. For example, Figure 3 shows four possible relationships from the concept “tree” to the concept “roots,” and each of them denotes a somewhat different meaning.

Similarly, a set of relationships that connect the two concepts in the opposite direction (i.e. from the concept “roots” to the concept “tree,” e.g. “roots” - are a part of a → “tree”) could be identified as well increasing the possible set of relationships between the two concepts. Selection of a particular relationship and its direction for a map depends on the context and knowledge of the map creator. The context for a map is largely determined by a focus question that a map is supposed to answer and the purpose of the activity.

However, other concepts, already included in the map, their relationships, and the layout of the map also play a role in selection and representation of a particular relationship out of a set of possibilities.

Formulation of concepts and their relationships develops along with our understanding of a given domain. The development of knowledge changes both what is considered to be a meaningful concept in a given field and how that particular concept relates to other concepts. Development of knowledge begins with description of events and objects and forming classifications and categories. However, as science has progressed, it has moved away from the creation of hierarchies and categorizations, and toward establishing functional relationships among concepts (Lewin, 1935). Scientific concepts, which have contributed to

the advancement of knowledge, are based on an abstraction of what Lewin (1926) called the *genotype* properties. For example, as an abstraction, the concept of mass in physics is a property common to all things. To note this property means to ignore all *phenotype* properties including shape, size, colour, function, and so forth.

Safayeni et al. (2005) distinguished between two types of concept relationships, static and dynamic. The static relationship organizes knowledge by grouping similar items, specifying composition, belongingness, similarity, etc. The static relationships also provide description of objects and events based on their phenotype properties (Lewin, 935). The dynamic relationship is concerned with functional interdependency between the concepts, their interaction, and how change in one concept affects the other. We briefly discuss these two types of relationships below and for more elaborate discussion of these ideas the reader is referred to Safayeni et al. (2005).

STATIC RELATIONSHIPS

The static relationships between concepts help to describe, define, and organize knowledge for a given domain. These relationships are concerned with establishing and describing hierarchies, categorizations, and specify meaning The static relationships could denote

- *inclusion*, when one concept is part of another concept, e.g. cats are part of mammals;
- *common membership*, when both concepts belong to the same super-ordinate category, e.g. cats and dogs are related to each other because they both are mammals;
- *intersection*, when the meaning of a concept is generated by crossing two other concepts, which could be from different domains or related to each other through their membership in a super-ordinate category. The intersection of concepts could be based on similarity, e.g. *rectangles are like squares,* or *the soldier fought like a lion*; difference, e.g. *squares have one more side than triangles*; or the intersection could denote a subset of the two concepts, e.g. *life is about learning*, or *chair requires design*, which can also be probabilistic.

The inclusion and common membership types of relationships are fundamental to the construction of conceptual hierarchical structures (Jonassen, 2000). Intersection type of conceptual relationships is the basis for most communications and help disambiguating and specifying the intended meaning. The hierarchical organization of CMap makes it a natural form for the representation of classifications and hierarchies.

DYNAMIC RELATIONSHIPS

The dynamic relationship is concerned with the description of a system of influences among concepts. It shows how change in *quantity*, *quality*, or *state* in one concept causes change in *quantity, quality,* or *state* of the other concept. More specifically, for any two

concepts, the question is how the change in one concept affects the other concept. Two types of dynamic relationships are possible (Thagard, 1992); those based on causality (e.g., travel time is an inverse function of speed for a given distance), and those based on correlation/probability (e.g., academic performance in high school is a good predictor of academic performance in university).

Scientific knowledge is based on both static and dynamic relationships among concepts. However, progress in modern science is attributed to mathematical formulations of dynamic as opposed to static relationships among concepts. Whitehead (1967) noted "Classification is necessary. But unless you can progress from classification to mathematics, your reasoning will not take you very far" (p.28). He considered classification to be a "halfway house between concreteness of individual things and the complete abstraction of mathematics" (p.28).

Rapoport (1968) discussed the dynamics of causality expressed in mathematical equations in comparison to ordinary language in the following quote:

> The formal language of mathematical physics is literally infinitely richer than the 'vulgate' language of causality, because the equation which embodies a physical law (such as that of propagation of heat or electromagnetic waves, or the law of gravity) contains within it literally an infinity of 'if so … then so' statements, one for each choice of values substituted for the variables of the equation. (p. XIV)

Mathematical formulation of a relationship between concepts is possible only with great level of knowledge development in the field, when the concepts represent highly abstracted fundamental properties and their relationships are precisely defined. While mathematical formulation is the desirable form of expressing dynamic relationships, it is not always possible due to insufficient conceptual development in certain fields of knowledge. However establishing, formulating, and representing dynamic relationships is the fundamental goal of science.

CONCEPTUAL RELATIONSHIPS IN CMAP

Having its own characteristics and properties, CMap as any other tool has a tendency to influence how people use it and what and how knowledge become represented in this form. The influencing tendency of CMap toward a certain representation might be more fitting in some situations than others. It is worth examining what representation of conceptual relationships CMap encourages in its traditional form.

Safayeni et al. (2005) examined both the list of appropriate concept map linking terms from Jonassen (2000, p. 71) and a set of linking phrases from a collection of CMaps constructed by a variety of people and located in the Institute for Human and Machine Cognition Public CMaps servers (Cañas et al., 2003). In both sets, only a fraction of linking phrases were dynamic – less than 24% of the list of appropriate CMap linking phrases from Jonassen (2000) and less than 4% of the linking phrases used in the actual CMaps (Safayeni et al., 2005). The fact that some of the appropriate CMap linking terms might denote dynamic relationship indicates that it is possible to construct dynamic propositions in CMaps. However, their extremely low frequency in the actual CMaps suggests that although

theoretically possible, in practice CMaps are rarely used to represent dynamic relationships between concepts.

This lack of dynamic relationship representation in CMaps could be because there have been no functional relationships established in the domain of knowledge being represented (which is possible but highly unlikely) or the CMapper is not aware of them, or it could be because dynamic relationships happen to be omitted either intentionally or unintentionally. Scientific development and deep understanding of a subject matter cannot be achieved with static relationships only - both static and dynamic relationships are necessary. Thus, any comprehensive knowledge representation system needs to have a capability to represent not only static relationships but also allow expressing dynamic connections as well. It is worth investigating how dynamic representation in CMaps can be encouraged.

The selection of concepts and their relationships for inclusion in a map depends not only on the individual's knowledge and level of understanding, but also on the properties of the chosen representation system and context of the activity. During the process of map construction, such factors as the way the topic of the map is specified i.e. the formulation of a focus question, what structural form of a CMap is encouraged, and the starting point of map construction, i.e. the root concept; all have influence on the final outcome, the CMap. We argue that it is possible to manipulate these factors to encourage dynamic thinking and CMap representation of dynamic relationships. Below we discuss three strategies for encouraging representation of dynamic relationships in CMaps.

STRATEGIES FOR ENCOURAGING REPRESENTATION OF DYNAMIC RELATIONSHIPS IN CMAPS

Structure of the Map

We have argued that hierarchical structural organization encouraged in CMaps makes it a natural form for representing static relationships and hinders the representation of dynamic relationships (Safayeni et al. 2005). Thus, changing the structure of a CMap to better suit the requirements of dynamic relationships could potentially solve this problem. One such possibility could be to impose a structure where all concepts are a part of a single system and are highly interdependent, e.g. a cycle. Safayeni et al. (2005) proposed Cyclic Concept Maps (Cyclic CMaps) as an extension to traditional CMaps that would facilitate representation of dynamic thinking in concept mapping. In its simplest form, the Cyclic CMap has a cyclic structure where all concepts are connected in the form of a loop, each having one input and one output. In this structure, concepts are highly interdependent and a change in the state of any concept affects the states of all other concepts.

Cyclic relationships among concepts is the basis of cybernetics (Wiener, 1961), and systems thinking and modeling (Ashby, 1957; Beer, 1974; Forrester, 1961; Sterman, 2000). The approach has played a significant role in the modeling and understanding of organized complexities (Rapoport, 1968) in biological, electromechanical, and social systems (Beer, 1993). For example, the cyclic relationship between input, transfer function, output, and the difference between desired output and the actual output, which is fed back into the system for corrective purposes (negative feedback), can be applied to how a thermostat regulates room

temperature, or how specialized cells detect blood sugar level changes and release insulin to keep the output within a desirable range (steady state).

This line of thinking has also been applied in different areas of psychology. Human action has been modelled in cognitive psychology as a cycle of the *test - operate - test - exit* (TOTE) model (Miller, Galanter, and Pribram, 1960), and the *goals, operators, methods, and selection rules* (GOMS) model (Card, Moran, and Newell, 1983). Similarly, Katz and Khan (1978) developed their *role model* in social psychology as a system of communication between expectations, behaviour, and a feedback loop for modification of expectations. As another example, Safayeni et al. (1992) modelled computerized performance monitoring systems based on cyclic and dynamic relationships between concepts of behaving systems, information collecting systems, and information evaluating systems.

System dynamics has been used to model complex situations in industry, representing management's concepts and their dynamic interrelationships (Sterman, 2000). There is also the argument that system dynamics can be an effective representational tool in education (Forrester, 1995). The System Dynamics in Education Project (SDEP) was founded in 1990 at the Massachusetts Institute of Technology under the direction of Professor Jay W. Forrester, founder of system dynamics, with the primary focus of using and promoting system dynamics in education.

Cyclic CMaps could be a particularly useful tool for representing knowledge of functional or dynamic relationships between concepts in cyclic systems. Educators and researchers in the field of biology experience the need for cyclic representation as cycles are fundamental to all biological systems (Bertalanffy, 1972), however the appropriate strategies and tools for teaching these ideas are not always available to the educators (Buddingh, 1992) and students might experience difficulty with understanding these systems (Brinkman, 1992).

The structural interdependence of concepts in cyclic maps represents a system of interrelationships rather than a collection of independent propositions. Fundamentally, the relationships between concepts in Cyclic CMaps are dynamic in that each concept is influenced by the changes in the preceding concept, and contributes to changes in the subsequent concept. The structural interdependence in a cyclic map captures how a system of concepts works together and encourages dynamic thinking.

"Quantifying" the Root Concept

Starting point of map construction also has a significant influence over the content of the resulting map. Map construction begins with a focus question and a root concept, which is the top most concept in traditional CMaps and it is usually the starting point for reading the map. We discuss the role of a focus question in the next section, but first, we would like to draw your attention to the role of the root concept.

Hierarchical organization of CMaps requires root concept to be the most general concept in the map. As a result, the process of map construction begins with a fairly general as opposed to specific concept. Whether the concept is a category, i.e. represents a collection of objects, e.g. "trees" or "cars", or a fundamental property, e.g. "mass" or "speed," that points to an abstracted property, also determines the nature of propositions that could be constructed with this concept. We have argued that specifying concepts in CMaps to the level of their easily changeable properties makes dynamic thinking and representation easier.

Adding what we called “a quantifier” to a concept, e.g. “the number of trees” instead of “trees,” does not only specify the concept further, but also changes the meaning of the concepts from a general category, i.e. “trees,” to a property of that concepts that has an explicit changeable dimension, e.g. the quantity of trees. Thus, the next strategy of increasing the likelihood of thinking about dynamic interrelationships is by “quantifying” the concepts in a map.

By concept quantification we mean specifying the concept further by drawing attention to its specific changeable property, e.g. quantity, quality, rate of change, etc. Quantification of a root concept in a map makes the concept more dynamic, and could lead to construction of more dynamic propositions (Safayeni et al., 2005; Derbentseva et al., 2007). Quantification of a concept reduces the variability with respect to the possible set of meanings that the concept could potentially refer to, and at the same time draws attention to the specific property of the concept that can change.

Quantification of a concept makes reference to change much easier, because it selects a single dimension of change for the concept. For example, it might be fairly ambiguous to discuss change in the concept “soil” since there are many parameters of soil that could potentially change, and such discussion will require further specification. In the discussion of change in the concept “soil” one might want to emphasize the change in the “quantity of soil,” or the “quality of soil,” or the “color of soil,” etc. Consider, for instance, the dimension of “quantity of soil.” The quantifier “quantity” activates the dimension of the “amount” of soil measured by weight or volume, and this dimension can easily be changed.

Similarly, the dimension of “quality of soil” allows for variation on the dimension of “goodness” of soil, which can be measured by rating the composition of the soil. This sets the concept “in motion” and allows it to vary along the specified dimension. In other words, quantification of a concept makes the concept dynamic as opposed to a static category such as “soil.”

Beginning the process of map construction with a more dynamic concept, i.e. a quantified root concept, increases the likelihood of thinking about change in that concept and its causes and consequences. This might lead to including in a map other concepts that are interrelated in the propagation of the change. In other words, thinking about the change in the root concept is anticipated to stimulate dynamic thinking and raise ‘what-if’ questions that will affect the selection of other concepts for the map. These concepts most likely will be selected on the basis of the degree to which they affect, or are affected by, the change in the property of the quantified root concept.

The strategy of quantifying the root concept violates to a certain degree the hierarchical organization of CMaps. This is so because quantifying the root concept makes it much more specific, thus potentially disrupting the hierarchical organization. In fact, if only dynamic relationships are included in a map, the hierarchical organization of these concepts might even be impractical. It is worth noting that hierarchical organization of concepts in such conceptual systems as the laws of physics (e.g. F = m*a) will not be helpful in understanding their functional interrelationships.

Root concept quantification strategy might not only increase the likelihood of dynamic representation in a CMap, but also it might implicitly affect the structure and organization of concepts in the map.

Formulating the Focus Question

Another starting point of CMap construction is the focus question, which the CMap is supposed to answer (Novak, 1998; Novak and Gowin, 1984). The focus question is a vital piece of information for any given map because it explicitly defines the context and scope of the map and constrains selection of concepts and their relationships to be included in the map. Nevertheless, focus questions are often omitted and are not recorded anywhere in the CMaps.

When a focus question is not explicitly stated on the map, for the map reader it is not clear what the topic of the map is and whether it will be able to answer map reader's questions. On the other hand, for the map creator, the absence of the focus question might lead to going off topic, including unnecessary details and not including important relationships, and loosing the focus of the map and eventually answering a different question with their map than they initially might have intended.

The review of a collection of CMaps suggests that whenever the focus question is not explicitly stated on the map (which is often the case) most maps seem to answer a question of "What is [root concept]?" In such maps, the "topic" of the map becomes its root concept and the map describes and defines it. The question of "what something is" necessitates a description of that concept, which mainly consists of identifying the concept's components or parts (e.g., plant has roots, stem, leaves, may have flowers, etc.), and by specifying the categories to which the concept belongs (e.g., plant is a living organism, or bear is a mammal). Uses or functions of the concept can also be specified in the process of describing the concept (e.g., plants are used as food and medicine), which would also place the concept in more specific categories (e.g., plants are food and drugs). Such a description is most likely to be static, because it identifies what the concept is, but not how the concept may change. That is, it is unlikely to include functional interrelationships among the concepts when answering the question of "what something is."

Dynamic representation during CMap construction also can be encouraged by posing a focus question that prompts dynamic thinking and making this question explicit in the map for the map creator. For example, a process oriented question such as "What happens when the 'concept X' changes?" require one to think about change in the concept X and how it affects other concepts, thus making the representation of dynamic relationships more likely. Another example of a process oriented focus question could be the question "How does the 'concept X' work?" Providing an answer to this question requires one to think about change and interdependencies in the system of concepts that produce the output – concept X.

We argue that the focus question has a direct effect on the nature of the propositions that are represented in the map. However, it is not sufficient to only formulate the focus question that will lead to the desirable outcome. It is also necessary to make the focus question explicit during the CMap construction process and available to the map creator at all times during this process.

Thus, a third strategy to encourage dynamic representation in CMaps is to formulate and record in the map a process-oriented focus question.

EMPIRICAL EVIDENCE IN SUPPORT OF THE PROPOSED STRATEGIES

We conducted a set of preliminary experiments to test the effect of the discussed above strategies (Derbentseva et al., 2004, 2006, 2007). Below we briefly describe the studies and summarize the results.

Cyclic Structure Effect

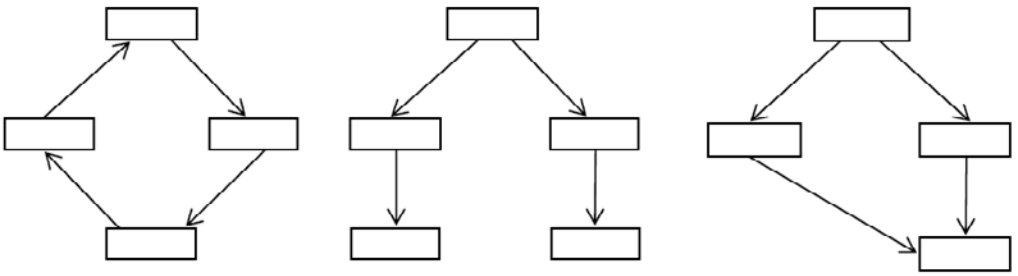
The effects of imposing a cyclic structure and root concept quantification on the resulting propositions were tested using a set of three simple structural prototypes shown in Figure 4.

These prototypes were constructed to reflect the main properties of the represented structures, while having minimal complexity.

Undergraduate students, who participated in our studies in exchange for a partial course credit, received one of the structure prototypes from Figure 4 and were asked to fill it out with meaningful concepts and relationships. The root concept (the top-most box) in each structure was specified, but the remaining boxes and arrows were blank. Depending on the condition, the root concept was either "*Plant*" or "*As the number of plants increases*." The latter was the quantification version of the root concept "*Plant*."

We analysed propositions from all the collected maps and scored them as either being static or dynamic. Each map received a map dynamic score based on the proportion of dynamic propositions it contained. Mean and standard deviation values of map dynamic scores for all experimental conditions are reported in Table 1.

To examine the effect of the cyclic structure on the represented relationships, we compared dynamic scores of the maps constructed with the root concept "*Plant*" for cyclic structure prototype (Figure 4, a) with the two hierarchical structures (Figure 4, b and c) constructed with the same root concept. Our analysis showed that cyclic maps had significantly higher proportion of dynamic relationships than the hierarchical maps (*p*s < 0.001). These results supported our argument that imposing a cyclic structure on a CMap increases representation of dynamic relationships.



a) Cyclic structure prototype

b) Hierarchical tree structure prototype

c) Hierarchical cross-link structure prototype

Figure 4. Structure prototypes used to test the effect of cyclic structure and root concept quantification of the representation of dynamic propositions (Derbentseva et al. 2004, 2006).

Quantified Root Concept Effect

To examine the effect of the quantification of the root concept, we compared dynamic scores of maps constructed with the same structure prototype but with different root concepts, e.g. cyclic maps with the root concept "*Plant*" were compared to cyclic maps with the root concept "*As the number of plants increases*." Mean and standard deviation values of map dynamic scores for maps constructed with quantified root concept are reported in Table 1.

Our analysis revealed that in all three structure prototypes, maps constructed with the quantified root concept had significantly greater proportion of dynamic propositions than the maps constructed with a plain root concept, i.e. "*Plant*" (all *p*s < 0.001). Moreover, the effect of the structural difference on the proportion of dynamic propositions that we observed with the plain root concept was non-existent with the quantified root concept. Even maps with the hierarchical tree structure (Figure 4, b) constructed with the quantified root concept contained significantly higher proportion of dynamic propositions than the cyclic maps (Figure 4, a) with a plain root concept ($p < 0.001$). These results supported our argument that quantifying the root concept in a CMap encourages representation of dynamic relationships.

Process-Oriented Focus Question Effect

To investigate the effect of process-oriented focus question on the representation of dynamic relationships we asked our participants to construct CMaps that answered either the question "*What is a car?*" or the question "*How does a car work?*" The latter being an example of a process-oriented focus question. The participants received a sheet with six disconnected boxes arranged in a circle. In both conditions, the root concept, *cars*, was already written in the top-most box, and the participants had to fill out the remaining boxes and connect them in meaningful propositions such that the whole structure answered the specified focus question.

Similarly, we analysed propositions from all the collected maps and assigned each map the map dynamic score based on the proportion of dynamic propositions it contained. Mean and standard deviation values for these two experimental conditions are presented in Table 1.

We compared map dynamic scores of CMaps that answered the focus question "*What is a car?*" to dynamic scores of maps that answered the focus question "*How does a car work?*" Our analysis showed that the proportion of dynamic propositions was significantly higher in maps that answered the process-oriented question "*how*" than in maps that answered the "*what*" question ($p < 0.001$).

This analysis provided support for the third strategy that we proposed for encouraging dynamic representation in CMaps – formulating a process-oriented focus question.

Empirical Evidence: Summary of the Results

The results of the first study supported the basic idea that the structure of a map affects our thinking in how we relate concepts to each other. Cyclic structures, due to the

interdependency among concepts, increase the likelihood of dynamic thinking, whereas hierarchical structures act as a constraint on dynamic thinking.

Table 1. Descriptive Statistics of the Map Dynamic Scores for All Experimental Conditions (Derbentseva et al., 2007)

Condition	*N*	Map Dynamic Score	
		Mean	SD
Cyclic Non-quantified	38	45.39%	0.33
Cyclic Quantified	25	93.50%	0.20
Cross-Link Non-quantified	38	21.05%	0.25
Cross-Link Quantified	25	95.00%	0.14
Tree Non-quantified	36	13.54%	0.19
Tree Quantified	25	92.00%	0.19
"What" focus question	40	21.00%	0.21
"How" focus question	41	55.00%	0.30

The results of the second experiment demonstrated that concept quantification is a very powerful technique for encouraging dynamic thinking in CMaps. The third study demonstrated that the type of a focus question of a map likewise affects our thinking.

The process-oriented focus question triggers thinking about the interdependency among the concepts and how they interact with each other resulting in a desired output. The static focus question, e.g. "what is "X"?" stimulates description of X, which is best represented with static relationships, thus, the dynamic relationships are under-represented.

Overall, we found support for each of the three strategies, i.e. each particular strategy was effective in encouraging dynamic relationships compared to no manipulation. However, there are also some interesting comparisons between the strategies can be drawn. Table 2 provides the results of all pair-wise comparisons across all experimentally manipulated strategies. Significant differences are noted and the direction of each difference is specified. The boxes with no entry indicate no significant difference at the 0.01 alpha level.

Examination of Table 2 reveals that the most powerful manipulation out of the three strategies tested was the root concept quantification regardless of the structure in which it was used. The proportion of dynamic propositions was very high (over 92%) in maps of all three structures with the quantified root concept. Root concept quantification eliminated the structure effect observed in the first study (where the plain root concepts was used), and produced a more powerful effect than the cyclic structure with the plain root concept or the process-oriented focus question manipulation. There was no significant difference between the cyclic structure strategy and the process oriented focus question strategy. The lowest level of dynamic representation was observed in the two versions of hierarchical structure (Figure 4, b and c, used with the plain root concept) and maps answering the static focus question "what." Figure 5 graphically summarizes the comparison of the level of dynamic representation achieved by the strategies used in the studies.

It is worth noting, that the concept quantification used in the second study is an extreme version of the idea of concept quantification. That is, the concept was not only quantified, but it was set in motion, meaning that a dimension was specified ("number of plants") and the direction of change was indicated ("as the number of plants increases"). Such an "aggressive"

form of concept quantification acts as a strict constraint on other possible concepts in a map and the type of relationships between them. The root concept quantification led to quantification of other concepts in the maps – the effect that was not observed under any other strategy. Linking two quantified concepts almost forces construction of a dynamic proposition. This constraint is so powerful that it is hard to imagine how a proposition can be completed without making it dynamic. Consider, for example, the root concept in the concept quantification condition "as the number of plants increases," and try to construct a proposition where the second concept is static or the relationship is not dynamic.

However, it might be the case that only an "aggressive" form of concept quantification might produce such a strong effect. We did not observe concept quantification effect on dynamic representation in CMaps in our pilot studies, in which we quantified the root concept but without setting it in motion (Derbentseva et al., 2004). More investigation is needed in this area.

While evaluating the results of these studies, it is important to recognize that the measure of dynamic representation used in these studies – proportion of dynamic propositions in a map – has certain limitations. The maps were analyzed as a set of independent propositions, thus the propagation of change beyond a single proposition was not captured by this measure. The propagation of change beyond a single proposition might be an important indication of dynamic thinking. Improving the measure of dynamic representation in CMaps might allow making further distinctions among the specific strategies and re-evaluating their comparative effects.

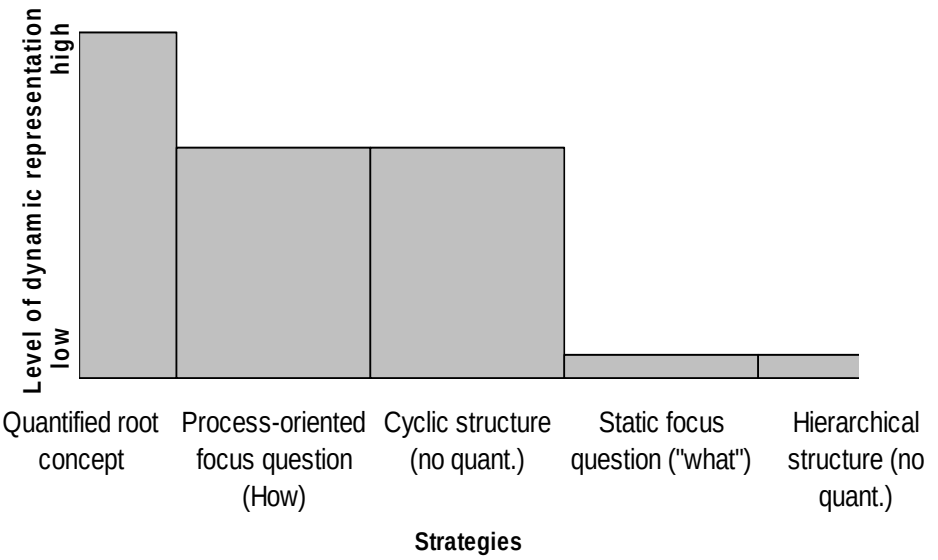


Figure 5. Level of dynamic representation achieved with various strategies.

CONCLUSION

In this chapter, we drew the reader's attention to the significance of dynamic relationships in science and the necessity to have the means of formulating and representing them as precise as their formulation allows. We pointed out that the highest known form of representing functional relationships is through a tightly coupled system of mathematical relationships. However, mathematical formulation is possible only if the conceptual development in the field has achieved sufficient level of abstraction. Until then, other means of representing and developing dynamic relationships are necessary.

The CMap as a graphical knowledge representation tool has a number of characteristics that give it certain advantages over some other forms of knowledge representation. The CMap allows for a concise representation of complex knowledge structures, since it represents knowledge in a graphical form minimising the amount of text. The CMap focuses attention on the concepts and their relationships, which makes it a useful tool in identifying the map creator's misconceptions. The CMaps could be an effective study tool, which helps the learner not only to organize the information that needs to be learned, but also to identify any existing gaps in their knowledge. Because of their useful characteristics, the CMaps have a history of successful application in educational and knowledge management settings.

However, due to some of their properties, especially the emphasis on hierarchical organization, the CMaps have been primarily used for representing static conceptual relationships. It is important to recognize this fact and be aware of this tendency in the CMap representation. It is not to say, however, that dynamic representation in the CMaps is not possible. The CMap as a knowledge representation system has a potential to represent dynamic interrelationships among concepts and can be effectively used to do so, especially in the domains of knowledge, which have not reached the level of mathematical formulation. Nevertheless, to encourage dynamic representation with the CMaps, it is necessary to overcome certain prevailing tendencies in the CMap construction practices.

In this chapter, we discussed three strategies that can be used to encourage representation of dynamic relationships in the CMaps. These strategies are encouraging a cyclic structure in a map (as opposed to a hierarchy), quantifying the starting (root) concept in a map, and posing a process-oriented focus question during a map construction task. It is worth noting, that two of the three strategies require abandoning the traditional hierarchical organization of the CMaps – the cyclic structure and the root concept quantification. It is possible that the third strategy, the process-oriented focus question, also resulted in a less hierarchical representation, however, we did not compute any structural measure to determine whether it was the case.

A series of studies provided preliminary empirical support for each of the three proposed strategies for encouraging dynamic relationships in the CMaps. While root concept quantification strategy produced much more powerful effect than the other two strategies, any conclusions at this point are premature. No doubt, more research is needed in this area.

In conclusion, both static and dynamic relationships are necessary for adequate representation of knowledge. The CMaps are robust in representing static relationships, and in this chapter we demonstrated that there are at least three ways of encouraging representation of dynamic relationships in the CMap form. These strategies are sufficiently simple to be applied in practical situations.

Table 2. Significant Differences* in Maps' Dynamic Score Across All Experimental Conditions (reprinted from Derbentseva et al. (2007)

Condition	Cyclic Non-quan.	Cyclic Quant.	Cross-Link Non-quant.	Cross-Link Quant.	Tree Non-quant.	Tree Quant.	"What" FQ	"How" FQ
Cyclic Non-quantified		Cq>Cn	CLn<Cn	CLq>Cn	Tn<Cn	Tq>Cn	WQ<Cn	--
Cyclic Quantified	Cn<Cq		CLn<Cq	--	Tn<Cq	--	WQ<Cq	HQ<Cq
Cross-Link Non-quantified	Cn>CLn	Cq>CLn		CLq>CLn	--	Tq>CLn	--	HQ>CLn
Cross-Link Quantified	Cn<CLq	--	CLn<CLq		Tn<CLq	--	WQ<CLq	HQ<CLq
Tree Non-quantified	Cn>Tn	Cq>Tn	--	CLq>Tn		Tq>Tn	--	HQ>Tn
Tree Quantified	Cn<Tq	--	CLn<Tq	--	Tn<Tq		WQ<Tq	HQ<Tq
"What" focus question	Cn>WQ	Cq>WQ	--	CLq>WQ	--	Tq>WQ		HQ>WQ
"How" focus question	--	Cq>HQ	CLn<HQ	CLq>HQ	Tn<HQ	Tq>HQ	WQ<HQ	

* *based on pair-wise Wilcoxon-Mann-Whitney tests $p < 0.01$.*

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Chapter 12

COMPETENCY-BASED ASSESSMENT IN A MEDICAL SCHOOL: A NATURAL TRANSITION TO GRADUATE MEDICAL EDUCATION

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ABSTRACT

Performance evaluation in traditional graduate medical education has been based on observation of clinical care and classroom teaching. With the movement to create greater accountability for graduate medical education (GME), there is pressure to measure outcomes by moving toward assessment of competency. With the advent of the Accreditation Council for Graduate Medical Education's Outcome Project, GME programs across the country have shifted to a competency-based model for assessing resident performance. This system has enhanced the quality of feedback to residents and provided better means for program directors to identify areas of resident performance deficiency. At the same time, however, the majority of medical schools have maintained a traditional approach to assessment with the passing of comprehensive examinations and "honors' on clinical rotations as measures of student achievement. The added value of new assessment approaches in graduate medical education suggests that medical educators should consider broadening the use of competency-based assessment in undergraduate medical education. This paper describes the design and implementation of a portfolio-based competency assessment system at the Cleveland Clinic Lerner College of Medicine. This model of assessment provides a natural transition to competency-based assessment during residency training, and a framework for tracking and enhancing student performance across multiple core professional competencies.

During the last decade, the Accreditation Council for Graduate Medical Education (ACGME), under the leadership of David Leach, M.D., initiated a philosophical shift in approach to the assessment of resident performance. A comprehensive review of GME was

undertaken with the intent to define specific competencies that could be applied to all residents. The result was published in February of 1999 as the ACGME Outcome Project (www.acgme.org/Outcome). Full text definitions for these competencies were published in September 1999 with expectation of a 10 year, three-phase implementation timeline. Mastery of 6 Core Competencies (Table 1) was established as a standard for all residents in training and all residency programs reviewed after July 1, 2003 were obligated to demonstrate curricular objectives and new assessment processes focused on these competencies.

Global clinical evaluation and standardized testing have been the typical approach to evaluation in traditional GME. Direct and indirect observation of resident performance by staff is the norm and assessment of competence is often based on global impressions ("I know it when I see it"). In this context, the curricula of residencies have been based on diversity of cases, global assessment, didactic teaching and measurement of medical knowledge via standard tests such as in-training examinations, written board examinations or written examinations produced by testing groups or the programs themselves. The penultimate evaluation for many programs has been the six-month Clinical Competence Committee forms submitted to specialty boards, although the criteria for "satisfactory" performance are unique to each training program.

Competency-based assessment, in contrast to traditional approaches, recognizes that multiple competencies are needed for the practice of medicine in addition to clinical skills and medical knowledge, such as professionalism and communication. The competency-based approach measures predetermined learning outcomes in which performance is compared against a set standard or threshold and is criterion-referenced rather than norm-referenced. Thus competency-based assessment places an emphasis on feedback and reinforcement of learning to help the learner achieve the standards.[1,2] While individual competencies need to be assessed, the ways in which these competency domains are integrated depend on the context and the content of the task. Thus as medical education moves towards competency-based assessment, tools are being developed to assess a broad range of competencies and the ability to integrate these competencies.

Findings reported in the literature suggest that more attention needs to be given to observing and assessing actual performance in order to provide useful feedback for learning purposes. Knowledge acquisition and demonstration of competence for a complex task involving this knowledge is different [3] than breadth of knowledge tested by multiple choice questions, since the latter may not reflect the ability to use this knowledge to solve problems. [2] The closer the assessment intervention to the clinical learning experience, the more likely that assessment will enhance learning [2]. Real-time feedback creates interest in the subject material, the interest prompts retention [4]. Assessment interventions that are built in a realistic clinical setting also create interest in the material and achievement of the learning goals measured [2]. Non-traditional assessment methods that stimulate learning include self-assessment [5], peer-review [6], and portfolio [7]. An additional advantage of linking assessment with a task [1] is that it creates motivation toward retention of the learning experience [8] in contrast to "studying to the test" and the inevitable purging of memorized facts that occurs in the immediate aftermath. [9]

Although change is difficult, this competency-based approach has transformed the GME learning environment and enhanced the overall quality of feedback and assessment in resident education. The value of such a system is equally, if not more, important in undergraduate medical education. The added value of new assessment approaches in graduate medical

education suggests that medical educators should consider broadening the use of competency-based assessment in undergraduate medical education.

This paper describes the design and implementation of a portfolio-based competency assessment system at the Cleveland Clinic Lerner College of Medicine and addresses the portfolio approach and implementation challenges more generally. We conclude that this model of assessment provides a natural transition from medical school into competency-based assessment during residency training, and a framework for tracking and enhancing student performance across multiple core professional competencies.

COMPETENCY-BASED ASSESSMENT IN UNDERGRADUATE MEDICAL EDUCATION

In July 2002, the Cleveland Clinic established the Cleveland Clinic Lerner College of Medicine (CCLCM) in partnership with Case Western Reserve University to create a new medical school program that focused on the training of physician investigators. In contrast to the challenge faced by many medical schools that seek to change existing curriculum or assessment processes, faculty at the Cleveland Clinic had the unique opportunity to design a curriculum and complementary assessment process from a clean slate.

With a goal of training physician investigators who are critical thinkers and self-directed learners, the faculty established a set of founding principles that included a commitment that *assessment should enhance learning*, with emphasis on mastery of 9 Competencies (Table 1). Although the competencies map directly to the ACGME Competencies, undergraduate developmentally appropriate performance standards for medical students were set for each competency across the five years. Small class size facilitated opportunities for curriculum and assessment design that might otherwise be a challenge for larger programs. In order to ensure active student engagement in the assessment system, a decision was made to utilize a portfolio system to document student progress in meeting the 9 Core Competencies. The portfolio process provides a framework that forces students to take responsibility for their learning by requiring them to select representative evidence to demonstrate their mastery of competency standards and areas of weakness. These processes also fosters the skill of reflective practice as students must identify their individual weaknesses and develop appropriate learning plans to address these areas. A systematic mentoring system utilizing trained physician advisors was established to ensure student self-awareness, formative assessment and progress. Grades and class rank were intentionally avoided in our assessment model in order to achieve a non-competitive, cooperative learning environment designed to parallel the collaborative nature of current physician practice and biomedical research.

The assessment process and portfolio system designed by CCLCM faculty has been described previously (10,11). Students receive feedback regarding their performance from faculty and peers using a variety of assessment tools (sample included as Appendix One) designed to fit different learning contexts, with feedback compiled in an electronic assessment database. Under the guidance of their physician advisor (PA), students develop three formative portfolios in Year 1 and two in Year 2 of medical school. Students are expected to document their mastery of progressive standards for each competency by writing reflective essays about their own strength and weaknesses with supportive evidence they

select from their assessment database. This encourages mastery of self-assessment starting with the beginning of medical school. In addition, students are required to develop learning plans to address areas of weakness that they have identified. The ability to recognize gaps in performance and identify the means to overcome such deficiencies is regarded as a highly desirable component of our reflective practice competency. The PA has access to their student' entire electronic assessment database and part of the PA's role is to ensure that the students gain appropriate insight into their performance and utilization of appropriate evidence to accurately reflect their performance progress. At the end of Year 1 and Year 2, and after review and sign-off by each student's PA, a Medical Student Promotion and Review Committee (MSPRC) reviews a summative portfolio developed by each student. The PA's role is to verify that the portfolio accurately portrays the student's performance. The MSPRC then recommends that students either: 1) pass, 2) pass with concerns, 3) pass with remediation, 4) repeat the year.

In the advanced clinical years (Years 3-5), students develop formative portfolios in Years 3 and 4 with a summative portfolio in Year 5. Feedback from faculty during clinical rotations is based on the ACGME Competencies with standards appropriate to medical students as the minimum expectation for achievement. Rather than identify "honors" performance for an individual "clerkship", student performance is documented throughout their medical school experience so that their progressive level of achievement of discipline specific competency and cross-discipline competency (e.g. communication skills and professionalism) can be documented. The Year 5 summative portfolio review will be used to create a Competency Report that will be a summary of the student's performance and part of their application for residency training.

BENEFITS OF COMPETENCY-BASED ASSESSMENT IN MEDICAL SCHOOL

We are only now beginning to envision competencies as a way of building a coherent curricular and assessment system that begins in medical school and continues into a lifetime of practice. Habits of professional practice desired by residency programs should begin to be developed from the first day of medical school. After all, habits take time to develop and once developed, are difficult to change. Currently, the leap from medical school to residency training presents a major transition. Undergraduate medical education gives primary responsibility to faculty for ensuring that students are ready to graduate, and traditionally considerable emphasis has been placed primarily on medical knowledge and clinical skills. Residency programs, however, desire interns who are self-directed in their learning, able to act on feedback, and embody the professionalism expected by society. By moving undergraduate medical education to a portfolio-based competency assessment model, we have the potential to greatly enhance student preparation for subsequent professional responsibilities.

An important advantage of a competency-based assessment system in medical school is the ability of such a system to track cross-discipline competencies, particularly communication skills and professionalism. A consistent frustration of residency program directors is the occasional recruitment of talented medical school graduates with high

USMLE scores and honors in individual disciplines who are lacking in communication skills or display unprofessional behavior with patients or colleagues. The issues that are most difficult for assessment in medical students fall into these behavior categories (12,13) and there are a variety of obvious and less obvious reasons for this failure (14). In part, this difficulty occurs because discipline specific assessment tends to remain siloed such that weaknesses in cross-discipline areas (e.g. professionalism, communication skills) are less likely to be recognized and addressed. A competency-based assessment system in medical school helps to ensure that these skills are emphasized and assessed as critical areas of performance.

Our early experience with medical students suggests that recognition of weakness in these core areas of professionalism and interpersonal communication with appropriate early intervention can effect changes in behavior. Although identification of cross-disciplinary competency issues can be challenging in a test-based assessment system, members of the Medical Student Promotion and Review Committee at CCLCM uniformly reports that the CCLCM assessment system is sensitive to early detection of behavioral performance issues. This is particularly important in light of reports documenting professionalism issues in medical school as predictors of subsequent formal disciplinary action by state medical boards (15).

Perhaps the most critical aspect of competency-based assessment is the potential of this system to foster self-reflection. In residency and beyond, the ACGME competency of "practice-based learning" is recognized as an essential attribute for successful practice in a field such as medicine that is constantly advancing through new discoveries and innovations. An inability to recognize deficiency in one's knowledge or learn from experience will undoubtedly result in substandard practice whether as a physician or an investigator. In many ways, "reflective practice" in medical school, serves as the counterpart to the "practice-based learning" competency expected in later years. The use of portfolios to provide students with a vehicle to document and reflect on their strengths and weaknesses can facilitate the ability of students to have a clear window into their performance and with the help of their mentor, learn to interpret feedback and set appropriate learning goals. The portfolio process can also help to identify students with limited insight and gives mentors concrete evidence to use in teaching students skills in self-reflection.

In the "preclinical" years, such self-reflection is focused on helping every student achieve competency. Students are encouraged to identify gaps in knowledge or clinical skills rather than being concerned with passing a comprehensive, end-of-course examination. Their focus becomes improvement relative to competency-based standards rather than achieving passing grades. In the clinical years, competency assessment and reflection allows students to focus their progressive learning in areas of relative weakness that may be discipline specific or applicable across disciplines. Such a system facilitates the ability to progressively track student performance in a discipline across multiple rotations. Rather than competing for "honors" in an individual clerkship, students can progressively build on their discipline specific skills, and their level of performance at or near graduation can be communicated to residency program directors instead of their performance during a short time period in their 3rd year of training. Medical school training becomes a process aimed at mastering skills over time rather than passing shelf examinations and competing for achievement of clinical honors in comparison to other students on the same rotation. Well-defined competency standards

require all students to achieve performance excellence relative to common, objective standards.

BUILDING A COMPREHENSIVE PORTFOLIO APPROACH TO COMPETENCY ASSESSMENT

The starting point for portfolio assessment in medical education is to define performance in terms of competencies, such as the 6 competencies in the ACGME Outcome Project. The next step is to define standards within these competencies and the kind of evidence that can be used to demonstrate mastery of these standards. In an active portfolio system, the student or resident is responsible to select the evidence to demonstrate achievement of competencies, often accompanied by written demonstration (essay) or oral defense of performance. In a passive portfolio system, the evidence is assembled in a similar manner for all being assessed. For summative assessment, the portfolios are reviewed by a group of experts. Prior to examination of any portfolio, the assessment group needs to establish a common definition of achievement for each competency standard. It is then possible to review each portfolio, and for each competency define whether the individual trainee has met the standards, not met the standards or not provided sufficient evidence. For the Outcome Project, this kind of portfolio assessment could be applied to one or more competencies, or become the primary means of assessing all the competencies. As a tool, portfolios can also be used to encourage competency-related desired outcomes.

REFLECTION ON LEARNING AND SELF-ASSESSMENT

Adoption of the portfolio approach has in part been driven by the search for a tool that encourages reflection and that requires active participation by students in the assessment process [16,17]. Reflection is a valuable tool within portfolio assessment because it drives the student to use evidence to document their own performance and learn in the process. Reflection and self-assessment are key concepts in portfolio assessment systems [18-21]. The process of determining mastery of each standard is ideally suited to the creation of a learning plan to modify subsequent training for the individual trainee, and when this feedback is assembled cumulatively for a group of trainees, it is well suited for use in program improvement.

A relatively under-used assessment tool is self-assessment of competence. Accurate self-assessment skill does not come naturally and requires training. Residents were able to arrive at the same evaluation of technical skills as their teachers with a modest amount of training [22] especially if the training included explicit expectations [23]. An added advantage is the additional learning from the act of self assessment [24]. Specific training for reflection improves the ultimate product in a system of self-assessment [25]. In an Ob Gyn rotation, reflection was taught using the medical literature and applied to clinical situations, improving the student's ability to evaluate their own performance [26]. In a general practice setting, reflection about challenging cases combined with journaling and third party feedback improved self-assessment skills [27]. Student performance on self-assessment activities

matched their progress in clinical skill acquisition [28]. Oral surgery residents were able to accurately identify areas of skill in which they required more experience and teaching [29]. When initial attempts at self-assessment by residents were compared to subsequent attempts, training and repetition resulted in improved skill [30]. Self-assessment may be more effective when combined with auditing and feedback for residents [31]. In general, trained self-assessment is harsher than faculty assessment of the same event [32].

Formative and Summative Assessment

The portfolio can be used as a tool for assisting with both formative and summative assessment. During formative portfolio review, students reflect on assessment evidence from their coursework and feedback from faculty to self-evaluate progress and set learning goals [33]. In this process, assuring that appropriate progress is occurring and setting learning goals that specify activities addressing areas of weakness is essential [34]. When portfolios are used for summative assessment, the portfolio review must determine whether the student has achieved the determined level of mastery of competencies, and this in turn dictates promotion decisions [35].

Challenges to Implementation

The feasibility of portfolio assessment can be problematic because a large amount of data must be assembled for each portfolio and the review process requires considerable faculty effort [36]. The technical difficulty of accumulating the data can be improved with computerization [37]. Paper-based portfolios are large and review for assessment is difficult. These feasibility issues in turn create serious validity concerns. Reliability of portfolio assessment has been challenged when the available evidence is limited [38]. Some portfolio assessment projects have been reported in GME, including psychiatry [39], and emergency medicine [40]. Higher test scores as evidence of improved learning as a result of portfolio assessment has been reported in undergraduate medical education [41]. The amount of information needed to evaluate a portfolio and the number of faculty to read the portfolio has been reported from a psychiatry residency [42]. The use of one portfolio process to assess all six competencies has been described in a psychiatry residency [43,44]. The ACGME is sponsoring a portfolio-design project at several sites, with the intention of creating a structure with the flexibility to be implemented at any ACGME accredited residency to achieve comprehensive assessment.

At the Cleveland Clinic Lerner College of Medicine, the portfolio system is the sole method of assessment. Because this was a decision made during the creation of the curriculum, it was possible to design evidence collection tools for all elements of the curriculum that work effectively in a portfolio assessment system. Representative examples are presented in Appendix One. With the evolution of the curriculum, it has been possible to direct faculty development to steadily improve the ability of faculty to provide evidence of the mastery of competence. Because of teaching and using peer review, the student's learn progressive assessment of competence of their classmates. In addition, the formative portfolio encourages progressive increase in the skills of self assessment of competence. Reflective

practice encourages the student to recognize gaps in knowledge or performance, and to create plans to address these gaps. In a paradigm shift, the recognition of a performance issues by a student that results in a plan to overcome this obstacle that succeeds is regarded as a strength of the student, versus a weakness. This, in turn, encourages the student to develop the skills of life long learning. All of these elements of our assessment system should be ideally suited for preparing the student for competency assessment in GME. No only will this not be unfamiliar to the new resident, but students who experience our system will bring the skills of peer review and self assessment, which are highly valuable in any competency assessment system. The standards for graduation from our school (Appendix Two) are all competency based, and this should be a natural transition to competency based assessment during GME, and later during CME for maintenance of competence.

A critical challenge to the implementation of a competency-based assessment system is the need to create a culture that embraces assessment as a tool to enhance learning rather than a competitive mark of achievement. Although the traditional approach of "clinical honors" and passing of comprehensive exams has historically been successful in guiding students from medical school to residency, the current system remains deficient in the ability to adequately assess certain competencies that may only become apparent during residency. In part this may be the result of limited cross-talk between courses or clinical experiences. Summative portfolios that require evidence to substantiate performance may help to identify such deficiencies earlier in training. Requiring students to create their own remediation plans, as necessary, and closely monitoring their progress forces students to take responsibility for their learning but does not penalize them for performance deficiencies that are ultimately corrected.

Another potential challenge for a competency-based portfolio approach to assessment may be communicating student performance to residency program directors. GME program directors traditionally rely on transcripts that report "honors" and Dean's letters that summarize student performance. Competency-based Dean's letters with transcripts that document achievement of standards is a different approach to conveying student performance that may provide program directors with more valuable data to help select candidates. Such information also provides a natural starting point for GME based competency assessment.

In summary, competency-based assessment in medical school provides several advantages for the individual learner and for the medical school responsible for investing in the education of subsequent generations of physicians and investigators. Portfolios complement competency-based assessment by fostering self-reflection and individual responsibility for learning. Such a system creates a natural transition to residency, and can provide residency program directors with better information regarding individual student performance than current systems where performance is comparative to peers rather than standards of achievement. Although change is always difficult, whether in curriculum design or assessment approach, we would suggest that just as medical school is part of a natural professional continuum with residency, and eventually physician practice, so should the focus on continuous improvement of performance in core areas of competency be a continuum. Since core competencies have already been designed and embraced by residency programs across the country, medical schools should consider implementation of similar models of feedback and assessment.

APPENDIX ONE
SAMPLE ASSESSMENT FROM YEAR 1 CLINICAL PRECEPTOR

Expected Level of Competence	Targeted Areas for Improvement	Areas of Strength
Competency: Medical Knowledge		
Basic Science Knowledge Applies basic science principles learned in organ systems courses to problems in clinical medicine		You consistently are able to relate learning in blocks to clinic, especially cardiac physiology to blood pressure and pulse rates
Competency: Communication		
Patient-Centered Interview Establishes comfortable atmosphere Appropriately greets and establishes rapport Uses open-ended questions and transition statements Negotiates agenda	You frequently forget to focus the patient's complaint by asking closed-ended questions I've noticed that you break eye contact with patients frequently to write and review your notes	You consistently greet patients in a friendly and respectful way and consistently elicit the patient's perspective when setting the agenda. With the patient you saw last week with lupus, you provided appropriate and genuine empathic statements. I think it made a difference
Competency: Clinical Skills		
History-Taking Skills Elicits chief complaint Explores dimensions of present illness Obtains past medical history, surgical history, medications/allergy Elicits family and social history	You don't seem to have developed a systematic approach to getting the past medical history. This has resulted in incomplete patient presentations	You consistently asks the patient if they have any other concerns. Recently a patient told you something about her history that she had not mentioned to me.
Physical Examination Describes the patient's general appearance Demonstrates ability to take vital signs Cardiac examination Pulmonary examination	Your pulmonary exams have become more ordered , however you appear very uncertain about what you are hearing and I get the sense at times that you are going through the motions	Your CV exams have been complete, and systematic over the last 2-3 weeks. This shows real improvement
Competency: Professionalism		
Work Habits Eager to participate Punctual and prepared Dresses appropriately Directs own learning agenda Accurately self-assesses gaps in knowledge/skills Completes tasks efficiently and thoroughly	Although you come to clinic ready to work, I have been directing the focus rather than you telling me what you'd like to work on. Let's work together to change that approach.	You are consistently on time, always dress in clean, neat shirt and tie and come prepared to practice skills learned in physical diagnosis and communication skills classes

Expected Level of Competence	Targeted Areas for Improvement	Areas of Strength
Interpersonal Skills Respectful toward patients, office staff and preceptor Actively listens to and responds to preceptor Admits and corrects his/her own mistakes; truthful Offers and accepts constructive feedback		You appear respectful (greet all patients by surname and is responsive to the patient's requests.) The Nursing staff report that you are respectful in your interactions. Responsive to my feedback. Brings in articles, takes initiative

Narrative: You have come a long way in the past few months. I have noticed real improvement in your physical examination skills, especially the cardio-vascular exam. Your interactions with patients and my staff are consistently respectful and pleasant. In your desire to elicit the patient's story "in their own words", you still seem to be having trouble focusing that story in the end, resulting in vague or sometimes unorganized presentations. Let's both work on changing who "directs" your learning. Try coming to clinic with some specific learning goals

APPENDIX TWO
CCLCM YEAR 5 STANDARDS

Research

- Analyzes and effectively critiques a broad range of research papers.
- Demonstrates ability to generate research questions to test hypotheses in basic and clinical science.
- Applies basic principles of the scientific method to formulate a hypothesis and design and perform experiments to test it.
- Demonstrates ability to initiate, complete and understand all aspects of his/her own research project.

Medical Knowledge

- Demonstrates appropriate level of clinical and basic science knowledge base.
- Demonstrates ability to apply knowledge base to new clinical and research problems citing medical literature and other sources of evidence

Communication

- Uses effective written and oral communication in research settings.
- Uses effective written and oral communication in clinical settings.
- Demonstrates patient-centered communication.

- Demonstrates cultural sensitivity when interacting with patients, families and co-workers from diverse backgrounds and abilities.

Professionalism

- Demonstrates compassion, honesty and ethical practices.
- Meets professional obligations in a reliable and timely manner.
- Treats others in the healthcare environment in a manner that fosters mutual respect, trust, and effective patient care.

Personal Development

- Critically reflects on personal values and priorities and develops strategies to promote personal growth.
- Identifies challenges between personal and professional responsibilities and develops strategies to deal with them.
- Identifies personal biases and prejudices related to professional responsibilities and acts responsibly to address them.

Clinical Skills

- Demonstrates ability to perform a complete history and physical examination and distinguish between normal and abnormal physical findings.
- Demonstrates ability to adapt the history and physical based on clinical setting and patient presentation.
- Demonstrates ability to perform clinical procedures required by each core discipline.
- Demonstrates appropriate responsibility for follow-up care of patients.

Clinical Reasoning

- Uses the patient's history, physical examination, and other data to formulate and prioritize a differential diagnosis.
- Uses available resources to develop an evidence-based approach to prevention, diagnosis, and treatment.
- Demonstrates awareness of the impact of genetics, ethnicity, age, gender, and socioeconomic diversity in the care of individual patients.

Health Care Systems

- Applies concepts of patient safety, medical error and quality improvement to clinical experiences.
- Demonstrates understanding of health care system issues that result in health care disparities.
- Participates with other health care professionals in transition planning and identification of community resources.

Reflective Practice

- Interprets and analyzes personal performance using feedback from others and makes judgments about the need to change.
- Identifies gaps in performance and develops and implements realistic plans that result in improved practice.

Table 1. CCLCM Core Competencies

1) *Research*: Demonstrate knowledge base and critical thinking skills for basic and clinical research, skill sets required to conceptualize and conduct research and understand the ethical, legal, professional and social issues required for responsible conduct of research.
2) **Medical Knowledge in the Basic, Clinical and Social Sciences:* Demonstrate and apply knowledge of human structure and function, pathophysiology, human development and psychosocial concepts to medical practice.
3) **Communication:* Demonstrate effective verbal, nonverbal and written communication skills in a wide range of relevant activities in medicine and research.
4) **Professionalism:* Demonstrate knowledge and behavior that represents the highest standard of medical research and clinical practice, including compassion, humanism, and ethical and responsible actions at all times.
5) *Personal Development*: Recognize and analyze personal needs (learning, self-care, etc.) and implement plan for personal growth.
6) *Clinical Skills: Perform appropriate history and physical examination in a variety of patient care encounters and demonstrate effective use of clinical procedures and laboratory tests.
7) **Clinical Reasoning:* Diagnose, manage and prevent common health problems of individuals, families and communities. Interpret findings and formulate action plan to characterize the problem and reach a diagnosis.
8) **Health Care Systems***:* Recognize and be able to work effectively in the various health care systems in order to advocate and provide for quality patient care.
9) **Reflective Practice:* Demonstrate habits of analyzing cognitive and affective experiences that result in identification of learning needs leading to integration and synthesis of new learning.

*Map to ACGME Core Competencies

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Chapter 13

BELIEFS OF CLASSROOM ENVIRONMENT AND STUDENT EMPOWERMENT: A COMPARATIVE ANALYSIS OF PRE-SERVICE AND ENTRY LEVEL TEACHERS*

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ABSTRACT

This project explored the possibility of establishing a classroom model of motivation. One-hundred-forty-four current elementary and secondary teachers with one or two years of teaching experience and 116 university pre-service teacher education students completed a 40-item Likert-type questionnaire that focused on four classroom dimensions of affirmation, rejection, student empowerment, and teacher control. The results of this project suggested that early career teachers and university student pre-service teachers varied on their reported desire for teacher empowerment versus student empowerment in the classroom, and on their desire to provide a positive classroom environment as opposed to one that may encourage a classroom atmosphere of rejection. Implications for future research and the need for creating affirming, empowering, motivational classroom environments are discussed.

INTRODUCTION AND LITERATURE REVIEW

This project focused on the goal of exploring a model of student motivation where the source of this motivation is based on internal student mechanisms and positive classroom

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environments. Based upon the earlier work of McCombs (1991, 1993, 1994a) who argued that students can become architects of their own learning, McCombs (1994b) also suggested the importance of positive social relationships in educational contexts. Although schools in the 1800 and 1900s were dominated by authoritarian control surrounded by a strict learning environment, (Newman, 2006) the evolution of school practice has begun to suggest that students and their ability to learn might be better served in a supportive environment where student engagement is augmented by self-motivation and self-regulation (McCombs, 1993).

Building upon the work of others (Bandura, 1997, Pajares, 1997, Pintrich and Schunk, 1996), the concept of student self-efficacy suggests that personal perceptions of one's ability, may, in fact have a positive impact on student motivation and achievement. From the early stages of development, students begin to evaluate their own abilities based upon a series of feedback loops and eventually develop a sense of self-efficacy (Bandura, 1997, Pajares, 1997). In effect, these efficacy expectations may predict behavioral changes and task choices resulting in positive or negative effects on student motivation and achievement (Nichols and Miller, 1994; Nichols, 1996; Pintrich and Schunk, 1996; Tuckman, 1999). In effect, these efficacy expectations may predict behavioral changes and task choices, each of which may impact persistence at a task (Deci and Ryan, 1991). Dweck's work (1995) and more recently Yee and Quay (2001) suggested that individual interpretations of intelligence or the establishment of learning or performance goals may ultimately impact student effort output and their reactions to success or failure in academic pursuits. Self-efficacy alone is not enough to ensure a sense of self-esteem and internal intrinsic motivation; these efficacy beliefs and expectations must be accompanied by a sense of autonomy (Deci and Ryan, 1991) in that self-assessment of ability and interpretations of progress along with an internal locus of control work in tandem to create a student motivational profile.

Learning and performance goals are two unique orientations proposed by Dweck (1995), in that students who adopt learning goals base their success on internal gains in their ability rather than comparisons to their peers. Learning goal oriented students also interpret failure as part of the learning process, while those with performance goals tend to assess their success based upon comparisons to others and fail to persist at difficult tasks (Dweck and Leggett,1988). Others have also suggested that student goal orientation can impact achievement (Miller, Greene, Nichols, and Montalvo; Nichols, 1996) and others have suggested that different types of instructional strategies may also encourage students to adopt greater learning goal orientations (Nichols, 1996). Baron and Harackiewicz (2001), have also suggested that both performance and learning goals are natural and necessary so a mixture of learning and performance may work to maximize student motivation.

In 1990, a special presidential task force was given the task to determine ways in which the psychological knowledge base related to learning, motivation, and individual differences could contribute directly to improvements in the quality of student achievement. This task force was also asked to provide guidance for the design of educational systems that would be supportive of student learning and achievement. As a result of some their work on this task force, McCombs (1994a) and her colleague (McCombs and Whisler (1997) have suggested that schools are "living systems", and that their central function is to provide a supportive learning environment. Following the concepts of the learner-centered classroom proposed by McCombs and her colleagues (1997) and more recently by Nichols (2004), one source of motivation may be understood as internal (Harter, 1991; Csikzentmihalyi, 1990). This internal focus may serve the basic function of learning for the primary recipient (the student), and also

for the other people who support the learning process (including teachers, counselors, administrators, parents and other community members). In effect, advocates for learner-centered classrooms also propose that schools must concern themselves with how to provide the most supportive learning context for diverse students and their teachers (McCombs and Whisler, 1997). Student motivation may be supported when classrooms are sensitive to promoting student-teacher relationships along with allowing for the development of self-efficacy and learning goals that ultimately result in classrooms that are learner-centered with students having greater control of their own learning. This project explores a potential classroom environmental model that centers on two factors or dimensions of internal motivation: the locus of control or empowerment dimension, and a classroom affirmational dimension that is defined by positive and negative student-teacher relationships.

The empowerment dimension moves from excessive power or control by the teacher to a minimal power dimension where learners are empowered to take control of their own learning. This structure is characterized by the amount of explicit information available in the classroom in order to achieve a specific and desired outcome. Teachers often communicate this desire level by setting clear boundaries and goals and responding consistently and predictably to students. Stimulation is characterized by the structure of activities that allows students to experience and achieve goals that are appropriate for the learner's abilities, therefore permitting the learner control within the classroom environment. On this continuum, the classroom environment is defined as teacher centered or driven, while empowerment is defined as student centered or driven (Nichols, 2004).

The relationship dimension is also characterized by two cultural features; engagement and feedback. Engagement informs the learner how the teacher views them as a person and refers to the quality of the student/teacher relationship and indirectly has an influence on the relationship between peers within the class. This level of engagement is directly related to the teacher's support and understanding of student learning, and indirectly to their willingness to develop positive relationships with students. Feedback informs the learner how well they are doing and begins to develop the qualities or attributes that influence future success or failure. Positive student engagement and feedback results in a valued classroom environment, while rejection or negative relationships may result in limited positive student feelings of self-worth and self-efficacy (Nichols, 2004).

As these two dimensions interact, it potentially results in four separate and unique classroom environments (see Figure 1), the complexity of understanding the impact on classroom environments and school culture may be closely explored. The dimensions of this model are potentially interdependent contributors to student motivation in that each may impact student self-efficacy, goal orientation, and intrinsic motivation to learn. For example, if appropriate feedback exists on the positive relationship continuums, this feedback may also have an empowering attribute for students. This intersection of the two continuums potentially provides four separate unique classroom types. Broadly defined, a destructive classroom may develop when negative relationships or an attribute of rejection exists, combined with maximum control from the teacher.

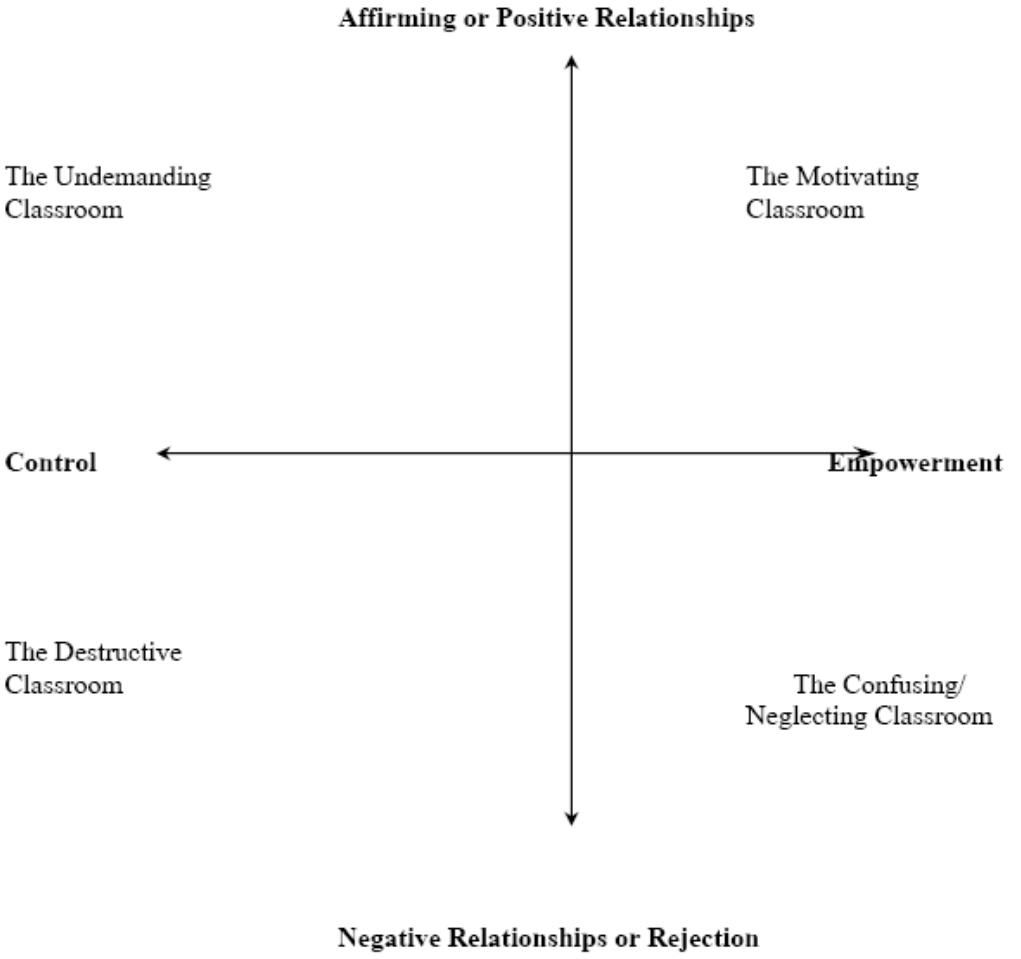

Figure 1.

A confusing or neglected classroom may be the result of negative student-teacher relationships that have developed, coupled with teacher efforts to empower students. An undemanding classroom may occur when positive relationships are developed, but maximum control is maintained by the teacher. The motivating classroom may be defined as one where students are empowered, and at the same time, receive feedback from the teacher that supports positive relationships, thus indicating to students a positive self-worth and efficacy (Nichols, 2004). In the future, each of these four dimensions, the motivating, destructive, undemanding and confusing classroom will be further explored to clarify and establish more explicit definitions and descriptors of each potential classroom environment.

The goal of this project was to continue the validation of the original classroom motivation model instrument (Nichols, 2004), while adding the opportunity to explore and compare the differences in the perceptions and responses of early career teachers and pre-service university students who have little or no classroom teaching experience. The results of the earlier project suggested that clear differences existed in the perceptions and responses of veteran teachers from those of pre-service teachers in terms of how they viewed the process

of developing a motivating classroom environment. This project extends the previous findings in that the perceptions and beliefs of pre-service and early career teachers were compared. The specific hypothesis that was explored was that early career teachers (1st or 2nd year educators) would differ in their perceptions of each of the four classroom dimensional attributes when compared with the perceptions of pre-service teacher educators (1 year from their student teaching experience).

METHODOLOGY

A 40- item Likert-type questionnaire was developed to explore and identify each of the classroom dimensions previously described. Ten items were developed to explore each of the classroom dimensions with a specific focus on items that would measure affirmation, rejection, control, and empowerment. After the initial results were examined to support the initial quadripolar classroom structural model, correlational coefficients were used to determine the relationships among each dimension to clarify the combination of the classroom dimensions of affirmation/empowerment, affirmation/control, rejection/control, and rejection/empowerment. Several items on the instrument were adapted from earlier work by McCombs and Whisler (1997) and Nichols (2004). See Table 1 for examples of sample questionnaire items.

One hundred sixteen pre-service elementary and secondary teacher candidates from a large regional university campus voluntarily completed the instrument along with 144 elementary and secondary teachers with one or two years of teaching experience in three large urban school corporations in the Midwest. Initially 250 current teachers completed the questionnaire; however, only teachers with 2 or less years of classroom teaching experience were included in this analysis. This not only allowed for confirmatory analysis of the quadripolar classroom structural model, but also allowed for comparative purposes, an exploration of classroom structures based on responses from pre-service teachers with no classroom experience, to those who had limited classroom exposure.

RESULTS

Preliminary results indicated positive support for the quadripolar classroom structural model. Initially, a reliability analysis was used to confirm the authenticity of the classroom structural model instrument. Alpha reliability values for each of the four dimensions; affirmation, rejection, control, and empowerment were $\alpha = .91$, $\alpha = .83$, $\alpha = .86$, and $\alpha = .72$ respectively. Correlations among the variables that were explored with the questionnaire are reported in Table 2. The consistency of these correlations with theoretical predictions and previous empirical findings (Nichols, 2004) provide support for the construct validity of the subscales. Most noteworthy was the significant positive correlation between student empowerment and positive classroom relationships, $\underline{r} = .86$, and the significant correlation between teacher control and a negative or rejecting classroom atmosphere $\underline{r} = .78$.

Table 1. Sample Items From the Response Instrument

Positive Relationships (α = .91)

1) Addressing students' social, emotional, and physical needs is just as important to learning as meeting their intellectual needs.
2) Taking the time to create caring relationships with my students is the most important element for student achievement.

Negative Relationships (α = .83)

1) Even with feedback, some students just can't figure out their mistakes.
2) It's impossible to work with students who refuse to learn.

Teacher Control (α = .86)

1) One of the most important things I can teach students is how to follow rules and to do what is expected of them in the classroom.
2) If I don't prompt and provide direction for student questions, students won't get the right answer.

Student Control or Empowerment (α = .72)

1) For effective learning to occur, I prefer to let my students be in control of the direction of their learning.
2) I allow students to express their own unique thoughts and beliefs.

Note: Some items are adapted from McCombs and Whisler (1997)

Table 2. Correlational Matrices for Each Component of the Classroom Quadripolar Model

	Empowerment	Control	Postreal	Reject
Empowerment	---			
Control	-.76**	---		
Postreal	.86**	-.76**	---	
Reject	-.73**.	.78**	-.77**	---

Note: ** = $\underline{p}$< .01, n = 260

The strong negative correlation on the student/teacher control continuum, $\underline{r}$ = -.76, and the positive/negative relationship continuum, $\underline{r}$ = -.77, helped to confirm the validity of the quadi-polar classroom model.

The means and standard deviations for the classroom questionnaire responses of both pre-service and early career teachers are provided in Table 3. In an effort to examine the potential differences in the responses in pre-service and early career teachers, an analysis of variance

(ANOVA) was used to explore mean responses of these two groups. Analysis of Variance results indicated that pre-service teacher responses on the student empowerment subscale were significantly greater than early career teachers $F(1,259) = 930.17$, $p < .001$, and their responses to developing positive classroom relationships were also significantly greater than early career teachers $F(1,259) = 1753.19$, $p < .001$. In contrast to these results, veteran teacher responses were significantly greater than pre-service teachers in their desire to establish teacher control in the classroom $F(1,259) = 610.47$, $p < .001$, and their responses to establish what is defined as a negative classroom environment were significantly greater $F(1,259) = 594.62$, $p < .001$ when compared to pre-service teachers. See Table 4 for complete ANOVA results.

Table 3. Mean Responses of Pre-service and Veteran Teachers for Each Motivation Component

Pre-service Teachers (n = 116)			First/Second -Year Teacher (n = 144)	
	mean	sd	mean	sd
Affirmation*	4.13	.33	3.89	.36
Rejection**	2.60	.48	3.80	.30
Control**	2.98	.49	4.18	.26
Empowerment*	3.71	.27	2.90	.25

ANOVA results suggested significant differences on this component (*), $p < .01$, (**), $p < .001$.

Table 4. Analysis of Variance Results for Early Career and Pre-service Teachers

Source	Sum of Squares	df	Mean Square	F	Sig
Empowerment Between Groups	63.96	1	63.96	930.2	p < .001
Within Groups	17.53	255	0.07		
Total	81.50	256			
Control Between Groups	89.41	1	89.41	610.5	p < .001
Within Groups	37.06	253	0.15		
Total	126.46	254			
Postive Relat Between Groups	214.55	1	214.546	1753.2	p < .001
Within Groups	31.33	256	0.12		
Total	245.87	257			
Reject Between Groups	92.03	1	92.03	594.6	p < .001
Within Groups	39.62	256	.16		
Total	131.65	257			

DISCUSSION

We are pleased with the initial results of this project as they suggest the need for additional discussions with teachers to reflect on their classrooms and those learning environments that might promote student motivation. Classroom structures that potentially can be defined in terms of motivational boundaries will encourage the research community to continue to explore classrooms and learning environments. These results also provide support for the development of learner-centered classrooms as defined by McCombs (McCombs and Whisler, 1997), in that providing a classroom environment or community culture that is based on positive social relationships, while encouraging the empowerment of students, may well be an initial step to improving student motivation and achievement.

Although teachers may have a direct impact on student motivation based on their classroom environments and classroom culture, the model is defined by the premise that the source of authentic motivation is internal to the self (Csikzentmihalyi, 1990; Harter, 1991). Authentic motivation that is supported by positive relationships and student empowerment would represent a radical change in practice for some schools. Although early career and pre-service teachers alike appeared to differentiate between the constructs of empowerment and positive classroom environments, motivation remains to be defined as an internal construct for the learner, and thus, teachers must define not only a classroom culture that is motivating for their students, but also motivating for them as teachers. In 2005, with mounting emphasis on the standards movement and standardized tests that promote these efforts, the consequences of narrowing of choices, teacher accountability, and reduced empowerment and tighter control for teachers and their students, schools are inadvertently forced to create learning environments that contradict a culture that could be more motivating to students.

In university pre-service teacher programs, more work is needed to encourage undergraduate students to explore more specifically how classroom environments can be designed to promote greater affirmation and empowerment of their students. Although both early career and pre-service teachers alike agreed with the need to promote positive classroom relationships, early career teacher responses suggested their need to exhibit control of the classroom and to provide limited empowerment to students. This may be an indication of pre-service teachers' lack of experience in the classroom and, in a sense, a lack of confidence in their ability to allow students the power to control the classroom learning environment. In reality, university methods courses often encourage pre-service teachers to maintain control of student behavior, the curriculum, and in effect learning, in order that they are not observed to be out of control in a chaotic classroom.

Early career teachers responded that they were less affirming and offered less opportunity for student empowerment, again perhaps reflecting the need for control and perhaps as a reflection of their limited breadth of experience and the greater emphasis on the national standardization movement of school cultures. The results of the project show that early career and pre-service teachers differ on some aspects of what may constitute a motivating classroom environment and culture.

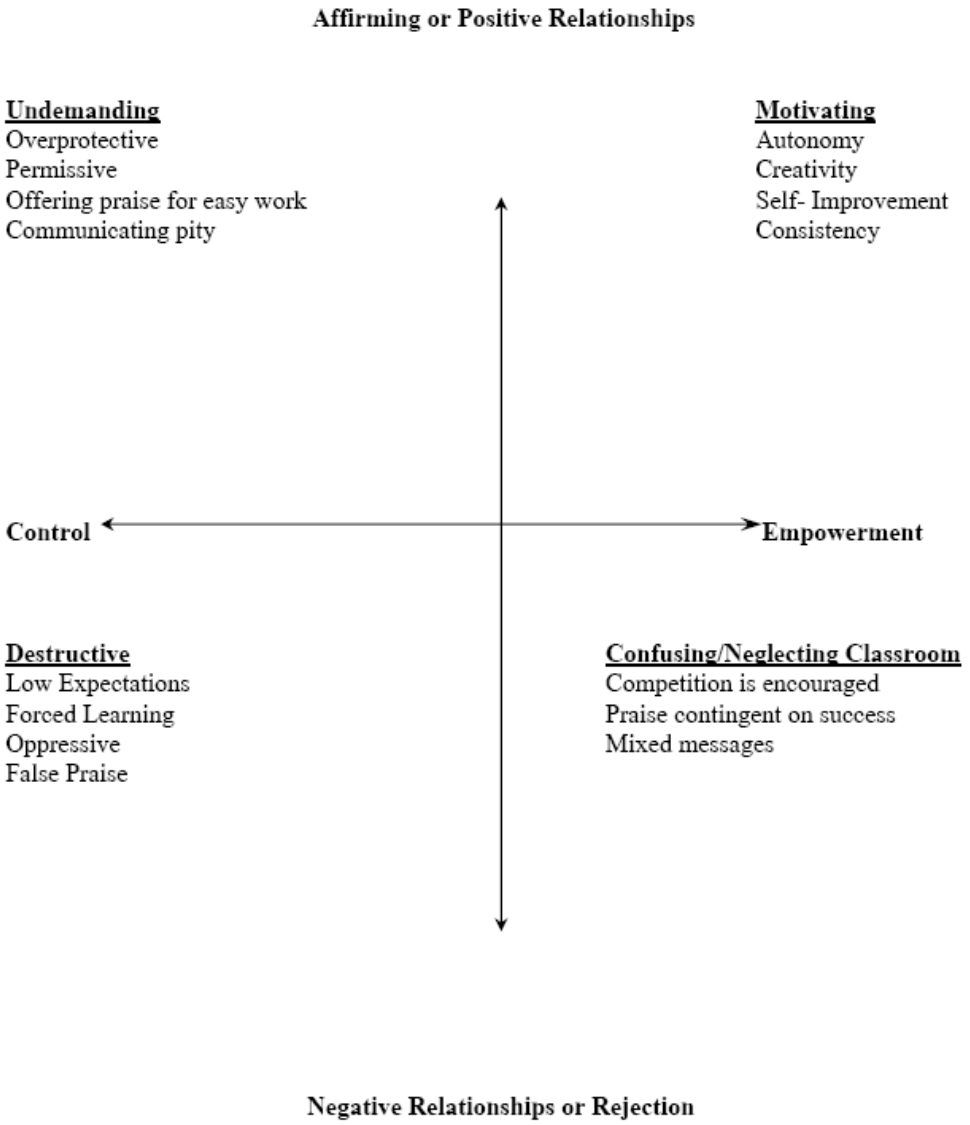

Figure 2.

In the near future, researchers should continue to explore the four potential classroom types that are suggested by the affirmation and empowerment classroom continuum. Additional research should explore and eventually define a combination of positive affirmation and control as an undemanding classroom, potentially characterized by an overprotective, restrictive, learning environment that offers praise for less than quality work. A combination of control and rejection may result in a classroom environment characterized as destructive and encouraging low expectations and "forced" learning in an oppressive atmosphere. Similarly, a combination of empowerment and rejection may result in a confusing classroom where competition is encouraged and where many students would eventually feel less worthy than their peers. Obviously, a combination of empowerment and affirmation may result in a classroom environment or culture that might be characterized as

motivating, where students are allowed to become autonomous and creative learners, while instilling in them a sense of personal value and worth. This will perhaps ultimately encourage a life-long desire for learning (See Figure 2).

If a teacher either develops, or is trained, to have an attitude of failure, having low self-efficacy, low self-worth, pessimistic attributions, and fixed beliefs about themselves and their intellect, how is it possible for them to lead students toward a classroom environment where self-worth and optimistic attributions will be limited at best? In essence, we continue the search for a classroom model that supports teachers, veteran and those with limited experience, to reflect on the kind of learning environments they encourage and create in there clasrooms. Effective learning-centered classrooms are not without dedicated teachers who encourage affirmation and positive relationships within the classroom and, at the same time, empower students to develop and achieve to their full potential (McCombs, 1994a). Learning centered schools also become those where upper level administrators empower teachers and local administrators to make decisions in an effort to create the best classroom learning environments possible. While empowering those at the local level, administrators would do well to promote a building level environment that encourages teachers' and support staffs' self-worth by encouraging an affirming, supportive building environment. We in the field of education have a long road ahead of us as we attempt to assimilate and accommodate legislative decisions at the national and state levels in the name of accountability. Professional development of teachers and administrators should continue to focus on opportunities to support motivating classrooms with the goal of improving students' academic and social confidence and ultimately their personal future achievement.

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Chapter 14

INTERACTIONISTIC PERSPECTIVE ON STUDENT TEACHER DEVELOPMENT DURING PROBLEM-BASED TEACHING PRACTICE

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ABSTRACT

The paper deals with the implementation of problem-centred teaching by four 2nd year pre-service teachers doing their Subject Didactics Practicum (SD 2) in one primary school classroom (grade 3) at the University of Lapland, in northern Finland. We focus here mainly on student teachers' experiences of mathematics teaching. The aim of problem centred mathematics teaching is to assist pupils to acquire new mathematical content through problem-solving, and help them understand how the new knowledge is connected to their former mathematical content knowledge.

In this article we focus on how participating student teachers' former beliefs, experiences and goals influence, and are in dialogue with the situational demands of the classroom which involve a new approach to teaching and learning mathematics: problem-based approach. The data gathering is based on the portfolios and interviews of four student teachers doing their practice teaching in the same classroom. The interview and field notes of cooperative class teachers and supervising lecturers are used as complementary data to check the credibility of the results.

The results are presented in the form of student teachers' developmental profiles. Due to different former beliefs and experiences, the students' initial orientation to a new situation and their strategic adjustments to it varied a lot. The article sets out different concrete examples of how the students put problem solving into practice. On the whole, the participants' view of teaching and learning mathematics became more many-sided and versatile. In the case of three students, the changes in their views of mathematics teaching and learning were clearly reflected in their teaching practices, while in the case of one student the changes in action were meagre, and he did not seem to have internalised the new approach**.** The results suggest the importance of paying attention to students' mathematical biography when aiming at changes in their pedagogical views and practices.

1. INTRODUCTION

Finnish secondary school students' performances in mathematics and science are of a very high level, according to PISA. The explanation for this success can be a combination of several factors (see Pehkonen, Ahtee, Lavonen (eds.) 2007). According to PISA, in Finland secondary school students' attitudes and school satisfaction are, however, among the lowest in Europe, which gives a reason to pay attention to pedagogical issues and students' role in learning. New approaches are needed especially within teacher education to give prospective teachers new ideas and practices.

The study focuses on how problem-centred learning is reflected in student teachers' beliefs of learning and teaching mathematics, and in their developing professional identities. Teachers' professional identity is understood as being constructed on the basis of the dynamic relation between their former beliefs and experiences, and the new knowledge acquired during the SD2. This involves becoming acquainted with new pedagogical approaches i.e. problem-based teaching. Former experiences and beliefs of learning and teaching mathematics are assumed to be related to the construction and reconstruction of students' pedagogical knowledge and identities (cf. Lauriala, and Syrjala, 1995; Lauriala,1997). These former images of teaching, gained as pupils, are often actualised during first practice teaching phases. Students' stories reveal the predominance of traditional methods in our schools, even today. Hence, deviating, new contexts are needed for pre-service teachers to become aware of the influences of these former experiences and thereby to be able to break the chain of influences of cumulative socialisation (cf., Lauriala, 1992; 1997, p. 128). Here, changes are studied in relation to classroom contexts, interaction and cultures, as well as to student teachers' co-learning and collaboration. The study describes changes in student teachers' beliefs and action, the interrelations of these, as well as the different paths and profiles of professional learning and development. The study also highlights the relationship between theoretical, cultural and practical knowledge. Methodologically and theoretically the study adheres to the interactionistic approach. Data gathering is based on four student teachers' portfolios and interviews, as well as on the interview and field notes of the cooperative teachers and education lecturers supervising them.

According to earlier studies, where it was explored the structure of 269 Finnish students' view of mathematics at the beginning of teacher education, 43 % of students had positive, 35 % neutral and 22 % negative view of mathematics (Hannula, Kaasila, Laine and Pehkonen, 2005). Student teachers' memories from their own years at school seemed to have an important meaning in their views of mathematics at the beginning of teacher education. Negative experiences often involve a negative view which can seriously interfere students' becoming good mathematics teachers. On the other hand, student teachers who have experienced only success in school mathematics may find it hard to understand pupils for whom learning is not so easy. In addition, at the beginning of elementary teacher education, students' beliefs regarding mathematics teaching are often quite teacher-centred. (Kaasila, 2000.)

Our research focuses on teaching practice, which is a crucial component of teacher education, and therefore a worthwhile context to study the development of students' views of mathematics. In studying the construction of preservice teachers' views of mathematics, we are concerned to see how the changes in views and practices take place, and how these

changes are related to each other. From earlier studies we know that a change in a student's view of mathematics does not necessarily mean a change in his or her teaching practices (Vacc and Bright, 1999). The first author's (see Kaasila 2000) earlier research findings indicate that in some practicum classrooms several students developed a rich array of beliefs, whereas in others the change and variety in beliefs was comparatively slight.

2. THEORETICIAL, METHODOLOGICAL AND METHODICAL UNDERPINNINGS AND CHOICES OF THE STUDY

The theoretical framework of the study draws firstly on the theories of beliefs and view of mathematics (Eagly and Chaiken, 1993; Hannula, Kaasila, Laine and Pehkonen, 2005; Kaasila, Hannula, Laine and Pehkonen, 2008). Beliefs can be placed in the three-component theory of attitudes, and can be seen as forming the cognitive component of attitudes (Eagly and Chaiken, 1993). Students' beliefs refer to their subjective, experiential, often implicit knowledge and feelings about a thing or a state of affairs (Lester, Garofalo and Kroll 1989). Beliefs are thus a part of a person's subjective knowledge, they involve affective components, are context-bound and open to changes (cf. Lauriala 1997). More specifically, a person's mathematical beliefs are understood to form a filter which deals with, and has an impact on his or her thoughts and actions (Pehkonen and Pietilä, 2004).

Secondly, the study adheres to the socio-cultural and socio-constructivist approach to teacher change (Putnam and Borko 2000; Feiman-Nemser and Beasley, 1997). In the socio-constructivist approach, a teacher community - and cultural contexts in general - are regarded as a primary factor in change (e.g., Vygotsky, 1978; Stein and Brown, 1997). Applying the socio-constructivist approach, we examine the development of students' view of mathematics as both an active individual process of construction and a broader process of enculturation (see Cobb, 1994). In, for instance, getting to know the new pedagogical culture, a person's former beliefs are brought to the dialogue, and even conflict, with the new ones, represented by the new context (Lauriala 1997). In our case the innovation involved problem-based learning, and meant changes in both teacher and pupil roles, in the learning material, as well as in the learning environment and climate, which deviated from the traditional teacher directed approach, and hence meant breaking the norms of dominant school culture.

Thirdly, self-beliefs have been demonstrated to play an important role in learning. We see that to learn is to develop an identity through modes of participating with others in communities of practice. Identity is the who-we-are that develops in our own minds and in the minds of others as we interact. Identity can be defined as a person's conception of self at a certain point, not totally or universally, and involving reference to "we" or a group a person identifies him/herself with (Hall 1999; cf. Lauriala and Kukkonen, 2003, p.2). Identity can be regarded simultaneously as both stable and changing (e.g., Demo, 1992; Strauman, 1996; Lauriala and Kukkonen, 2001). It includes our knowledge and experiences, and also our perceptions of ourselves (e.g. beliefs, values, desires and motivations), others' perceptions of us and our perceptions of others (Wenger, 1998). Further, people often develop their sense of identity by seeing themselves as protagonists in different stories: What creates the identity of the character is the identity of the story and not the other way around (Ricoeur, 1992).

Mathematical identity is a construct that describes the relationship of a person with mathematics (Bikner-Ahsbahs, 2003). According to Op't Eynde (2004), students' learning in the mathematics education community (e.g., in a school class) is characterised by an actualisation of their identity through their interactions with the teacher, the books, and their peers. While these interactions are largely determined by the social context they are situated in, students also bring with them the experiences of numerous other practices in other communities in which they have participated. Our earlier studies support the view of teacher identities as both situated and memory-based cognitions (Lauriala and Kukkonen, 2001).

A student's view of mathematics is an important part of his or her mathematical identity, consisting of knowledge, beliefs, conceptions, attitudes and emotions. According to earlier studies, we distinguish three components in students' views of mathematics: 1) their view of themselves as learners and teachers of mathematics, 2) their view of mathematics and its teaching and learning (Pehkonen and Pietilä, 2004), and 3) their view of the social context of learning and teaching mathematics, in other words, the classroom context (Op't Eynde, De Corte and Verschaffel, 2002). One essential aspect of the first component is self-confidence, which has a central role in the formation of a student's view of mathematics. The second component pertains to how instruction should be organised. The third component can be analysed in terms of socio-mathematical norms, in other words, normative aspects of interactions that are specific to mathematics (Yackel and Cobb, 1996). These are interpretations that become taken-as-shared by a community, for example, a school class. One example of a socio-mathematical norm is what constitutes an elegant solution in mathematics.

According to earlier studies it seems that mathematics education courses can influence teacher trainees' views of teaching and learning mathematics, as well as their views of themselves as teachers of mathematics. The most central facilitators of change were found to be the handling of and reflection on the experiences of learning and teaching mathematics, exploring with concrete materials, and collaboration with a pair or working as a tutor of mathematics. The most challenging task is to influence students' views of themselves as learners of mathematics (see Kaasila, Hannula, Laine and Pehkonen, 2008).

3. RESEARCH QUESTIONS

1) How were the student teachers' school experiences and earlier teaching experiences related to: a) their views of themselves as learners of mathematics, b) their views of themselves as teachers of mathematics, c) their views of learning and teaching mathematics and especially to their views of problem-based mathematics teaching.
2) How did the participants define problem-based learning, and how did they implement it in their own mathematics teaching during the SD2?
3) How did the implementation of problem-based learning relate to: a) student teachers' view of themselves as learners of mathematics, b) their view of themselves as mathematics teachers, and c) their view of learning and teaching mathematics?

4. THE METHOD

The study was carried out as connected to Subject Didactic Practicum 2 (SD 2) at the 3rd class in the Training School of the University of Lapland in February and March 2007. The goal of the four-week SD 2 practice was to familiarize students with planning and teaching lessons in mathematics and two other subjects, as well as with evaluating pupils' development in these subjects. As to pedagogical approach, in this practice the emphasis was on problem-centred teaching. Students gave about 12 lessons each, including 3 to 5 lessons in mathematics. During SD 2, they received guidance from university lecturers specialized in education of subjects, and from a cooperative class teacher in the training school.

The teacher of the classroom in question (the cooperative teacher) has worked for some years in the training school, and she has actively developed her teaching and supervision practices during that time. She is regarded as a competent and empathetic supervisor. There are about 20 pupils in the classroom, and they are accustomed to active, collaborative studying and learning.

Our research material consists of: 1) the interviews of four students and one cooperative teacher, 2) the observation notes of university lecturers in mathematics, science and handicraft and 3) the students' mathematics portfolios. The portfolios comprise the individual lesson plans and related self-assessments, an assessment of the progress of one pupil in the class, chosen by the student teacher, as well as the students' reflections on two self-chosen articles forming part of the required course reading (Räsänen, Kupari, Ahonen and Malinen, 2004).

When interviewing the student teachers, our approach was through narrative. The goal of the narrative interview is to get the interviewee to tell stories about things that are important to him or her**.** Riessman (1993) has identified some open questions that usually elicit narratives: the open-ended prompt "tell me …" makes it possible for interviewees to tell about things and events which are meaningful to them and often also to produce detailed narratives. Especially at the beginning of the interview we used narrative questions, for example: ″Tell me about that event or thing you best remember during SD 2.″ We also asked them to tell about their mathematical autobiographies. After that we asked them to tell about central themes e.g. what they understood problem-based learning to be, how they had applied it in their lessons in mathematics, how their views of mathematics had changed and how they felt that their cooperation with other student teachers had worked. The duration of each interview was between 40 and 85 minutes.

The Subjects

The four student teachers - Jari, Kirsi, Risto and Meri - were chosen for the study on the basis that they all were practising in the same classroom during SD 2 practicum. The other reasons for choosing them were the following: a) Their biographies varied as to the amount of mathematics teaching experience, and as to their success in learning mathematics at school, b) When starting to plan their mathematics lessons at the end of the mathematics education course before the SD 2, their collaboration started well, and c) one of them, Jari, functioned as tutor in mathematics for the 18 students' practice group from autumn 2006. The aim of the

tutor was to guide the other group members while preparing themselves for examinations in mathematics education course.

The participants' teaching experience: Meri had 7 years' experience of acting as a substitute elementary teacher, and Jari had 3 years' experience as a substitute special teacher, and he also acted as a substitute elementary teacher during his teacher education. Kirsi has been nearly half a year as a school assistant in a lower secondary school, she has also been for some time a substitute teacher. Risto's first teaching experiences were gained during teacher education in Subject Didactics 1 (SD 1) practice teaching, preceeding the SD 2, under study here.

The participants' proficiency in mathematics: Jari, Risto and Kirsi took advanced courses in mathematics in upper secondary school. Jari and Risto had succeeded quite well, but Kirsi poorly in the mathematics component of Matriculation Examination. Meri took only general courses in mathematics in upper secondary school with poor success in the mathematical section of Matriculation Examination.

The participants' view of mathematics at the beginning of mathematics education course: Jari and Risto had a mainly positive, and Kirsi a rather positive view of mathematics. Meri had a rather negative attitude and view of mathematics.

Problem-based learning: The problem-based learning was introduced to the second year students in the mathematics education course, which were given by the first author of this article. He taught the trainees in the course also with content (one area being geometry) and educational components. The latter emphasised principles drawn from socio-constructivist and socio-cultural learning theories. At the end of the course, the first author provided the students with some advance guidance in making their plans for the mathematics lessons for SD 2. During SD 2, he provided feedback on one mathematics lesson by each student.

The problem-based learning was presented during the second year studies also in technical work and handicrafts, as well as in biology. In the mathematics education course, students were introduced into the basics of problem-based teaching by adapting for instance the theoretical model presented by Haapasalo (1997), based on Galperin's (1957) orientation models.

The model of problem-based learning used involved following preliminary ideas and notions: The task is called a problem or research task if a pupil must combine former knowledge in a new way. It is to be noted that the concept of a problem is relative: it is bound to time and person. (Haapasalo, 1997) In problem-based or inquiry-oriented teaching of mathematics, pupils learn through solving problems: a pupil acquires new mathematical knowledge through problem solving and at the same gets insight of how new contents is related to his already existing mathematical knowledge (Nunokawa 2005). The idea of new learning contents is not given directly, but pupils must orient themselves to new contents, which aims at making the core points of the learning contents clear. This is carried out through pupils engaging in solving one or more research tasks related to the contents to be learned. In addition, pupils use manipulative tools or figures as an aid when solving the problem. The aim of using manipulative tools is to help pupils understand mathematical symbols (Uttal, Scudder and DeLoache, 1997).

The phases of problem-centred mathematics teaching are the following: 1) Orientation into a new mathematical concept, theorem, or procedure by solving a problem, 2) Definition of a concept, theorem, or procedure. After that pupils are practicing the new concept (or

theorem or procedure) through the following phases: 3) Identification, 4) Production, 5) Reinforcement. (See e.g., Haapasalo 1997.)

Data Analysis

In narrative analysis we analysed 1) the content and 2) the form of the narratives in student teachers' portfolios and interviews (see Lieblich, Tuval-Mashiach and Zilber 1998; Kaasila 2007a, 2007b), although the emphasis was on the former.

1) In analysing the content of the student teachers' narratives we first read their mathematical autobiographies which were included in their teaching portfolios. In a mathematical autobiography a student teacher tells about her or his own development in learning and teaching mathematics. A mathematical autobiography usually involves personally meaningful episodes, important persons, explanations, and the development of one's beliefs of learning and teaching mathematics. (Kaasila 2007b.) Then we constructed student teachers' mathematical biographies: our task was to explicate how a student teacher's earlier experiences have influenced his or her past and present mathematical identity. Here we used emplotment: a story line or plot that serves to configure or compose the disparate data elements into a meaningful explanation of the protagonist's responses and actions' (Polkinghorne, 1995). Within each mathematical biography we compared the teacher student's view of mathematics at the beginning and at the end of the mathematics education course. We also looked for principal facilitators of change manifested in the trainees' talk. So each mathematical biography contained a retrospective explanation (Polkinghorne 1995) linking central events in the student teacher's past to account for how his or her mathematical identity had developed.
2) We were also interested in the forms of narratives, i.e., the different ways in which a student teacher relates content, for example, problem-centred teaching. Especially, we paid attention to the way, in which each student told about the changes either in his/her teacher identity or mathematical identity.
3) Finally, in the analysis of narratives (see Polkinghorne 1995) we compared the teacher students' narratives systematically according to our main themes, especially problem-centred teaching.

5. THE RESULTS

We present the results in the form of case descriptions involving student teachers' former beliefs and experiences, their initial definitions and conceptions of problem-based learning as well as their practices and development while experimenting problem-based teaching during SD2. The study also addresses the students' views of themselves as learners and teachers of mathematics. The latter concerns the construction of their professional identity. Lastly, students' views concerning their future views of teaching are highlighted.

Jari's Case:

Memories from school: Jari's experiences from his mathematics lessons at school were mainly positive: "I liked maths, and it was easy for me. Especially in lower secondary school I succeeded really very well in maths. Learning mathematics demanded hardly any work, it was usually very clear to me". A turning point towards weaker learning took place in first advanced mathematics courses in upper secondary school: " I had become accustomed to do well at school without much effort, but at upper sceondary school it did not work anymore". Jari tells that during the last upper secondary school year "he took himself in hand" and did really work with maths. He succeeded quite well in the mathematics component of Matriculation Examination, which indicates a good knowledge of the subject.

Jari had a lot of teaching experience before entering teacher education. He had been as a substitute special teacher at lower secondary school for three years: "While teaching a small group, mathematics and mother tongue were the subjects that I mostly taught". In addition, he has been a substitute teacher for many times during his teacher education

View of mathematics at the beginning of teacher education: Due to his mainly positive school time experiences, Jari's view of himself as a learner of maths was positive already before starting the second year studies in class teacher education: "I've a lot of positive experiences of studying mathematics. Generally taken they are related to my own capability and success". Having had an opportunity to be a substitute special teacher has had a very positive impact on his view of himself as a mathematics teacher**:** "I enormously enjoyed teaching maths. I got the impression that also the pupils liked my teaching",

*Problem-based learning during teaching practice***:** Jari defined problem-based learning as follows: "Problem-based learning means that pupils find the answer by doing things themselves. It isn't given as ready, but the pupils must search for the answer by themselves, in one way or the other."

Jari applied problem-based teaching in all of his three mathematics lessons, and besides in first lessons of technology**,** and in one biology lesson. As an example, Jari describes his first mathematics lesson:

> "The goal of the lesson was that pupil would learn the concept of perimeter and learn to calculate the perimeter of a figure. I started the lesson with a reasoning task in where a man has a horse that ran away. I puzzled over with pupils how could we prevent the horse to run away. Pupils made some good proposals and after them someone discovered the solution I was looking for: The man built a fence to surround the horse. I illustrated this by securing a picture of the horse fast to the blackboard and then I drew a fence to surround it. Then I puzzled over with pupils how long the fence must be. In this phase I dealt out geoboards to pupils by means of which they built a fence similar to I drew on the blackboard. Pupils' task was to reason with their geoboards the length of the whole fence. I drew more rectangles on the blackboard, and pupils constructed them on their geoboard and calculated the circumference. I summed up this (phase) by asking pupils how they could find out the circumference of the figures."

> "Then I continued my lesson by telling that the circumference is called in mathematics by using a particular word. I was asking four pupils to stand hand in hand around the tables and I asked what kind of thing the pupils created. I gave some hints and then pupils discovered the word 'perimeter' I continued the lesson by giving pupils reasoning task in which pupils made on their geoboard different rectangles with a given

perimeter. For example, make a rectangle whose perimeter is 20 (units). At the end, the pupils calculated exercises of their text book."

Jari assessed his lesson as follows: "I think that the lesson was very successful. We achieved the goals we had set. Pupils learned to calculate the perimeter. They also understood, what the perimeter means. At the end of the section there was a self-evaluation which involved a question about which issue had been most interesting and easiest. Many pupils had mentioned in answers that the perimeter was the easiest content for them. It was nice for me as a teacher of the perimeter to read."

In his self-assessment, Jari evaluated his lesson very analytically. He gave reasons for his successes by referring to achieving the goals set for the lesson and by the likeability of the content to be taught, which could be seen in the collected and analysed self-assessments of the pupils. The first author observed this lesson, and his assessment is congruent with Jari's description of how the events went on during the lesson. Besides, Jari had a very effective way to draw out pupils' attention to him. This could be seen for instance while Jari was presenting the framework story (the horse running away) attached to his problem.

Already, during his substitute teaching experiences, Jari had constructed a preliminary view of problem-based learning. He emphasized the importance of why-questions: "I liked the question 'why'. I always demanded that the pupils give grounds for their solutions. We discussed and experimented with different solution models".

During SD 2 Jari experienced many successes and became to think that "problem-based learning is very meaningful from the teacher's point of view". The positive feedback given by the pupils was of main importance for Jari: "pupils liked problem-based learning."

Changes on the view of mathematics: Jari's view of himself as a mathematics learner and teacher was confirmed during mathematics method studies and SD 2. The change was enhanced by Jari's functioning as a mathematics tutor for his own group: "My view of myself as a mathematics learner was confirmed by being a tutor. The members of my group often asked me for advice to their tasks as well during the exercises as before the examination. Tutoring also increased my confidence in being a mathematics teachers. I felt like a good teacher."

Also Jari's view of mathematics teaching and learning changed towards more action-oriented direction: "In the mathematics' course I finally comprehended how important it is to use manipulative tools in mathematics. Actually while planning mathematics lessons I decided to emphasize the use of manipulative tools as much as possible. The subject of our section, geometry, gave us a good possibility for that." At the same time he takes some distance from the pedagogical methods he used as a substitute teacher: "My attitude towards teaching was then much more teacher-centred than what it is now."

Jari's identity talk is crystallized in the following sentences: "I have had that kind of feeling already for a long time, I have acquired pretty many teaching experiences, so I didn't have anything to worry about. I always knew when going to the lessons, how I would act and how I would do things. I was prepared so that if something goes wrong, I'll continue by acting on another way. In problem-based learning I really liked it that things were somewhat uncertain and not so clear." The identity talk points out that Jari's view of himself as a teacher was as positive as to give him very good skills to tolerate uncertainty brought by the new innovation. In addition he had a good way of thinking about the teaching task (for example a skill to 'bend' with the situation from the planned lesson plan).

Kirsi's Case:

Memories from school: Kirsi had a pretty positive view of mathematics from her own time in the comprehensive school. The following positive experience has best stuck in her mind from the upper level of comprehensive school: "One of my friends has always been poor in mathematics and I can remember when I was teaching her percentage before the math exam. She got grade of seven or was it eight (the maximum grade is ten). Anyway it was the best grade in mathematics she had ever got and I can remember how happy she was. This has stuck on my mind very well. I was very glad to be able to help her." On the other hand Kirsi criticizes very strongly the teaching methods used by her teachers: "My mathematics teacher in the upper level of comprehensive school was very teacher-centred. He usually just explained the new thing on the blackboard and then we started to calculate. The teaching really was not motivating to us pupils." Kirsi told that in the end state of comprehensive school "my interest towards mathematics was moderate and as a whole I felt that I knew mathematics, so I chose advanced courses of mathematics in the upper secondary school."

At the beginning of the secondary school Kirsi's view of herself as a mathematics learner changed notably: she did poorly on exams and her level of motivation decreased: "I remember when the stress and fear consumed me when I studied for the examination. I tried to memorize things… I was totally ashamed, when I did so poorly…Mathematics felt nightmarish then." Kirsi had to admit after few courses that she would not succeed in the style she had assumed in the comprehensive school: "I had to start studying seriously." The next course covering geometry went well. After that she did sometimes better and sometimes poorly. Kirsi failed in the advanced component in mathematics of Matriculation Examination. Later she did the general component in mathematics and it "went well".

Kirsi had very little of practice in teaching before teacher training: "I got some experience as a school assistant in the upper level of comprehensive school, well over six months…I also taught some of the school subjects, but it usually went so that they told me in the preceding recess that this is the topic of the lesson."

*View of mathematics at the beginning of teacher education***:** At the beginning of the teacher training Kirsi's view of herself as a learner of mathematics was somewhat controversial. In one hand she told about many oppressive experiences from the secondary school and, in the other hand, she described her learning of the mathematics in the secondary school as very useful: "Thinking afterwards, I think of, my study of the advanced courses of mathematics as an adventure. I do not regret that I ploughed through it." Kirsi had teacher centred and textbook bounded beliefs of mathematics teaching. "All of the mathematics teaching I experienced during my school years were teacher centred. In that time I did not even realise it, because I thought that it was the way to teach mathematics."

Problem-based learning during teaching practice: Kirsi emphasised that she had got to know of the problem-based learning only during the teacher training: "As a matter of fact it has brought new perspective for myself. The pupil is the active one in it, taking part in the action and you give the pupil space to figure it out himself and to think about these things. The teacher will not give everything … The pupils themselves explore those things by action."

"Problem-based learning has come up in the university especially in the mathematics' course, but also during the first study year in the science course and in the second study year

in the handicraft course: For example, the handicraft teacher here at the university does not give us very clear answers but makes us think it over ourselves."

In the following Kirsi describes her first mathematics lesson, where the topic was to lead the pupils to concept of the co-ordinates:

> "First I asked pupils to solve a problem. I told an outline story, where Maija and Matti needed help from pupils of our class (3a) for finding an ice cream kiosk. Pupils must advise how Matti and Maija find the kiosk by using a map (on the blackboard) which reminds about the co-ordinates. At first each pupil thought about the problem with his or her pair, and then we talked ideas through together. Pupils discovered different solutions eagerly. At first pupils talked freely about different possibilities… a part of them was also false. Then I began to introduce to them how to use co-ordinates so that because of road works we must first go rightwards the street below. We finished our examination when pupils answer was "three streets rightwards and two upwards". I was satisfied with my introduction, and pupils participated eagerly. Certainly, I would emphasize more that the ice cream kiosk was located on the intersection of the streets."

> "I continued the lesson … by presenting a problem and then we talked it through together. Pupils had also to think, how we could call the point. At the beginning, some of pupils were a little bit embarrassed and they thought it was difficult to use co-ordinates… Because the handling of the first problem took more time than I thought beforehand, I did not present all the introduction tasks. Of course, it was important that, that pupils have an opportunity to train the new content independently by solving the tasks from their exercise book…. At the end I got an impression that pupils did understand the thing"

According to Kirsi the cognitive and affective goals set for the section became realised. "Everybody learned to know the co-ordinates and most of the pupils learned how to use them according to the aims set for the first lesson. The affective goals set for the section involved that the pupils would have experiences of success and that they would develop a positive attitude towards mathematics. In my opinion these aims became realised. There was a positive learning atmosphere in the classroom and the pupils' disposition towards the contents to be learned was enthusiastic."

In the lesson given by Kirsi the principle of the problem-based learning worked well. The lesson was also pupil-centred, and the new content (concept of the co-ordinates) was well linked to the pupils' life experiences. In addition Kirsi evaluated the success of her lesson in relation to the goals of the whole mathematics section. As a whole, Kirsi applied problem-based teaching in three of her mathematics lessons. She reflected on her lessons widely and related them well in her portfolio to the literature of the course: "In the constructivistic teaching the teacher is the facilitator of learning and the pupil is the active agent. It is essential to understand the issues at hand, not to learn to repeat in the 'pike is a fish, pike is a fish style."

Changes on the view of mathematics: Kirsi's view of herself as a teacher and as a learner of mathematics did not change much after the mathematics education course and SD 2: "As a matter of fact I think that my view of myself as a learner of mathematics has not changed much during the course. I still feel that I know the basic things well and the course did not change that view much. The SD 2 was the first time that I was a real teacher. At least based on the experience of the SD 2 I got a view that I am a pretty good mathematics teacher, and I

also have a positive view of mathematics as a whole and the teaching of it. Indeed four lessons is pretty small amount." Kirsi's attitude towards mathematics teaching changed into a more positive one: In the beginning of the second study year, the mathematics was "rather neutral" subject to teach. After SD 2 the mathematics belonged to the group of the most pleasing subjects to teach.

The biggest change took place in Kirsi's view of learning and teaching mathematics. Her view changed from a teacher-centred one, involving emphasis on 'drill and practice', towards pupil-centred and problem-based teaching: "In the lectures and the practice of the mathematics education course the emphasis was on the using manipulative tools, problem-based teaching and discovery learning. They were the skeleton of the whole course. The course has dramatically changed my view on mathematics and teaching of it and has given me a fresh point of view on teaching of the subject."

In many points, Kirsi can be seen to distance herself from her earlier beliefs. The ideas brought by the new innovation, are in clear conflict with the view Kirsi has become acquainted with during her own school years. This tension between present and former mathematics identity also forms a basis for the construction of her new, emerging identity. Kirsi intends to implement problem-based learning also later:

> "Problem-based learning does not necessarily seem to be the easiest alternative for the teacher to realise teaching, and I do have myself a lot to learn in it, but what is most important is that I have however internalised some of its principles and would like them to be a natural part of my teaching,"

Risto's Case

Memories from school: Risto had many positive, critical or significant experiences of learning mathematics already before his school years. He described intensively how he had enjoyed playing with Legos, and how he had learned calculations and spatial thinking through them:

> "I remember being interested in mathematical things as a child. Especially I played with the Lego-blocks durin the winter. While playing with Legos I remember learning addition and subtraction. I do believe that the building with the Legos also developed my dexterity and spatial thinking." (Pf.)

Risto also learned to read time by the age of five**.** During comprehensive school his experiences of learning mathematics varied a lot, depending on the teacher, and his/her style of teaching. His talk reveals feelings of pride when he had succeeded in maths, as during the grades 3-6, and 9. His achievements, however, became weaker when starting the upper secondary school. He had chosen the advanced course in mathematics, but was not willing to use enough time for just practising and solving tasks. Risto regarded the teaching methods used in the upper secondary school as old-fashioned: "All the lessons were teacher-centred and we had a constant hurry to the next issue". As to his own studying, Risto would have wanted to understand the tasks and formulas which he was using, but it would have demanded time, which he didn't want to waste on mathematics. During the last year of upper secondary

school his attitude changed, once again. The new teacher, who was the Head of the school was more demanding, and so Risto started to do his homework properly:

> "It was good that I was finally awakened to do maths and solve tasks properly. I had enormous gaps in my knowledge concerning the eight former courses". (Pf.)

Risto did a lot of work, and his performance in the mathematics component of the Matriculation Examination was quite good. When reading earlier research on teacher students' mathematical views, Risto recognizes in himself features of theoretical, reflective learning style.

View of mathematics at the beginning of teacher education: The experiences of success during his own school time contributed to that Risto had a rather positive view of himself as a learner of mathematics when ending the school:

> "I ended the school with such a view of mathematics, that if am persistent and work hard, so I'll certainly succeed in mathematics". (Pf.)

The above quote indicates that Risto attributed his failure or success in mathematics to internal issues, such as his own ability and effort, and so he felt that he was in control of his learning achievements, which is associated with high self-confidence.

Because Risto had no previous experiences in teaching mathematics, his view of himself as a teacher of mathematics had not taken shape yet. Although Risto criticized the teaching methods of his upper secondary school teachers as being too teacher-centred, his own view of teaching accorded with these and was traditional.

Problem-based learning during teaching practice: In the interview Risto defined problem-based learning followingly:

> "It's not that information loading, but that it is about that the learner by him- or herself goes into the actual issue. And that he is able to find out the knowledge and then also to process it in his own mind". (Int.)

During teaching practice Risto experimented with problem-based learning in his three first mathematics lessons. The phases of the first mathematics lesson were what follows:

Risto has fixed on the blackboard different triangles cut from carton. The pupils' task is to classify triangles as acute-angled, right-angled and obtuse-angled ones on the gounds of the angles. All volunteers can in turn go to the blackboard and classify one triangle. After that Risto revised with the other pupils if the solution was right. Then Risto shows a transparency, which consist of a cute-angled, a right-angled and an obtuse-angled triangle. He asks: How do you describe these polygons? Can you classify triangles by using some of these features? Then Risto asks about the features of different triangles. At the end pupils are solving tasks from their exercise book. (Based on Risto's lesson plan, Pf.)

During the first lesson, Risto's approach was rather teacher-centred, although he tried to apply problem-based learning. The pupils were not allowed to classify their paper-made triangles in peer groups, but the discovery of an insight took place on the black board so that the work pair who had solved the problem first, told the solution to the others. This meant that

only some of the pupils had an opportunity to find by themselves the insight of how to classify the triangles (Based on the education lecturer's observation notes).

At the beginning of the second lesson, Risto gave pupils different quadrilaterals and their task was to classify the figures. In the summarisation, the concepts as well as the mind map connected to them, were dealt with. After that the pupils searching for different quadrilaterals in the classroom. (Based on Risto's lesson plan, Pf.)

On the basis of the lesson plan, the second lesson was clearly more pupil-centred than the first one, and the problem-based learning was utilised to a greater extent**.** Risto's reflection on the lesson is interesting: he paid only relatively slight attention to the use of manipulative tools or to the realisation of pupil-centredness. This may indicate that Risto has not yet internalised all the essential principles of problem-based learning**.**

In the interview after SD 2 Risto's attitude towards problem-based learning was slightly reserved:

> "Maybe the problem-based learning is slow as if..…it feels much easier to teach by using quite usual methods… perhaps the learning by imitating (following a model) might be the best method" (Int.)

Changes in the view of mathematics: As to Risto's view of himself as a learner of mathematics, it was positive and didn't change during practice teaching. Although he had no previous experiences in teaching mathematics, Risto was rather satisfied with his mathematics lessons. He was also able to present some suggestions for how to develop them. On the whole, Risto's view of teaching mathematics seems to be more developed or sophisticated than his practice. This is quite understandable, often teacher talk and action may differ, and in the case of student teachers more time is needed to internalise the innovation and to get used to implement it. As compared to others, Risto's case represents an interesting conflict: his lessons (at least in mathematics) were partly teacher-centred, but when evaluating his lessons, Risto paid however attention to pupils' reactions and doings. He was able to deeply reflect on his own and pupils' actions, and these reflections unfolded understanding of the core meaning of problem-centred teaching and learning.

On the other hand Risto's portfolio indicates changes in his views of teaching and learning:

> "Learning is much more than just silent cramming, rote learning and copying the teacher". (Pf)

As to the future, Risto wants to cultivate joy and inventiveness in his teaching:

> "Pupils must have an opportunity to feel happiness, which comes from grasping things. This is what I do want to cultivate in my own teaching. Children must have an opportunity to experience joy while solving different kind of mathematical problems. They need to see mathematics as challenging, but manageable issue". (Pf.)

It seems that Risto was striving for interactive and pupil-centred teaching, but the teacher-centred model, dating back to his school years, was deeply rooted and more easily accessible in his teacher identity and action, which impeded the change process.

Risto compares in many points his way to plan the lessons to that exercised by more experienced students Jari and Meri: "I feel as if they were already ready as teachers, they had their own, clear thoughts beforehand. I was maybe such a one who needed more time to think about"

The development of Risto's teacher identity seems to be affected by his own school experiences, which became activated in the mathematics teaching situations he confronted during SD 2. These memory-based influences involved both pleasurable elements (his own success) as well negatively coloured aspects (old-fashioned methods, lack of interest) which makes Risto's identity construction somewhat complicated (cf., Lauriala and Kukkonen, 2003). Furthermore, it seems that due to his greatly varying success and motivation in mathematics at school, Risto had been 'compelled' or induced to reflect a lot on his learning and its dependence on both external (such as teacher's attitude, teaching style, and preferences) and internal factors (e.g., his own effort and allocation of time). It seems that he has developed meta-cognitive knowledge and skills, as well. He has grown to understand, through his experiences, the importance of emotions in learning, as well as the decisive role that the teacher plays in the formation of the quality of pupils' experiences of mathematics and views of themselves as learners. To sum up, Risto's teacher identity came to involve both emotional and cognitive aspects. His case indicates restructuring of language, but not wholesale internalisation of the new approach in mathematics learning and teaching. He states that joy of learning is possible to achieve through problem-centred teaching, although he is still hesitant or sceptical about its use more widely or totally in his teaching.

Meri's Case

Memories from school: As to the experiences gained during secondary school, Meri's view of mathematics was neutral, but during the upper secondary school her view had dramatically changed:

> "I do not know what happened to me. Maybe my belief that only boys learn maths emerged as so stunning and formed an obstacle for my learning… Especially the tasks involving applications caused me enormous anxiety. I stopped trying."

She carried on: "I was ashamed of my poor achievements in general course in mathematics and my performance in the mathematics component of the Matriculation Examination". She thought then "Never mathematics anymore" (Pf.) The following extract from Meri's portfolio describes her experiences:

> "By working diligently and punctually I coped with maths during secondary school, but at the upper secondary school even the word mathematics made me powerless." (Pf.)

However, Meri needed mathematics later, while being a school helper and when acting as a substitute teacher for over 7 years. She felt that mathematics was a most challenging subject to teach. Meri points out how lucky she was to have an opportunity to teach pupils, who had a strong motivation to learn maths, and who were genuinely interested in it. She found different learning games as well group as pair exercises interesting. Thus children became important

definers of Meri's teacher identity, and a source of learning to teach mathematics, which shows a dynamic and mutual interaction between the teacher and pupils, as well as their interrelated identity formation. This coincides with our earlier studies on how teacher and pupil identities are reciprocal and interdependent cognitions that develop in and through dynamic interactions in the classroom. (Lauriala and Kukkonen 2005)

> "It was so nice to follow pupils' playing and solving different kind of problems, because the small pupils often spoke out maths while playing and solving problems". (Pf.)

View of mathematics at the beginning of teacher education: Meri represents a teacher whose view of self as a learner of mathematics was weak. According to Gellert (2000) teacher trainees who find mathematics to be awful during their school years will have a tendency to protect their pupils from mathematics, for example, by using various learning games and ignoring the subject proper.

*Problem-based learning during teaching practice***:** Meri defined in the interview problem-based learning as follows:

> "Problem-based learning is such that a teacher doesn't give the answers as ready, and neither other things. These aren't taken as ready, but in a way it (problem-based learning) means offering a problem which pupils start to reflect on, it's such problem-based studying". (Int.)

Meri applied problem-centred teaching in all the three lessons she gave. On her first lesson she utilised the following research task. "There are many kinds of different figures on the overhead, among which there is also a point, line, segment of line and ray. Pupils work in groups and search for suitable names for each figure. In summarisation the names given by the pupils are dealt with, and the point, line and ray are taken under a closer scrutiny, for instance how does a segment of line differ from ray? (Pf, extract form Meri's lesson plan).

The first lesson Meri gave in mathematics during SD2 succeeded well, which gave her confidence in coping with mathematics teaching. In the interview, Meri tells how nervous she was beforehand, especially when confronting the pupils. She, however, felt that the pupils were acting as if she had been teaching them before, which made it easy for her to start the following lessons. In her self-evaluation Meri describes pupils' enthusiasm to learn, their experiences of success when each group's solutions were presented and when there was not only one right answer to the problem in question. Besides pupils' enthusiastic participation, Meri attributes her success as a maths teacher to her continuous and deep reflection on the essence of geometry.

During her second lesson Meri applied problem-centred learning appropriately. The lesson was pupil-centred and pupils used manipulative tools on a versatile way. (Based on the mathematics didactic lecturer's observation notes.)

Meri's narrative reveals features of different types of reflection, as well reflection for action, in action, and on action. In her portfolio, she reflected on her choices and action, and was able to give justifications for these. The following is an extract from her portfolio:

> "I chose the angle for the focus of repetition in this lesson, deviating from the section plan, instead of point; the line and the segment of a line and a ray. These concepts pupils

> already seemed to know well, but I though that while dealing with the angle some points remained unclear and I wanted to be sure that the pupils really understand the angle. Through blackboard pictures I still concretely illustrated the different parts of the angle. Pupils seemed to understand the issue". (Pf.)

Meri felt that the goals for the lessons were reached and that she had achieved a good feeling of teaching. She said: "I don't feel it to be a monster anymore", referring to her negative experiences of learning geometry at school.

According to Meri, problem-based learning had been realised in the practicum classroom already before SD2-practicum, which made it easier for students to realise it there:

> "The pupils very eagerly participated in the activities, and you didn't need so much to explain the problems. They seemed to know how to act, so the approach must have been used here (in the classroom)".. (Int)

Problem-based learning also corresponded with Meri's ideal teacher identity, which she had set for herself during SD2. It is very important for commitment and outcomes of learning that a person's own goals and aims coincide with the new knowledge. Meri's experiences reflect a balance between ideal and norm identity, which partly explains her feelings of satisfaction and joy (cf., Lauriala 1997, pp. 86-88; Lauriala and Kukkonen 2003).

When reflecting on her practice teaching experiences, Meri concludes that the most challenging issue in problem-based learning is giving problem instructions and drawing the solutions together:

> "So that it would be as simply said as possible. And that it's on a child's level, so that you don't use such a concept that the pupils aren't able to comprehend" (Int.)

Besides learning by doing, and being in interaction with the pupils, Meri's view of problem-based learning was based on reading relevant literature. She had read an article on constructivism (Leino 2004), the basis of which seems to complement her view of problem-based learning in the following way:

> "The basic thing that I learned from the article is that knowing mathematics means finding problematic situations, formulating these into adequate questions, and solving these questions, either alone or together with the others. This is what makes learning mathematics meaningful. Through shared experiences learning becomes easier and one gets new perspectives". (Pf.)

Changes in the view of mathematics: Meri's experiences of teaching mathematics during SD2 were very positive. Becoming acquainted with problem-based learning during SD2 seemed to change Meri's view of learning and teaching mathematics.

Meri's identity talk can be crystallised by two points while citing Schaffer's ideas: a) as an openness to learn new things, and as b) questioning of the taken-for-granted beliefs; "I do want to get practice in seeing a miracle also in the taken-for-granted". (Pf.)

The above said justifies the conclusion that the familiarization and experimentation with problem-based learning during teacher education meant a critical turning point in Meri's professional development. The child-centred ideas that she already had realised, became even

more firmly rooted in her mind. They seem to form the main part of Meri's key rhetoric, which means a strategy by which a person constructs continuity and coherence in his or her narration (cf. Komulainen, 2000; see also Kaasila 2007b).

As to the impact of literature on Meri's views of teaching and learning mathematics, she refers to an article on constructivism (Leino, 2004), and writes on her portfolio that a teacher must be able to pay attention to pupils' beliefs and views on mathematical knowledge, which sets challenging tasks for the teacher. Meri claims that for this reason mathematics must be pupil-centred, and the teacher should induce pupils to discuss on problems. In addition, the teacher can achieve valuable knowledge by observing the pupils.

For Meri, learning seemed to be connected to, and enhanced by her interaction with, and close observation of the pupils: Observing the pupils, and reflecting teaching and learning from their view point, were important tools in her efforts of learning to teach. Both positive experiences of teaching mathematics during the practicum and the mathematics education course contributed to Meri's overcoming her former view of herself as a poor learner of mathematics, and to constructing a positive view of herself as a teacher of mathematics.

> "Last autumn, at the beginning of the mathematics course here in teacher education, a terror caught my mind for a moment. My uppermost question was: How do I cope with math. My greatest fear was that I don't pass the exams. Then I understood, that we are going to be taught how we could as if teach the mathematics. And then the exercises contributed a lot in achieving this end. And then, after the autumn term, I sought for the knowledge about mathematics and read different researches, and actually I was working on and around it all the time. I felt that mathematics doesn't make me powerless anymore" (Pf.)

Due to her positive teaching experiences, Meri's constraints of and fears in mathematics teaching were removed and she felt that she was actually willing to teach mathematics. The most critical experiences concerned teaching geometry; she felt that she had learned a lot herself, and that many issues that had been difficult before became clear. She gained self-assurance and confirmation in the new teaching approach:

> "That it's really possible to challenge the pupils to invent and induce insights also when dealing with new or unfamiliar issues."(Int.)

Good and supporting supervision seemed also to be an important factor in Meri's change from a poor learner of mathematics to a self-confident and efficient teacher of mathematics. The following quote from Meri's interview illustrates this change of view:

> "Then in a way I have got rid of thinking about myself, that am I good or poor in the mathematics myself…That you can teach mathematics even if you didn't know maths so much yourself" . (Int.)

One reason for Meri's ability to learn from children might be her long teaching experience; beginning teachers usually are so overwhelmed with learning the subject contents and managing the classroom, that they don't have a capacity for paying attention to individual pupils. Meri had also read an article on conceptual change (Merenluoto and Lehtinen, 2004), which made her reflect on how the pupil's former knowledge plays a significant role in their new learning, The theory had contributed to Meri's view that a teacher should prefer teaching

methods that aid pupils to become aware of their own thinking, in other words such that generate meta-cognition.

6. COMPARISON BETWEEN THE CASES

In the following table (see Table 1) we have collected the different aspects of the development of our four student teachers' mathematical identity. The biggest changes took place in Meri's mathematical identity: Meri's view of herself as a learner and teacher of mathematics had noticeably changed and her attitude towards teaching mathematics had changed from unpleasant to pleasant. Jari's, Kirsi's and Meri's view of teaching mathematics had changed into broader perspective. Also their attitude towards problem-centered teaching changed to a very positive direction. Clearly smallest changes took place in Risto's mathematical identity.

Table 1. Changes in the four student teachers' mathematical identity during SD 2 practice

	Phase[1]	Jari	Kirsi	Meri	Risto
Memories of school mathematics	1	++-	++-	---	++-
School time teachers' mathematics teaching	1	Teacher-centered	Teacher-centered	Teacher-centered	Teacher-centered
Course selection and success in Matriculation Examinations' mathematics test	1	Advanced Good	Advanced Poor	General Poor	Advanced Good
Teaching experience in mathematics before teacher education		3 years	Very little	7 years	Not at all
Attitude towards teaching mathematics	2	Pleasant	Pleasant	Unpleasant	Pleasant
View of oneself as a mathematics learner	2	+++	++-	---	+++
Teaching practice in SD 2	SD 2	Pupil-centered	Pupil-centered	Pupil-centered	Mainly teacher-centered
Attitude towards teaching mathematics	3	Pleasant	Pleasant	Neutral	Partly unpleasant
Attitude towards problem-centered teaching	3	Very positive	Very positive	Very positive	Hesitant

Table 1. (Continued)

	Phase	Jari	Kirsi	Meri	Risto
View of oneself as a mathematics learner	3	+++	++-	++-	++-
View of oneself as a mathematics teacher	3	+++	++-	+++	-- +
Change in view of mathematics teaching	3	Big	Big	Big	Quite small
Teacher identity in mathematics	3	Confir-med	Adjusted Moderate Changes	Transformed	Incongruent Conflictual Potential new elements

In this study the development of Meri's and Risto's beliefs and teaching practices in mathematics varied considerably from each other. Meri gained many significant positive experiences in mathematics during the mathematics education course and second-year teaching practice. In Risto's case the changes were smaller. We can try to explain the differences observed here by the following things: 1) Meri was an experienced teacher and it seems that she could use the pupils of the class as a resource for learning a new innovation in an effective way. The deviating critical experiences led Meri to partly reconstruct her pupil conceptions and at the same, her view of a teacher's role, indicating the relationship between these two perceptions. Views of pupils as inquisitive, active learners challenged especially Meri to change her role and actions, which in turn influenced her situational identity (cf., Lauriala and Kukkonen, 2001), and her view of herself as a teacher of mathematics, too. 2) Although, Meri had negative experiences from mathematics from her own years at school, it seems that she could transform her memories into positive action. It was easy for her to take the role of weaker pupils. This seemed to be one of the main reasons why her teaching changed towards pupil-centredness. We can say that Meri used her earlier experiences of mathematics to define her present identity: She entered into a dialogue with her past mathematical identity and defined it in a new, more positive manner. (see also Kaasila 2007a), 3) Risto was a novice as compared to Meri and Jari and he taught mathematics for the first time during SD 2. He also received some critical comments from the other students concerning his first mathematics lesson. These processes seemed to influence negatively Risto's view of himself as a teacher of mathematics. In addition, it seems that he had internalised teacher-centred beliefs used by his own mathematics teachers so strongly that the mathematics education course and SD 2 teaching practice could not influence very much his beliefs. Also Kaasila's (2000) study gives hints that teacher students with mainly positive experiences from their years at school have difficulties to take the role of weaker pupils and to adopt pupil-centred beliefs. One main explaining factor may be that Risto’s commitment to collaboration between the students was notieably smaller than that of the others (Kaasila and Lauriala, 2008).

[1] Phase: 1 = school time, 2 = at the beginning of second year studies, 3 = at the end of second year studies.

Traditional learners becoming involved in new, problem-based learning were initially tentative about engaging in this process, because their previous experiences had given them too slight confidence about engaging in the process of learning. Their commitment to the process can be tentative, and engagement will only emerge over time (Crossan, Field, Gallacher and Merrill, 2003, 58). This can partly explain why Risto's mathematical identity did not change very much.

7. CONCLUSION

Our results indicate that the students learned from their teaching experiences, which were supported by, and reflected in the framework of research literature. The problem-based approach was thus likely to bridge the teaching-research gap, partly because the students read explanatory theory for research on teaching that could be directly and transparently linked to classroom realities (cf., Nuthall 2004). Our results thereby imply that to learn effective teaching methods, students profit a lot from research that adheres to theoretical understanding of daily activities in learning and teaching. The students seemed to be explicitly concerned with pupils' learning, as they tried to enhance pupils' active role in learning, and aid them to become creative thinkers and problem-solvers**.** The subjects also reported having gained new insights into their teaching from peers. We have analyzed students' collaboration in our other article (Kaasila and Lauriala, 2008).

What were the processes like through wich students' beliefs about mathematics changed. It seems that the views of mathematics teaching and learning of Meri, Kirsi and Jari became diversified already in the mathematics education course and while collaborative planning the mathematics teaching section which was part of the course. On the other hand, the experiences of the success in the SD 2's mathematics lessons confirmed their new beliefs. Our research supports the fact that there is an interactive link, an iterative, reciprocal connection between beliefs and teaching practices. This coincides with Goldsmith's and Schifter's (1997) ideas according to which new beliefs about learning and teaching mathematics and about the nature of pupils' mathematical thinking formed the basis, where the teachers acquire new perspectives on their pedagogical thinking and teaching practices. When student teachers are teaching according to their new beliefs, their beliefs are further modified and changed. More generally taken, this is associated with the question about the link between the action and the thinking. In this respect, the beliefs and the actions of Meri, Kirsi and Jari were in balance: their teaching methods during SD 2 and their definitions of the problem-based teaching of mathematics corresponded each other. Only Risto was an exception in this respect.

Although the findings of this study are promising, as to the influences of practice experiences in changing students' views of mathematics and views of self as learners and teachers of mathematics, two reservations are important to note.

Firstly, the different data gathering methods used in the study yielded partly contradictory results, especially in the case of Risto: We can think, that the interview gave a more spontaneous reaction, revealing hesitation towards problem-based teaching, while in the portfolio (done over one month later) Risto presented himself as favouring problem-centred teaching, which may be due to a need to present himself to the education lecturer as a proponent of the method. This may imply complying to the normative teacher identity within

the course. As a whole, the rhetoric of self-development, which is manifested in all the students' talk, can sometimes obscure the views students really have (see also Kaasila, 2007b)

Secondly, we do not know how permanent the changes are. It may be that the positive experiences gained during the mathematics education course will not necessarily suffice to maintain a positive view of mathematics after teacher education. Our earlier studies indicate it to be difficult for novice teachers to transfer the innovative ideas learned in teacher education to their own classrooms (Lauriala and Syrjala, 1995; Lauriala, 1997).

The results may benefit other teacher educators in understanding the variety of former learning experiences and beliefs of teacher candidates, which should be paid attention to in teaching different subjects. When trying to implement innovations within teacher education, it should be noted that some students, due to their background, are not able to adopt the new practices, without support which helps them to reconstruct the view of themselves as learners and teachers in a more positive direction. Also the models of teaching given by one's own teachers influence student teachers' teaching practices, if these experiences remain unreflected. This should be paid attention to both in practice teaching and theoretical courses**.** Collaborative resonance between the representatives of the university and teachers in practice schools (Demonstration Schools in Finland) is necessary to carry out effective innovation and also to understand it. Theory and practice -gaps can be overcome best by locating practice teaching in contexts which allow the prospective teachers as students to experience joy, freedom and safety in their learning. The activities provided by problem-centred learning and teaching, in which the student teachers engaged in the practice classroom here seemed to become a source of intrinsic reward for them (not only a means to enhance pupil learning outcomes). For instance, their reports imply how freedom and peace in the classroom climate provided them with opportunities to learn to know pupils better and to discover that learning can be enjoyable. (cf., Lauriala, 1997, p. 130.)

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Chapter 15

TO IDENTIFY WHAT I DO NOT KNOW AND WHAT I ALREADY KNOW: A SELF JOURNEY TO THE REALM OF METACOGNITION

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ABSTRACT

One of the most important descriptive models for adult learning processes, known as Experiential Learning, is that of Kolb (Kolb, 1981, 1984). The learning process according to Kolb occurs within a simple cycle, starting with a new "concrete experience" followed by reflective thinking on the part of the active learner. This study presents a model for the reflective learner which does not fall into line with Kolb's proposed model. This alternative model has been built following action research using the self-study approach tracking the experiential learning process of the lecturer (referred to as facilitator in the study) of an experimental course for fostering thinking at a college of education.

Analysis of the significant events occurring at each stage of the action research and of the factors that set the learning process in motion showed it to be a developmental process composed of four interdependent components: Knowledge of content (metacognition), pedagogical knowledge, knowledge of methodological research and personal metacognitive thinking skills. This study, which relates to essential aspects of the concept of metacognition, and includes recommendations for constructivist instruction focused on the development of the learners' metacognitive thinking, indicates the power of action research as a professional development tool for teacher educators. The research findings presenting the developmental process of a facilitator in an academic institution give new meaning to the concept of metacognitive thinking within an educational context. Through these research findings we receive insights into the complexity of the learning process which demands activation of metacognitive thinking. Contrary to Kolb's model, this occurs not only after "concrete experience". The

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application of the model presented in this chapter while implementing metacognitive thinking at different stages of the learning process will improve the thinking performances of the students in higher education. The chapter analyzes the developmental processes experienced by a lecturer in the sciences, and will be of interest to teachers in general, as well as science teachers who wish to integrate the instruction of higher order thinking skills into science topics.

INTRODUCTION

"I do not know when you have had time to visit all the countries you describe to me. It seems to me you have never moved from this garden." These are the words of Marco Polo to Kublai Khan in Calvino's book (Calvino, 1978, p.101). The true journeys are the invisible ones, which occur inside our head. My research deals with a learning journey to the world of educational metacognition, and poses the question: What are the characteristics of such a learning journey that occurs "inside the head," as a result of teaching an academic course at a college of education?

The research is deeply rooted in my own internal ponderings over the last ten years, while searching for meaningful instructional practices. Since completing a master's degree in Genetics and a doctorate in Science Education, I have felt that my new store of scientific knowledge is insufficient to help me formulate a solid pedagogical perception as a basis for teaching-learning processes for which I am responsible. I have tried using unconventional teaching methods out of a need for theoretical frameworks so as to develop meaningful instruction practices for the sciences. This chapter focuses on the story of my personal learning process. As it was evolving, I underwent the process of understanding the practical significance of the reflective thinking concept, the strength of reflective thinking for advancing knowledge-building processes, and the importance of action research for teacher educator development processes.

THEORETICAL FRAMEWORK

Experiential Learning

The constructivist theory that developed in the 70's and 80's views the learner as one who actively constructs his/her knowledge via assimilation and accommodation, and assimilates the new knowledge via processing and interpretation using that existing knowledge (Driver and Oldham, 1986; Von Glaserfeld, 1995). Based on this theory, learning is the transition from personal internalization of external knowledge to the externalization of knowledge constructed within one's brain, which is exposed through comprehension and application of concepts in different learning situations (Lampert, 1990; Steffe and Gale, 1995). Constructivist learning emphasizes the learner's activity and the act of thinking about the actions as essential to knowledge construction in learning.

Kolb provided one of the most important descriptive models for adult learning processes, known as Experiential Learning (Kolb, 1981, 1984). This model is based on Dewey's view (Dewey, 1933) that learning must be anchored in experience, and Piaget's theory (Piaget,

1964), which views cognitive development as a result of reciprocal activity between the individual and the environment. Kolb's learning model occurs in a simple cycle. It describes how the adult translates experience into concepts, which at the appropriate stage will serve as guidelines for creating new experiences. The process occurs in a four-stage cycle. Stage one: Involvement with new experience (Concrete Experience). Stage two: Development of insight into personal experience or the experience of others (Reflective Observation). Stage three: Creation of a theory that explains the experience (Abstract Conceptualization). Stage four: Using the theory to solve problems and make decisions (Active Experimentation). Most learners begin the process from stage one and progress through the cycle, but there are others who begin their learning process from a different stage. Kolb's learning process includes two dimensions which require the learner to exercise contrasting abilities in the information absorption process: Concrete experience versus abstract conceptualization, and reflective observation versus active experimentation. Kolb maintains that all learning that relies on experience requires the ability for reflective thinking, which the learner will apply following the experience. I will attempt to dispute this.

Teaching as Reflective Experience

Characterizing learning as an experiential activity integrated with reflective thinking is similar to characterizing teaching as reflective experience. Goodlad claimed that the art of teaching should be learned through reflective teaching means (Goodlad, 1990). This approach represents teacher education approaches that emphasize the importance of the student teacher's personal experience as the most significant source for developing professional knowledge (Berliner, 1986; Feiman-Nemser and Parker, 1990; Feiman-Nemser, 1992). Schön redefined the concept of expert teacher (Schön, 1983, 1987). If, in the past, expert teachers were perceived as indisputable authorities, they are now perceived as people dealing with questions by means of reflective thinking. As a reflective thinker, the expert teacher is in a continuous, interactive process that is influenced by the students and the classroom context. Korthagen and Wubbels' approach also perceives teaching as a reflective activity (Korthagen and Wubbels, 1995). They considered reflective thinking to be an important component in the expert teacher's learning process, which enables the development of professional knowledge.

Since Kolb published his book on experiential learning (Kolb, 1984), the use of the concept has changed. It has been expanded, and categorized into four villages, connected to social changes, group learning, to learning from events that have occurred and to personal growth and self-awareness (Weil and McGill, 1989). In this study, I will focus on experiential learning from an event that occurred in my life: Teaching an experimental course with emphasis on fostering thinking, while observing my own personal growth and self-awareness as a result of the experience. First, I will describe the learning processes that I underwent, and will then attempt to analyze the relationship between the experience and the reflective thinking processes. I will examine additional components that build the learning process and will suggest a different model for describing.

The Experimental Course's Theoretical Framework

Designing a course for learning environments that emphasize fostering thinking is anchored in a constructivist perception about learning. When involved with fostering thinking programs, attention is paid to two main questions. First, should thinking be taught as an independent course (Ennis, 1989) or within the subject discipline frameworks (Gardner and Boix-Mansilla, 1994; Perkins and Swartz, 1992)? Second, which is the most suitable approach for teaching thinking? A description of three main fostering thinking approaches follows: The general thinking skills approach, the infusion approach and the thinking dispositions approach.

The thinking skills approach is presented in the Cognitive Research Trust (CoRT) program, developed by Edward De Bono (De Bono, 1993). It includes various thinking tools, which help to develop lateral and vertical thinking skills.

The infusion approach was developed in the USA by Robert Swartz, Director of the National Center for Teaching Thinking in Massachussets, and Sandra Parks (Swartz and Parks, 1994). This approach infuses the teacher education of critical and creative thinking into content instruction in schools. This approach has unique tools to suit the various study fields. These tools can be used to impart focused thinking skills to students, and the ability to apply them in complex thinking processes.

The thinking dispositions approach was suggested by Tishman, Perkins and Jay, with the purpose of developing a school thinking-culture by educating students to permanently operate their thinking processes (Tishman, Perkins and Jay, 1995).When thinking abilities are non-functional, it means that the school system has not developed them for efficient usage.

The three approaches described above indicate the need to learn how to think, not what to think. This type of teaching emphasizes knowledge acquisition as a process, in which knowledge is created, organized, analyzed, applied and evaluated via thinking processes. The task it presents the teacher is different from the accepted one: It is to create conditions in which students can construct knowledge, or according to Perkin's definition *generative knowledge* that can be applied (Perkins, 1992). The three approaches emphasize that the cultivation of thinking about thinking, or metacognition, is an essential condition for increasing the scope for transfer and application of learned thinking skills to other fields. During metacognitive thinking, one thinks about different aspects of one's own cognitive processes. The knowledge produced as a result of metacognitive thinking processes is known as second order thinking (Nickerson, Perkins and Smith, 1985). Among the metacognitive abilities mentioned in literature are the following: Planning, conscious selection of a suitable problem-solving strategy, and evaluation of one's personal comprehension level of a given issue (Schoenfeld, 1987; Zohar, 1999). In this chapter, I will refer to the concept of metacognitive thinking in its broad sense, as a type of reflective thinking. The basis for the research was the connection between theory dealing with teaching thinking and practice. I was a participant in the Thinking Associates program for teacher educators at the Branco Weiss Institute for the Development of Thinking. Within this framework, I attempted to investigate the manner of applying theoretical ideas to academic instruction in teacher education, which would help to produce a future reserve of teachers capable of applying meaningful instruction that emphasizes fostering thinking.

METHOD

The Type of Research

I chose action research (Lewin, 1946) as the framework in which to monitor an experimental course in a college of education, which I named "Learning within a Culture of Thinking." The course was part of the educational study framework of the college, and aimed at effecting changes in the college directorate's outlook regarding teacher education emphases. Thus it constituted, according to Stenhouse, a suitable object for action research (Stenhouse, 1975). In his opinion, the ability to bridge between educational theory and practice is through action research with cooperation between academic researchers and education practitioners (teachers, supervisors and principals), while implementing the action research cycle in four stages: Locating the problem; planning and acting to effect improvement; experience, meaningful action while collecting data, and reflective thinking for analyzing and evaluating the action. This type of thinking leads to a new understanding and thus to a fresh cycle of action research.

Over the years, various models of action research have been developed, but Stenhouse's cooperative, practical model is still the most common, implemented in elementary or high school contexts (Zeichner, 2001, Zeichner and Noffke 2001). Over the last decade, interest in higher education instruction has increased, mainly because of the discrepancy between what the lecturers believed they had taught, and what their students had learned in practice (Prosser and Trigwell, 1999). These findings led to a particular stream of action research: Self-study. This examines teaching efficiency among higher education teachers, with the aim of improving the content and teaching practice (Hamilton, 1998; Zeichner and Noffke, 2001). However, there are still very few reports in the literature of self-study action research used by university lecturers (Cross and Steadman, 1996; McNiff, 2004; Whitehead, 2000; Zuber-Skerritt, 1996).

I used the self-study approach in my action research, in which I was required to carry out two functions simultaneously: Researcher and teacher educator at a college of education. My support group comprised of friends from the Thinking Associates program, and Naomi, a member of the college staff, an expert lecturer in rehabilitational teaching who asked to join the experimental course meetings as a non-participant observer.

Participants

A. Students (N = 17) in their final year of study at an Orthodox Jewish college of education in Israel. They had prior knowledge of didactic fields and some practical experience of teaching. Their learning program includes one specialized field (Natural Sciences, Mathematics, Computer Science, Accountancy, Special Education, and more), one Jewish studies field (Bible, Jewish Philosophy) and courses in education. On completing four years of study, they receive a Bachelor of Education and a teaching certificate.

The experimental course participants represented most of the college's specialization disciplines. Sixteen were in their first year of teaching and one was an experienced kindergarten teacher. They knew on registration that the college was running the course for

the first time, within the framework of an experimental project designed to present pedagogical principles for teaching with an emphasis on fostering thinking.

B. I am the lecturer of the course, and will refer to myself in this study as the course facilitator. I have been lecturing on Natural Sciences for the past 17 years. My teaching approach is based on the view that the natural sciences are a dynamic entity, which includes not only the outcome (the substantive content component of the scientific discipline) but also the process of its coming into being (its syntactic component) (Schwab, 1964). This approach works on fostering the students' thinking, as it deals with knowledge construction processes. This was the first time I had taken upon myself the teaching of a course in the field of education. I began the experimental course apprehensive of the journey into the unknown. I had no prior experience of teaching thinking as a field of knowledge, teaching a pedagogical course, or implementing action research. Although I did have experience of educational research within various frameworks, and had experienced success while teaching within a discipline and had confidence in my broad theoretical background in thinking education, I felt mingled anxiety and eagerness to succeed in this self-imposed challenge.

Tools

I used a variety of tools to collect the experimental course data, mostly qualitative, but a small number were quantitative. These were a personal thinking journal, in which I wrote the plan of every session and my reflective thinking summary following it; participatory observation notes; the students' written work and a students' feedback questionnaire from the college directorate. For data triangulation, the following were used: Session protocols and notes on feedback conversations written by Naomi, the non-participating observer; documents presented to the college directorate before, during and after the course; documentation of my consultation sessions with experts and of discussions in which I presented the action research findings to the Thinking Associates academic support group supervised by a university facilitator.

FINDINGS AND DISCUSSION

Here I describe four research cycles corresponding to the accepted stages of action research. As the chapter focuses on my personal learning process, it includes sections written while observing discussions with students. To supplement the verbal description, I present my principal reflective thinking findings in a table (Wolcott, 1990), showing the insights gained from each of my functions, researcher and teacher educator.

First Action Research Cycle

The initial question: How can one bring students to a meaningful understanding of learning processes within a thinking culture? This includes practical questions, such as:

Which themes to teach as part of the experimental course, and how to divide the time between them? Which form should the course assignments take?

Planning

- Course contents – three fostering thinking approaches will be presented: The thinking skills approach (in the first semester), the infusion approach (for half of the second semester) and the thinking dispositions approach (introduction only).

- Instruction principles:

  a) Combination within the thinking tool of theoretical background with the students' experience.
  b) Emphasis on implementing the approach for fostering thinking in teaching.
  c) Reflective writing by the students in their personal journal.
  d) Facilitation using an approach that stimulates thinking, rather than using lectures.

- Evaluation – according to two assignments:

  a) Group assignment: Introducing a new tool via peer teaching.
  b) A summation paper based on notes from the thinking journal, at the end of the first semester and/or at the end of the academic year.

At this point, I had many questions regarding the implementation of the teaching principles, and the course evaluation methods:

How, exactly, would I utilize the students' documentation in the thinking journal? Should I guide the students as to the method of documentation? Should I set the summation paper in the middle of the course or at the end of the year? How will I be able to evaluate the contribution of the course to the students?

Operation

The first three experimental course sessions dealt with De Bono's "Six Thinking Hats" (De Bono, 1993). This is a method for operating only one thinking mode at a given time. Each thinking mode is presented by a hat with a definitive color, for example, a red hat expresses emotions and intuitions and a yellow hat indicates a positive outlook. Each hat's color defines the task and thinking mode one must operate while wearing the specific hat. Each group of students received a written description of a hat, and prepared a presentation to introduce the other students to its specific characteristics.

Data Collection and Reflection

From the analysis of data collected during the three sessions, it appeared that, as facilitator of a course designed to demonstrate "alternative teaching," I had succeeded in arousing interest in the course, and the activity had achieved its goals. Most of the students' presentations were appropriate to their allocated hat.

The fourth session opened with metacognition on personal thinking: I asked the students to consider whether they wear a certain hat more often than others in real life? Here is the example of a response:

> Nora: I think with the red hat and often get hurt, as I'm always quick to blame myself. Now that I'm aware of it, I may be less vulnerable.

After hearing examples of the students' metacognitive thinking, we discussed the importance of the thinking journal, and I asked them "to document all sorts of occurrences and experiences relating to the course," as basis for the end-of-semester summation paper. At that point, I did not fully explain the assignment, as I had not yet succeeded in defining it for myself.

The students spent the rest of the session trying their hand at documenting typical questions asked by someone wearing a specific hat. During the subsequent discussion, they gained interesting insights – some I had not thought of in advance. Toward the end of the discussion, "*I was enlightened*. I succeeded in defining for myself more clearly the students' summation paper assignment, based on the thinking journal: 'Describe aspects relating to your personal thinking in which you feel a change has begun within you as a result of this course. Base your feelings on the documentation in your thinking journal.' " (My personal journal).

Conceptualization

The metacognitive tasks I set the students helped me move forward with my own thinking processes. Only through metacognitive discussions with the students did I succeed in formulating a metacognitive thinking task, which I was previously unable to define. Thus, I decided to change the course focus from the three fostering thinking approaches, to metacognition. In the first action research cycle, I focused on designing the course content. At this point, the approaches to fostering thinking became the content through which I decided to focus on the students' metacognitive thinking.

Second Action Research Cycle

New question: How can I bring the students to recognize metacognition as a tool for improving thinking skills?

The decision to change the course focus was not easy for me, as the practical significance was that it meant dealing with a field that was new also to me – metacognitive thinking. However, I was excited about the prospect of learning during the experience.

Planning

- Course content: Presentation of pre-planned approaches to fostering thinking.
- Teaching principles: In addition to those presented above, enough time would be allocated for the students' metacognitive thinking and its documentation in the personal thinking journal, following each experience.
- Evaluation: The change in course focus would necessarily affect assignments planned in the first research cycle.

At this stage, I had to deal with questions relating mainly to the practical translation of the theoretical concept of metacognition: What does it mean? How does one cultivate metacognitive thinking in practice? How does one evaluate this type of thinking?

Dealing with these questions from the course facilitator's point of view made me aware of the difficulty in finding a precise definition for metacognitive thinking. I discovered that my theoretical knowledge was insufficient, and began the journey in search of the roots of the concept, and the monitoring of its development.

It appears that defining the concept of metacognition is not so simple, as it is perceived by different researchers in different ways (Schneider and Pressley, 1989). We here present several definitions of the concept, which appear to be translatable into various types of cognitive questions that a teacher should ask in the classroom.

John Flavell (Flavell, 1971, 1976), a cognitive psychologist at the University of Stanford, USA introduced metacognition as a concept that relates to one's knowledge and regulation of the processes and outcomes of one's own cognitive system. In 1979, Flavell broadened the definition (Flavell, 1979, p. 906), determining that metacognition comprises:

1. Metacognitive knowledge;
2. Metacognitive experiences or regulation.

Metacognitive knowledge relates to beliefs or to knowledge acquisition of cognitive processes, knowledge that may be used in regulation processes. Flavell indicates three types of metacognitive knowledge:

a) Knowledge of personal variables – general knowledge about the way in which a person learns and processes information, and personal knowledge about one's own learning traits. For example, the awareness that one learns more efficiently in a quiet library than at home, where there are many distractions.
b) Knowledge of task variables – knowledge acquired through experience with the nature of the task, and of the type of cognitive processing required. For example, reading to comprehend a scientific text will demand more time than reading and comprehending a literary text.
c) Knowledge of strategy variables – knowledge of cognitive strategies for carrying out the task, and metacognitive strategies for monitoring the progress of the thinking process. Also, conditional knowledge as to when it is appropriate to use such strategies for realizing certain goals.

Metacognitive regulation is activated by experiences in which metacognitive strategies are used for regulating the metacognitive activity and for checking whether the metacognitive goal (such as understanding the text) has been realized. Thus, regulation processes comprise the planning and monitoring of the cognitive activities, and the checking of the activities' outcomes. For example, after reading part of a text, one may implement a known metacognitive strategy designed to monitor understanding, in the form of self-questioning as to the contents discussed in the text. If one is unable to answer the questions, or cannot understand the material, one must decide what to do in order to realize the cognitive goal of understanding the text. One can reread the section while concentrating on the goal of successfully answering one's own questions. If, after the second reading, one is able to answer the questions, one can establish that one has understood the material. In this way, the metacognitive strategy of self-questioning is a metacognitive regulation task for checking whether the cognitive goal of understanding the text has indeed been realized. It should be noted that there is often an overlap between metacognitive and cognitive activity as the following explains.

In a way similar to Flavell, Ann Brown, of the University of California, Berkeley defined the concept of metacognition by differentiating between knowledge of the cognitive system and its content, and the regulation of the cognitive activity (Brown, 1978, 1987).

Kluwe's definition (Kluwe, 1982) maintained the distinction between knowledge and regulation, but defined two types of processes for the regulation and management of metacognitive thinking as *executive processes*:

1. Executive monitoring processes.
2. Metacognitive experiences or regulation.

Monitoring processes are designed to acquire knowledge of a person's thinking processes. They involve decisions that help the person:

a) Identify the current task via questions such as: What should I do here? How shall I do this?
b) Check the progress of that work via questions such as: How shall I implement the work?
c) Evaluate the progress via questions such as: How does this step help me to move forward?
d) Predict the outcomes of this progress via questions such as: How will I move on from here?

The outcomes of the monitoring process may constitute a basis for the regulation processes. Regulation processes are involved in decisions that help a person:

a) Allocate resources for a current task;
b) Determine the order of steps needed to complete the task;
c) Set the intensity at which to work at the task;.
d) Set the speed at which to work at the task.

A survey of additional literature, such as Houston (1995) and Schraw and Moshman (1995) showed that in spite of differences in the definition of some characteristic aspects of metacognition, most researchers relate to metacognition as comprising of at least two different components: Metacognitive knowledge and metacognitive regulation processes. The metacognitive activities include planning, monitoring, checking, error location, correction implementation, and evaluation, among others (Brown, 1987, Brown, Bransford, Ferrara and Campione, 1983, Osman and Hannafin, 1992). Planning, monitoring and evaluation are accepted by many as the three central activities.

The multiplicity of definitions for the concept of metacognition is not the only reason for its complexity. When I attempted to apply these definitions to questions for the metacognitive discussion in the experimental course, I encountered further difficulties.

First, it is not always possible to clearly distinguish between the aspects of metacognitive knowledge with regard to cognitive framework and regulation, as they are often interconnected. For example, the knowledge that this is a difficult task will lead me to the precise monitoring of the cognitive processes, and vice versa. Successful metacognitive monitoring of cognitive processes will lead to knowledge of the difficulty levels (easy/difficult) for the various tasks.

Second, it is sometimes difficult to determine with certainty whether a specific activity is cognitive or metacognitive. Roberts and Erdos, based on Flavell (1979, 1987), attempted to respond to this difficulty (Roberts and Erdos, 1993). In their opinion, the starting point for distinguishing between cognitive and metacognitive activity is the understanding that metacognition involves overseeing whether a specific cognitive goal has been met. Accordingly, an understanding of how to use the chosen strategy is a necessary condition for our ability to identify metacognitive activity. We can examine this distinction in the following example: The use of cognitive strategies for deciphering a text is designed to help one achieve a specific goal, while metacognitive strategies, such as self-questioning in order to evaluate the understanding of the text, is designed to investigate whether the goal has indeed been achieved.

However, the self-questioning strategy can function cognitively and metacognitively, depending on the use of the strategy's goal. It can be used as a means of receiving information (cognitive activity) or as a means for monitoring what has been read (metacognitive activity).

Returning to the metacognitive components (metacognitive knowledge and regulation), knowledge considered to be metacognitive is actively used by a strategy investigating whether the cognitive goal has been met. As a student who has to read and understand a text, one will say to oneself: "I know that I (variable according to person) have difficulty in reading long texts (variable according to task). Therefore, I will read each part separately, and will ask myself questions to clarify each part (variable according to strategy)." One will use metacognitive knowledge in order to plan one's activity for accomplishing the defined goal.

From here, I reached a generalization: Knowledge of the strength or weakness of one's cognitive system, and of the type of task, will not be considered metacognitive knowledge, unless one makes active use of this knowledge. The function of the teacher facilitating the instruction is to develop the students' awareness of processes that occur during learning. A simple way to achieve this is to ask leading questions. With this background in mind, I planned the next course experience with emphasis on the contribution of metacognitive thinking to the learning process.

Operation

The next two sessions were designed to present De Bono's perception of lateral thinking (1993) and of changes in thinking that break accepted patterns. Session five involved the *suggesting ideas for describing a shape* experience. It included a metacognitive discussion, to help expose the development of an ability to think of many original ideas. It simultaneously used quantitative data processing as a tool for validating the development of thinking under the influence of metacognition.

The experience involved two tasks, each with a personal experience stage and a group discussion stage. In the first task, the students received a shape, and were asked to spend 10 minutes working individually to suggest as many ideas as possible for describing it. A metacognitive discussion of the suggested ideas ensued. A different shape was presented for the second task. The students, working individually again, suggested ideas for describing the new shape. Another metacognitive discussion followed, while checking for improvements in how they implemented the task.

Data Collection and Reflection

All suggested ideas for describing the first shape (such as "house," "equilateral pentagon") were written on the board and their frequency of occurrence was noted. A discussion followed about the types of ideas suggested. I opened the discussion with the following question: "What can you learn from this experience?"

While planning the session in advance, this was the only question I could think of which would stimulate the students' metacognitive thinking. It became clear that this general question drew their attention to the type of ideas that arose in describing the shape, for example:

Sara: Some descriptions were suggested repeatedly, such as *house*, and there were some less common ideas.

Sally: The 78 suggested ideas can be sorted into three types (patterns): 1) Shapes that came to mind when studying the given shape (*that reminds me*). 2) Geometrical shapes. and 3) Change (addition to or subtraction from the original shape) to create a shape that I was reminded of.

These examples indicate that my opening question spurred the students to sort the ideas and reach conclusions regarding the task content. I did not intuitively categorize this type of thinking as metacognitive, but according to Flavell (Flavell, 1979) it could be seen as metacognitive thinking, as it relates to the outcome of the cognitive system. However, the general question, as we will see later on, also prompted a type of thinking I considered as metacognitive from earlier — relating to the process the students underwent when trying to think of ideas, for example:

Rebecca: While hearing other people's ideas, I suddenly had new ideas that hadn't come to mind during the experience.

As an inexperienced metacognitive facilitator, I learned that the wording of a general question is sometimes a valuable thinking stimulant, through which we can reach a discussion not only about content, but also about the thinking process. However, students can interpret a general question as an invitation to reach conclusions about content alone. Thus, following the metacognitive discussion described above, I was left with a fundamental dilemma as to how to lead a discussion on metacognition: How, therefore, can I encourage metacognitive thinking related to the thinking processes via my questions?

In the metacognitive discussion following the second task, the students noted that many more ideas were suggested to describe the shape than in the previous task, and a new pattern was suggested for describing the shape.

As I was still deliberating how to encourage the students' metacognitive thinking, I set two homework questions, one focused and one general.

1) Compare the two experiences for describing the shape:
   a) Relating to the number of ideas you managed to suggest
   b) Relating to the stages you went through to suggest the ideas.

2) Did you use what you learned in today's session during the week, either in your job as a teacher, or in day-to-day life? Give details.

Throughout the following week, I thought constantly about metacognition. First, I arranged a consultancy meeting with Elaine, who is very experienced in instructing teachers of programs for fostering thinking. I told her of the students' responses to the general question used to stimulate their metacognitive thinking. Our conversation reinforced the idea of using the general question strategy for opening a metacognitive discussion. She also gave me two additional recommendations:

> "On hearing a student's response, try to bring the type of response into focus, by saying: This relates to the task content, or this response relates to the thinking process, and so on. Later in the discussion, you should add focused metacognitive questions in addition to the general questions asked earlier."

While simultaneously dealing with De Bono's approach, I decided to combine components of the infusion approach for fostering metacognitive thinking (Swartz and Parks, 1994). Swartz and Parks recommend that the teacher should foster the ability to activate metacognitive thinking by means of a hierarchy of questions. These questions will guide the students' progression from thinking about the learning content alone to observing their own thinking. The questions are listed below. They reflect different types of metacognition (from lowest to highest level):

1) With which thinking skill were we dealing?
2) a) Which stages did we cover while exercising the skill?
   b) Explain the function of each stage of the thinking process. Why was it necessary to implement each stage?
3) Evaluate the thinking process. Was it effective? Which difficulties did you encounter? How can it be improved?

4) Plan an improved thinking program, which you can implement next time you need to use this type of thinking.

These questions had two main functions: One was retrospective – to make the students aware of the thinking pattern just implemented, while using thinking skills terminology. The other was a function relating to future thinking. These questions helped the students to implement the monitoring processes described by Kluwe (Kluwe, 1982).

I opened the sixth session by applying these insights. I brought Elaine to the session, thinking that the students could also benefit from my insights gained from her recommendations. We started by discussing the homework assignment, while I focused on the goals of each question.

Below are several of the students' answers to the first question, comparing the number of ideas and methods used in the two tasks:

- In the second task, I got an idea from a new template.
- In the second task, I had more creative ideas.
- In the second task, the ideas came more quickly.
- I was aware of the patterns I was using, and tried to think of more possibilities.

Most students had written sentences like the first two in their thinking journals. These constitute a description of the outcome obtained in the second task. However, only two students managed to consider the stages of their thinking process during this second task.

Later on in the session, I handed the students a quantitative summary of the results from both tasks. It was designed to validate the metacognitive thinking (documented in the students' personal thinking journal), which reflected a description of feelings that indicate a change in the ability to suggest ideas in the second task. Without a doubt, it appears that the first experience, which included two stages – for suggesting ideas and for metacognitive discussion – improved the thinking process during the second task. In this task, an increased number of ideas and patterns were used to describe the shape, and a greater number of students suggested ideas from within the different patterns; thus the distribution was changed.

Having dealt with metacognition that related mainly to a description of the thinking outcome, I attempted to apply Swartz and Parks' recommendation (1994) to steer the students toward metacognitive thinking that relates to a description of the thinking stages. In Swartz and Parks' opinion, metacognitive thinking that is searching for an explanation may bring the student to research the stages involved in the thinking process.

As the summary presented differences between the two experiences in which ideas were suggested for a certain shape, I asked the students to suggest explanations for these differences.

The following are the explanations offered for the improvement in the second task:

- An awareness of possible thinking patterns was what brought about the differences.
- Once I had one idea, it sparked another.
- The pace quickened when I started to be creative.

When the students offered these three explanations, they believed them to be the only possible explanations for differences in the implementation of the two tasks. We then

discussed the need for divergent thinking, and I asked the students to think of another possible explanation for the differences. To my great surprise, the following two explanations were offered:

- One of the ideas heard in the class forum was transformation. I hadn't thought of this before, and it gave me a new idea.
- The first task gave me confidence. We listened to ideas, and saw that every one was legitimate. It broke down the barriers I had in the first task.

I also learned something new from this metacognitive discussion. First, I discovered that if steered toward searching for explanations for the differences in thinking, the students do succeed in identifying the stages of their thinking process. One way or the other, they reach a higher level of metacognitive thinking than is required for describing the thinking outcome. Thus I learned that I need a higher level of metacognitive question available for the students. Second, I had previously thought that a maximum of two explanations would be offered, one relating to the first task activity, and one relating to the efficacy of the metacognitive discussion. From the discussion, I learned another important facilitator function – to encourage divergent thinking. Even after the ideas have run out, it is possible to spur an additional thinking effort, which might also produce results. I also recognized the hidden potential in the homework assignments as an opportunity for implementing metacognitive thinking outside the course.

The two sessions described above (the fifth and sixth) demanded far more than three hours' teaching. Throughout these two weeks, my whole being was occupied with metacognition. I searched for literary material, consulted with experts, and, above all, had experiences and felt that I progressed.

Conceptualization

At this stage of the research, I discovered the start of a development (see Table 1) in each of my three functions:

- Specializing in the field of metacognition.
- Facilitator of a course for fostering thinking.
- Researcher conducting action research for the first time.

However, the insights reflecting my understanding of the field of metacognition and of the thinking course facilitator's function are intertwined. I did not know how to word a metacognitive question at the beginning, as the concept of metacognition was undefined. Now that I had progressed in understanding the theoretical background of metacognition, I could distinguish between different types of questions, which represent different levels of metacognitive thinking. As if this weren't enough, I also began to apply this knowledge by preparing leading questions that stimulate different levels of metacognitive thinking, and by planning assignments (including homework) for improving thinking performance. Simultaneously, I made progress as a researcher. The quantitative data processing of the

shape-describing experience emerged as a successful tool for reflecting the contribution of metacognitive thinking. This realization gave me strength to continue developing tools to reflect this contribution.

In all stages of the action research, I exercised overall reflection as a learner, i.e., in my three simultaneous functions – specializing in the field of metacognition, facilitator and researcher – I was a learner reflecting on the processes occurring within them.

From overall reflection as a learner at this stage, I discovered that the explanation for the progress in my ability to function as a facilitator and to run a metacognitive discussion lay in my deeper understanding of the theoretical basis for the field of metacognition. From here, there was a natural progression to the third action research cycle — the desire to apply my newly constructed knowledge in my function as a facilitator who encourages metacognitive thinking.

Third Action Research Cycle

New question: How can I make the students distinguish between different types of metacognition?

Planning

From the two sessions (that constituted the second action research cycle) in which I attempted to focus on fostering metacognitive thinking, I sensed that due to lack of time, I would have to change the course content and be satisfied with a perception of two fostering thinking approaches. I also decided to reorganize the content: Not only two approaches that would be taught completely separately, but also a combination of fostering-thinking components from the infusion approach, whilst teaching De Bono's approach.

Since it was proven that only a small number of students succeeded in spontaneously observing their own thinking processes during the shape-describing experience, I decided to make them aware of this by means of an external observer who would monitor the thinking stages.

Operation

In the seventh session, the students divided into groups of three. Two members of each group attempted to decipher the material written on a piece of paper, and the third took on the role of observer, and noted her group members' steps taken to complete the task.

Data Collection and Reflection

The subsequent metacognitive discussion was designed to expose the steps taken by the partners to complete the task. The observers reported that their fellow students examined the

direction of the written material, turned the paper around in all different directions, looked at the title and tried to read the symbols written from left to right.

At this stage, I applied the previous meeting's insights, and asked a general question: What did you learn from this experience? Write about this in your journal.

Below are several examples of students' responses.

Abigail: We recognized the importance of putting on the blue hat, whose main function was to observe our thinking steps.

Hannah: We tried to decipher the material in all its different ways. We were on the point of giving up, when we noticed the link and reached a solution.

Myra: It is important to notice the details, as they are significant. It was only on discovering the link that we reached a solution.

Rebecca: The group consultation was so helpful. We need to remember to take other people's advice in real life also.

At this point, I continued to apply my insights in directing the metacognitive discussion, by focused reference on the students' responses:

> We have now heard several types of metacognitive thinking. We are already familiar with the one that relates to what we underwent while searching for a solution to the task, in other words, to a description of the thinking stages. Myra referred to this type of metacognition, while Abigail noted the importance of monitoring the thinking stages. A new type of metacognition exposes and relates to the difficulties encountered during the thinking process. Hannah's response hinted at this. In the context of this type of metacognition, Rebecca's response reflects a suggestion for coping with difficulties encountered during the thinking process.

The next two sessions (eight and nine) dealt with two thinking tools for developing divergent thinking. Both tools were learned according to an approach that includes several stages: Experience in learning the tool, additional metacognitive exercise and discussion of the tool's principles and its application in life (De Bono, 1993). In addition, I invited discussions (according to the infusion approach) that stimulate different types of metacognitive thinking among the students, such as the question, "What did you learn about how you and your group's ideas were formed during the experience?" This resulted in identifying the thinking stages, locating difficulties and searching for ways in which to cope with them.

In these discussions, I learned to paraphrase the students' responses, while focusing on the thinking process implemented, for example:

> Here Anita pinpoints a difficulty she has encountered and how she has dealt with it, through self-encouragement,

or

> It is possible to overcome a difficulty by changing a previously mentioned idea to a new idea, as Myra suggests. A humorous idea can also be used for encouraging creative thinking, as suggested by Esther.

In this context, I will mention an entry in my journal, recorded as a significant event:

> Today…during focused reference on the students' responses to my general question, I realized that through this activity, I am applying the thinking dispositions approach (Tishman et al., 1995) which emphasizes the importance of using "thinking language." This approach states that the teaching of an active vocabulary for discussing thinking processes and the development of language awareness and metalanguage awareness may be effective in developing a culture of thinking. This is exactly what I am doing with my focused paraphrasing, and it's good to discover that my reconstruction method has a basis.

At the same time, I offered the opportunity of focused metacognitive thinking and allocated the necessary time for thinking and documentation. I learned that I was allowed to sit for a few minutes without speaking. Thus, during the metacognitive discussions, the students learned to identify the thinking process stages, locate difficulties and make creative suggestions that I had not thought of, for improving the thinking process. These creative ideas prompted me to spend time with literature that focuses on creative thinking, in which some of the students' suggestions for coping with difficulties during the thinking process were mentioned.

Conceptualization

After exercising metacognition on the abovementioned discussions (in sessions seven to nine), I gained the insights presented in the continuation of Table 1. From overall reflection as a learner, I discovered interesting insights:

1) A command of the field of metacognition is what enables me to develop my own unique pedagogical approach, which leans on three different approaches for fostering a culture of thinking.
2) The students' creative suggestions were a source of knowledge for me, which I reinforced via the literature.
3) My ability to connect between the need for focused reference on responses in the metacognitive discussion and the thinking dispositions approach, which espouses the use of thinking language, testifies to my own metacognitive thinking development, according to Schoenfeld (1987), who views the ability to connect new knowledge with previous knowledge as metacognitive ability.
4) My double function as facilitator for fostering thinking and researcher has advantages. The documented sessions strengthen my feelings and support the fact that the pedagogical approach I developed for fostering the students' metacognitive thinking produces results in actuality.
5) My sense of improved documentation ability and the ability to carry out qualitative research is the motive for setting the students an evaluation task (a concluding exercise described below), in which they would make use of their personal journal documentation.

At this point, I felt the need to evaluate the metacognitive thinking, a need with which I was occupied throughout the fourth action research cycle.

Fourth Action Research Cycle

New question: How will I be able to reflect the progress that has begun in the students' thinking, as a result of dealing with the different types of metacognition?

In the first action research cycle, I also wondered how to evaluate the students. At that stage, I was so busy learning the subject, understanding the meaning of metacognition and learning the pedagogy—researching approaches for developing metacognitive thinking, that I did not find time to deal with ways of evaluating the students' thinking. Now that I had a better understanding of metacognitive thinking, the need was of prime importance. Dealing with evaluation of metacognitive thinking continued for a relatively long period (from the end of the ninth session to the end of the academic year), but it is possible to identify it in several phases.

Fourth Action Research Cycle – Phase A

Question: Which tools can be used to evaluate the students' metacognitive thinking?

Planning

At the start of the research, I planned to carry out the evaluation via two assignments that I announced at the beginning of the course. I had succeeded in defining the aims of the individual assignment and wording it precisely, but had still not clarified the group assignment: What it would include and how it would reflect an application of material learned in the course.

With the insight that "*I already know* how to document in a much better manner, I now needed to give the students an opportunity to examine their documentation methods in their personal journal" (My personal journal), so I decided to bring forward the summation paper. Thus, at the end of the ninth session, I set the students the concluding exercise (the name was changed from "summation paper") and asked them to hand it in two weeks later.

I was faced with unanswered questions at the beginning of this cycle also. For example, how would I be able to grade the assignment? Would the evaluation tools (concluding exercise, presentation of a new thinking tool in class, final paper and session documentation) be sufficient for evaluating the students' level of metacognitive thinking and the change they underwent? Is the policy of giving no documentation guidelines for the thinking journal a pedagogical principle worth adopting?

When planning the next three sessions (10-12) I decided to continue with experiences using additional thinking tools according to De Bono's approach. The experiences were designed to constitute a model for teaching the thinking tools, which the students would present as a group assignment.

Operation

The tenth session began with a student's initiative, as described below.

Data Collection and Reflection

Abigail: Dr. …, can I say something about the exercise?
Facilitator: Of course.
Abigail: This was an excellent exercise for me. a) It organized things for me. b) As a result, over the past two weeks, I began writing independently in the thinking journal. and c) Since the exercise, my writing has taken on a different form. I describe the task I am metacognitively documenting in the journal, in detail, so I'll be able to understand what I've written in the future.
Rebecca: Until now, all I wrote in the journal were implications of the course material for my work as a kindergarten teacher. Suddenly, I discovered that the course influences decision-making at home. For example, the problem of which high school our daughter will attend next year…that was also written in the journal.

Similar reactions were heard, indicating that the exercise had helped us understand the function of the thinking journal as a documentation tool for different types of thinking. It indicated the need for continuous and sufficiently clear documentation. At this point, I informed the students of my deliberations upon deciding to use the thinking journal as an aid throughout the course: When getting the students accustomed to using the thinking journal, should I give precise guidelines as to the form of documentation and its organization in the journal; the time of writing; the size of the journal; or should I leave these decisions up to them? The ensuing discussion continued to the end of the session. The students voiced their difficulties in using the journal and practical suggestions for coping with these difficulties (using their own journals as examples). I experienced a sense of release — progress in the ability to lead an unprepared, spontaneous metacognitive discussion to fit the reactions expressed.

At the end of the session, five students approached me and warmly expressed their feelings about the course: "…you arouse our thinking processes…" (Esther), "…this course is affecting all parts of my life…" (Nora), "…the course is having a great influence on me…"(Myra). Their spontaneous comments led me to understand that I was moving in the right direction. The honest feedback reinforced the feeling of self-efficacy in developing metacognitive thinking.

In this meeting run on the students' initiative, from the opening which invited metacognitive discussion relevant to them, to the spontaneous expressions of thanks at the end, I saw the students' progression in metacognitive thinking. The students expressed their need for metacognitive thinking about the experience (writing the concluding exercise). They wished to express what they had learned from the exercise, and considered the ensuing discussion as an essential one before moving on to a new subject. I drew the explanation for this behavior from a personal experience I had had that morning. I had discovered that I was

using metacognitive thinking more often in my private tasks. At first, the discovery surprised me, but I very quickly understood it to be one of the direct repercussions of focusing on metacognition in the college course:

> On the one hand, I ask my students to think metacognitively both during the sessions and at home, so they will learn to ask the same of their students. On the other hand, this demand directly affects me in exercising metacognition on my own thinking processes. (My personal journal)

When I understood that *metacognition had become a necessary process in my thinking*, I identified it as the same process that motivated the students to express spontaneously how the course in general and the concluding exercise in particular, had contributed to their thinking processes. This initiative apparently indicates that they consider metacognitive thinking to be a necessary stage in learning.

Analysis of the students' responses to the concluding exercise showed that its aims were achieved. The discussion content reflected a relatively high level (level 3) of metacognitive thinking, according to Swartz and Parks (1994), related to evaluation of the journal from various aspects, including exposure of the difficulties involved in using it and suggestions for improving the situation.

Session 10 was a *powerful event* for me, as I wrote in the journal. I began to sense the value of qualitative tools for evaluating metacognitive thinking. While searching for literature on ways to measure metacognitive thinking, it became clear that this is also a problematic aspect. I discovered that different research made use of various methodologies, including different types of questionnaire; interviews and observations. The large number of methodologies is not surprising, as the concept of metacognition, as mentioned above, is defined in different ways. Osborne (Osborne, 2001) undertook comprehensive research of around 20 tools (questionnaires and interviews only) for measuring metacognition. His research showed that many of those involved with metacognition base their work on tools with problematic credibility and validity levels. Moreover, only isolated tools were found to be suitable for use by teachers in the classroom.

While searching for effective evaluation methods, I returned to the article on the principles of teaching thinking (Perkins and Swartz, 1992). Even though I had read it previously, only now did I discover that the four levels of metacognitive usage may serve as an evaluation tool, in which the highest usage level is by an experienced reflective thinker:

a) Tacit use: One does a kind of thinking, for example decision-making or comparison, without thinking about it. This involves no metacognitive activity.
b) Awareness use: One does that kind of thinking, conscious that one is doing so at a certain moment, for example: "I am now making a decision". This awareness is limited to identification of the type of thinking skill implemented.
c) Strategic use: One organizes one's thinking by way of particular conscious strategies, for example, questions, which enhance its efficacy.
d) Reflective use: One reflects comprehensively upon one's thinking before and after, or even during the process, pondering how to proceed and how to improve.

An additional aspect of the student's progress in metacognitive thinking was revealed from observing the discussion that related to the concluding exercise by means of the metacognitive thinking usage levels. The spontaneous nature of the discussion indicates a passage to a higher level of reflective metacognitive thinking.

I began the eleventh session with a pre-prepared open metacognitive question: Would anyone like to share additional insights from the concluding exercise?

I did not expect to hear further insights, after having spent the whole of the previous session on the subject, but to my surprise, a discussion arose in which the work stages were reconstructed, and various learning styles were manifest. To reach a generalization level, I spontaneously asked the students to *prepare questions that should be asked about the writing process of the concluding exercise*. With the questions written on the board, I asked the students to arrange them in sequence. While arranging the order, various comments were heard, such as:

Nora: Some questions should only be asked before, during or after the process, and others can be asked at any time.

This discussion also reflected different levels of metacognitive thinking: Describing the stages of the process, pointing out difficulties and suggesting how to cope with them, and suggesting ideas for improving the process in the future. In addition, the students gained a new insight, which is accepted by researchers from various disciplines (Perkins and Swartz, 1992; Swartz and Parks, 1994), that metacognition should be executed at different times: After a previous thinking process, during a current thinking process, and in preparation for a thinking challenge. This insight is characteristic of experienced reflective thinkers.

Conceptualization

Table 1 below shows the main insights gained from Phase A of the fourth action research cycle, after sessions 10-12.

From overall reflection as a learner, I discovered that the action research was becoming more powerful:

1) Focusing on metacognition in the course, both as facilitator and as one specializing in the field of metacognition, was the cause of my intensive metacognitive activity in various contexts (studies, home, disciplinary teaching).
2) Metacognitive thinking had become a necessity. I had moved to a higher level of metacognitive thinking usage.
3) My need to find an evaluation tool for metacognitive thinking caused me to find new meaning in the theoretical article I had read previously.

Fourth Action Research Cycle – Phase B

Question: How will the monitoring of the discussion initiators (course students and facilitator) help to evaluate the students' metacognitive thinking?

Planning

Once I understood that the students' initiative in starting a metacognitive discussion reflected a development in their metacognitive thinking, I discovered a new evaluation criterion. I realized that I had two evaluation objects to monitor in initiating metacognitive thinking:

a) The students: To what extent they initiate metacognitive discussions.
b) The course facilitator: To what extent I invite them to be partners in the course learning process.

Operation

The first two sessions of the second semester dealt with the Other People's Views (OPV) thinking tool. This tool emphasizes the need for another point of view in thinking situations (De Bono, 1993).

Data Collection and Reflection

By session 13, the students spontaneously initiated an in-depth metacognitive discussion, which began with Nora's comment: *I want to contradict De Bono's claim regarding the importance of the OPV tool…* Further doubts were then raised regarding the importance of the tool, while searching for conditions in which the tool is important, and indicating difficulties in applying it to the school situation.

I opened session 14 with a general question intended to stimulate metacognitive discussion. During the discussion, it became clear that most students had not correctly interpreted the function of the OPV tool, and therefore did not consider it to be important.

Leah: As thinking people, we need to act according to independent considerations, without paying attention to what others will say.

In both sessions, the initiative of the metacognitive thinking evaluation subjects was prominent – both the students and the course facilitator undertaking the research.

Naomi's documentation, as observer, emphasized my responsibility as facilitator for what happened during the session. She wrote:

> The use of a general metacognitive question to open the meeting turned out well. The question stimulated in-depth discussion, which exposed difficulties in understanding the OPV thinking tool. A good teacher should have anticipated these difficulties in advance.

I unashamedly admit that I had not anticipated such difficulties. However, when the difficulties arose, I learned a great deal from the ensuing in-depth discussion, as is apparent from the opening paragraph of my metacognitive thinking summary after the session:

> Today's session was particularly successful, due to participation of all those involved in the course: I, the facilitator, who initiated a general question and led the discussion; Leah, who kindly agreed to share her thoughts on the thinking tool, the many fellow students who supported her view and others who argued against it, all within a pleasant atmosphere of mutual respect […] Today, a number of very interesting metacognition-related events occurred, which testify to the students' spontaneous use of metacognition. I think we can point to four aspects of metacognition […] of which the fourth – a new aspect relating to the ability to connect learned themes to other learned material.

It is noteworthy that I was surprised at the connections made spontaneously, and wrote the following in my journal: *I have now discovered a new type of metacognition, which I will add to the list of abilities mentioned in the literature*.

Conceptualization

At this stage of the action research, I gained the insights presented in Table 1 below. From overall reflection as a learner, I discovered that it is my ability to connect between the findings from my different functions that enrich the theoretical knowledge, and enable its construction. Thus, for example, use of metacognition for making connections between learned themes, and the documentation of these connections in the thinking journal, may contribute to my thinking process and to the thinking process of others.

Fourth Action Research Cycle – Phase C

Question: How does collaborative dialogue assist the fostering of a high level of metacognitive thinking?

Planning

When I recognized that collaborative dialogue has potential for germinating high level metacognitive thinking, I decided to offer the opportunity of a discussion in the next two sessions that would deal with a group assignment planned as an evaluation tool for the students. In this discussion, I intended us to put our heads together as to how to structure the class in which a new thinking tool would be presented, and how to evaluate a class that would take the form of peer teaching. On the basis of the new insight, which views the ability to create connections between new and prior knowledge as an aspect of metacognitive thinking, I planned a preliminary activity, which will be referred to below as a decision-making experience.

Operation

The decision-making experience was arranged in groups, in session 15. Each group played the role of the committee whose job it was to determine the schedule for a college course in fostering thinking. The experience was designed to arouse the need for knowledge of new thinking tools, and to reflect the students' spontaneous connections to prior knowledge. A discussion followed.

Data Collection and Reflection

Part of the discussion is presented below:

Esther: We could wear De Bono's hats: The white hat for collecting information about the lecturer or the course contents, the yellow hat for finding the positive elements in each suggestion…

Analysis of the experience's activity papers and the discussion protocol showed a definite development in the students' metacognitive thinking ability. They were making connections spontaneously between different themes, which enabled a high level of metacognitive thinking.

The decision-making experience described above and the ensuing discussion, created an awareness of the need to become acquainted with additional thinking tools which could help in the decision-making process. This prepared the ground for holding a shared dialogue in the group assignment – teaching a new thinking tool in class. At this point, we had to decide which of De Bono's other thinking tools should be taught in the next sessions, and how to implement the group presentation of the tool. I initiated a discussion in which I involved the students with questions over which I had deliberated in the past, and together we thought of possible ways of presenting a new thinking tool. The atmosphere was pleasant, and my feeling was that we reached important decisions acceptable to all of us.

If at first I was concerned about questions without solutions, I was now at a stage where my students were involved in the search for solutions to questions about our shared learning process. This stage reflects the increase in the level of my metacognitive usage (Perkins and Swartz, 1992), as I felt capable of leading a flexible, open discussion during the session with the students.

The plan for session 16 was to discuss criteria for evaluating the group assignment. As this aroused much interest, it ran overtime into the next session. During the discussion, the students spontaneously expressed insights that reflected different aspects of metacognitive thinking. Some were focused on a class that the students were due to present, and others related to the evaluation process in general, to its importance and its application within the education system and their personal lives. Later on, expected difficulties with the evaluation process were exposed and a new criterion arose for evaluating the metacognitive discussion about thinking tools: Is a connection made between the new tool being taught and prior knowledge? Reference to the ability to connect between themes as one of the evaluation criteria indicates internalization of this type of metacognitive thinking.

I gained a tremendous amount from dealing with the evaluation process, and wrote in my journal: *Only now do I appreciate that dealing with evaluation is, in fact, a high level of metacognitive thinking*… Indeed, we have already mentioned the consensus in the literature that evaluation constitutes metacognitive activity.

The students also underwent a change:

> The collaborative dialogue in sessions 16 and 17 transformed the students from an inability to conceptualize how teachers evaluate work to an awareness of the importance of evaluation activities in a broad context. The discussions dealing with the group assignment had the accompanying plus of the students' change in status, from those carrying out an assignment "forced" upon them by the facilitator into partners in the assignment-building process and its evaluation (Naomi's Documentation).

The presentation of two of De Bono's thinking tools in sessions 18 and 19 was a practical expression of the students' metacognitive thinking development.

Sessions 20-23 were dedicated to acquaintance with the infusion approach, which was learned with an emphasis on collaborative dialogue with the students. The final sessions were devoted to the students' presentations which stimulated discussions and produced outcomes that could help others involved with the fostering thinking program. The end of session 26 also marked the end of the academic year, and with it, the third phase of the fourth action research cycle.

Conceptualization

With the end of the academic year (see Table 1), I understood that metacognition in an educational context is a whole world of content in itself. As a facilitator, I was exposed to the power of discussions on evaluation-related themes, which stimulate high-level metacognitive thinking. As a researcher, I located expressions that indicate the need for metacognitive thinking, such as *I must tell you*. The use of these expressions and of those indicating change, such as: *Previously I was*… and *Now I am*…. became more frequent.

From overall reflection as a learner, I understood that action research may serve as an important factor in empowering the teacher to develop both on a professional and a personal level.

Table 1. Conceptualization of the Main Insights from the Action Research

Specializing in the field of metacognition	Facilitator of a course for fostering thinking	Researcher conducting action research for the first time
Second cycle: How can one bring the students to recognize metacognition as a tool for improving thinking skills?		
1. The definition of the concept is complex. 2. The concept of metacognition includes:	1. The facilitator should develop awareness of metacognitive thinking via his or her questions. 2. Principles of wording questions	It is possible to build a tool for reflecting the contribution of metacognitive thinking.

Specializing in the field of metacognition	Facilitator of a course for fostering thinking	Researcher conducting action research for the first time
metacognitive knowledge and regulation of thinking. 3. Various types of metacognitive thinking exist, reflecting different levels.	for encouraging metacognitive thinking: general metacognitive question, focused questions, and questions directed toward different levels of metacognitive thinking. 3. Inviting the students to seek explanations may bring about a differentiation of the thinking stages. 4. The discussion facilitator's function also includes spurring implementation of thinking effort.	
Third cycle: How can I make the students distinguish between different types of metacognition?		
The various approaches to fostering thinking (De Bono, infusion, creative thinking) each have a different emphasis in metacognitive thinking cultivation.	1. As facilitator, it is very important to paraphrase what the students have said, with qualitative additions that focus on their own types of metacognitive thinking. 2. My pedagogical approach ─ unique. 3. Time should be allocated during the sessions for thinking documentation in the students' personal journal.	
Fourth cycle ─ Phase A: Which tools can be used to evaluate the students' metacognitive thinking?		
1. Isolated tools from a wide range used for measuring metacognition were found to be suitable for the teacher's use in the classroom. 2. The four usage levels of metacognitive thinking that were suggested by Perkins & Swartz (1992) may serve as a tool for measuring metacognitive thinking development.	The thinking journal ─ investing time spent to write in it and not setting documentation guidelines have proven justified.	Spontaneous initiative for metacognitive discussion ─ a new criterion that I found for evaluating metacognitive thinking.

Table 1. (Continued)

Specializing in the field of metacognition	Facilitator of a course for fostering thinking	Researcher conducting action research for the first time
Fourth cycle ─ Phase B: How will monitoring the discussion initiators during the course help to evaluate the metacognitive thinking?		
The ability to connect new knowledge with prior knowledge may constitute an additional type of metacognitive thinking.	A learning environment that invites collaborative dialogue must be provided.	The thinking journal is a possible tool for monitoring spontaneous connections between new and prior knowledge.
Fourth cycle ─ Phase C: How does collaborative dialogue assist the fostering of a high level of metacognitive thinking?		
The development of a dialogue resulting in high-level metacognitive thinking depends on the facilitator, the students and the learning environment.	Dialogue on evaluation-related subjects stimulates high-level metacognitive thinking.	The group discussion protocols are a powerful tool for evaluating the development of metacognitive thinking.

SUMMARIZING DISCUSSION

The action research started with a practical question about the learning program for an experimental college course in fostering thinking. It developed into research dealing with both practical and theoretical aspects of metacognitive thinking. It has been known for years that a learning process includes both theoretical content knowledge and practical knowledge (Shulman, 1987). The learning process that I experienced displays the interdependence of four components: Content knowledge (knowledge of metacognition), pedagogical knowledge, methodological research knowledge and personal metacognitive thinking ability. I invite you to reconstruct the learning journey with me, with attention to the description of how my metacognitive thinking process developed, to the factors that set the process in motion and to the relationship between the components that build the development process. These findings now served me as a basis for a model to develop a reflective learner and to define the concept of metacognition in an educational context. My model is presented further on.

METACOGNITIVE RECONSTRUCTION OF THE LEARNING JOURNEY

A. Description of the Development in My Metacognitive Thinking

Even though the action research was pre-designed to present the college directorate with the students' progress following the experimental course, the research findings indicate that

my metacognitive thinking development process resembled the students' process to a certain extent, as it included changes in content (Swartz and Parks, 1994) and in the level of usage of metacognitive thinking (Perkins and Swartz, 1992). The data concerning my personal level of metacognitive thinking were collected only after the research had started. Nevertheless, the move from a description of outcome to a description of the thinking process is clearly apparent from the professional language I later used referring to the thinking stages and its evaluation. Through conscious use of metacognitive thinking, I progressed to strategic use and then to reflective use, while metacognitive thinking became a necessity before, during and after each activity. Over time, I developed an awareness of how important it is to be able to connect new knowledge with prior knowledge. I saw the operation of this ability as an important strategy for knowledge construction in the learning process, and simultaneously as a criterion for evaluating metacognitive thinking. In the early research stages, I gained wisdom from situations in which I connected strategies for leading a metacognitive discussion with various approaches to fostering thinking, and finding connections between my own and the students' learning experiences. However, I had not recognized the ability to connect as a metacognitive ability, which also requires conscious cultivation.

My personal metacognitive thinking changes were applied in practice as facilitator. Thus, during the learning journey, I developed the ability to teach in uncertain conditions, as Naomi the observer indicates in her report presented to the college directorate:

> Dr. … navigated the development of her classes in a most intelligent manner, giving prior thought to the class, and reflective thinking during and afterward. However, she was flexible to change according to what occurred in practice…

It is true that I moved from facilitating pre-planned metacognitive discussion to flexible discussion, which developed during the learning process. I learned to involve the students with my professional considerations and with questions I was deliberating, related to the learning process. This development is in keeping with the expert teacher's outlook as a person constantly undergoing learning processes, due to the need to exercise comprehensive reflective thinking (Korthangen and Wubbels, 1995; Schön, 1983, 1987). However, the discussions reflected the fulfillment of one of the teacher-education goals ─ to educate the students to express their considerations verbally, as a basis for instruction that encourages reflective thinking (Fenstermacher, 1986).

B. The Factors that Set the Process in Motion

I embarked on a journey as facilitator of a course designed to demonstrate *alternative instruction*. In a particular session, *I was enlightened*, and the significance of this was twofold. First, I focused on an activity at which I succeeded and demonstrated knowledge. Second, the search for an explanation of this success led to new understanding. I discovered that dealing with metacognition with the students advanced my personal metacognitive thinking. This insight points to the link between the pedagogical knowledge component and my ability to function as a learner who exercises metacognitive thinking.

An awareness of my lack of knowledge in the field set the development of the second cycle in motion. I labored for many hours to understand the differences between the various

definitions of metacognition on the one hand, and their common components on the other. Thus, I wrote in my journal:

> Today I feel compelled to organize the definitions…I have decided to adopt definitions that I can apply to my function as facilitator of the fostering thinking course.

From analysis of the interrelationships between components that build the development process, it appears that the primary factor for progress in pedagogical knowledge was the broadening of the theoretical basis for the metacognitive content field. This progress was manifested by my ability to word leading questions for a metacognitive discussion. However, its application in experiences during the instruction process was found to be an essential condition for making inactive, inert knowledge, active (Bransford and Vye, 1989; Perkins, 1992, 1999). This content knowledge was operated in the facilitation process and created new pedagogical knowledge that led to integrated progress in the content and pedagogical knowledge fields. Alongside this, as a researcher, I successfully presented to the students how the metacognitive discussion contributed to an improvement in their personal thinking. By the end of the second cycle, it was already apparent that the experiential learning process does not include four consecutive stages, as Kolb described (Kolb, 1981, 1984). The process is much more complex.

The third cycle also started with considerations about the practical side of facilitating, which brought me back to the theoretical aspect. In this way, I firmly clarified for myself the hidden differences between De Bono's approach and the infusion approach (not documented in the literature). I integrated components from the infusion approach for fostering metacognitive thinking into my unique pedagogical approach. As I was now more capable of focused paraphrasing of the students' thinking processes, I moved forward in the pedagogical knowledge field and successfully connected the paraphrasing strategy to theoretical basis of Tishman et al. (1995), which supports the use of a *thinking language*. Connection between my new knowledge constructed in the facilitation field and my accumulated prior knowledge (thinking dispositions approach), was a manifestation of progress in personal knowledge construction related to the metacognition content field, and of my personal metacognitive thinking development.

Simultaneously, ideas that arose in discussions with the students set a widening of the theoretical background in motion, this time in the field of creative thinking. Up to now, I had lacked pedagogical knowledge that resulted in learning about the content field (metacognition). Here, the students were my knowledge source, a fact reinforced by the theoretical literature. At this stage, a progression started also in the methodological research field, which influenced the pedagogical knowledge field. The session protocols, which constituted part of the research data collection, validated my feelings and supported the success of my pedagogical approach developed for fostering the students' metacognitive thinking.

Thus it arises that in the third cycle, the interrelationships between the content knowledge and the pedagogical knowledge deepened my theoretical background. Combined with this, I developed for myself varied metacognitive fostering thinking strategies that I exercised intentionally, while aware of each strategy's different characteristics. I drew effective support from the methodological research component.

The primary motive for the fourth action research cycle was the sense of improvement in my documentation ability and the ability to carry out qualitative research. As a result of identifying *what I know*…, I decided at this stage to give the students the opportunity of evaluating the quality of their thinking journal documentation. If it was thought until now that the methodological research field made only a marginal contribution to the learning journey, in the fourth cycle this field became a central component in the development process. There is no doubt that its influence was made possible by the background of progress I sensed in my content and pedagogical knowledge.

At the start of the fourth cycle, as with previous cycles, I was troubled by practical questions about evaluating metacognitive thinking. However, even before I had time to seek answers in the literature, I made headway through analyzing a *powerful event*, in which the students initiated a session all about evaluating the concluding exercise and their thinking journal. I saw this event as a type of index for the progress that had been made in the students' metacognitive thinking. They had begun to see evaluation as an essential stage in their thinking process. Alongside my personal metacognitive thinking development and the broadening of my theoretical knowledge about evaluating metacognitive thinking, I successfully enhanced my pedagogical approach.

My progress as a researcher was built out of my personal progress as a learner, in the ability to connect themes in the thinking field. From here, it arises that the progress in the methodological research component influenced both content and pedagogical knowledge, but these were influenced by personal metacognitive thinking development.

The second phase of the fourth cycle was also set in motion by the methodological research component. Monitoring of the metacognitive discussion initiators on the course showed that both research subjects (students and facilitator) spontaneously initiated relevant discussions, reflecting development in metacognitive thinking. This displayed a higher level of metacognition. As facilitator, I understood that one of my important functions is to make sure the learning environment invites collaborative dialogue. And indeed, both the students and Naomi the observer unanimously agreed in the feedback questionnaires, that the special atmosphere had helped to build relationships of trust and empathy among the course participants and the facilitator. Thus, a learning community was created, which contributed much to everyone's metacognitive thinking development. These findings, which will not be dealt with in this chapter, match the view of Vigotsky and others, who saw learning as a social process, in which one gives personal interpretation of one's learning and thinking processes, following interpersonal and intrapersonal negotiation (Cobb and Bowers, 1999; Keiny, 1996; Perkins, 1993, Vigotsky, 1978).

At this stage of the research, in which I …*discovered a new kind of metacognitive thinking*…, the findings indicated how the methodological research field contributed to the construction of knowledge in the two other development components: Pedagogical knowledge and the content field.

The third phase of the fourth cycle investigated the ability to connect new knowledge with prior knowledge as part of the collaborative dialogue in the metacognitive discussions. This stage of the research was also set in motion by my function as researcher, and very quickly produced findings that can be expressed qualitatively and quantitatively. This stage, which sealed the action research, helped me to understand that *dealing with evaluation is, in fact, high-level cognitive thinking*… A discourse reflecting a high level of metacognitive usage was constructed before my eyes.

MODEL FOR THE DEVELOPMENT OF A REFLECTIVE LEARNER

Through general observation of the findings presented in Table 1, and of a description of the stages in my learning journey, a complex picture of interdependence between the process's building components is perceived. Sometimes, progress in the content field set progress in motion in the pedagogical field, and vice versa.

The progress in pedagogical knowledge as a result of the experience sustained the progress in content knowledge. The contribution of the methodological research component was most prominent in the fourth research cycle, but its gradual progress throughout the research reinforced the progress of other components. If we compare each component in the development process to a cogwheel, we can maintain that the rotation of one wheel causes the second wheel to rotate, forming a development process. This process is set in motion each time one component progresses, as it feeds the progression of the other components. The total progress of the three components builds a new component, now referred to as metacognitive thinking, which summarizes the developmental learning process of the reflective learner. This component is described by me earlier at the end of each action research stage with the title "from overall reflection as a learner," as these are the insights gained from the range of content, pedagogical and methodological research knowledge insights.

However, analysis of the motives for the different action research cycles shows that the ability to identify what I do not know and what I already know about each component: Content knowledge, pedagogical knowledge and methodological research knowledge, is what enabled my personal learning process throughout the academic year. On the basis of this, I claim that metacognitive thinking is what sets the learning process in motion. It is the cogwheel that turns first, bringing about progress in the three components mentioned above. However, the total progress of the three components also influences progress in metacognitive thinking.

From the above, a model is received, which views metacognitive thinking development as a consequence of the development of content knowledge, pedagogical knowledge and methodological research knowledge. It also sees metacognitive thinking as the motive for the development of these components. This model is consistent with researchers whose approaches viewed metacognitive thinking as operated at different times. Some were of the opinion that metacognitive thinking is operated at three specific times (Perkins and Swartz, 1992): Following a previously implemented thinking process, during a current thinking process, and in preparation for a new thinking challenge. Schön (Schön, 1987) distinguished between reflection in action and reflection on action, carried out as retrospective observation. Even though its definitions are subjected to different interpretations, they indicate the need for metacognitive thinking at different times in the learning process. If we return to the experiential learning model (Kolb, 1981, 1984), my research casts doubt on the simplicity of the model, which presents concrete experience as the first stage of the learning cycle, with reflective thinking operated afterwards. According to the model emerging from the action research findings for my personal learning journey, learning is motivated by an investigation of knowledge in all components that build the learning process, that is to say, from activating metacognitive thinking at the first stage of the learning process. My findings are in keeping with other researchers who objected to Kolb's model due to a lack of sufficient attention to

the functions of reflection, prior knowledge and the possibility of parallel learning tracks in the learning process (Jarvis, 1995, Tennant, 1997).

Use of the proposed model enables us to investigate the affinity more precisely between the ability to connect new knowledge with prior knowledge and the ability for metacognitive thinking. Just as certain conditions are required for one cogwheel to turn another, so it is with the learning process. Progress in one component can influence progress in others, if the learner will connect new and prior knowledge within and between the different components. Therefore, this ability to connect, which requires active, available knowledge, is an essential condition for the germination of the metacognitive thinking component. In a similar way, various researchers developing fostering thinking approaches see the importance of cultivating the ability to make connections (Perkins, 1992; Perkins and Swartz, 1992; Tishman et al., 1995). However, my claim is that the ability to connect is itself an expression of metacognitive thinking, which accompanies the learning process from its early stages. This ability accompanies awareness of a lack of knowledge on the one hand, and of existing knowledge on the other, thus setting the learning process in motion.

Implications for Education

The process I underwent enabled me to construct for myself a pedagogical-educational perception for the concept of metacognition. This is one's ability to define for oneself what one already knows and what one does not yet know, and the ability to connect new knowledge with prior knowledge, with the aim of locating effective strategies to advance the aim, experiencing those strategies and evaluating their implementation. The evaluation result will bring about a new definition of the missing knowledge and of the new knowledge gained from the experience, and will enhance the strategies. This definition, which develops from the overall reflection on the learning journey I experienced, is in keeping with Costa's definition of metacognition (Costa, 1991; Costa and Kallick, 2000). In his opinion, this is our ability to know what we do and do not know. It is also the ability to use prior knowledge for planning an efficient strategy, to carry out essential stages in problem-solving and reflect on our thinking quality in relation to a specific issue.

The insights from the fourth action research cycle support a broader definition of metacognition and indicate the required conditions for cultivating metacognitive thinking. I discovered that the dialogue about evaluation-related themes, which was of interest to the students and the discussion facilitator, stimulated a high level of metacognitive thinking. At this stage of the research, I discerned the power of the influence of the affective aspect on metacognitive thinking. And indeed, I found in the literature that over ten years ago, another component was added to the definition of metacognition: Self-efficacy, which relates to self-appraisal of one's emotional state. For example, some people have feelings of mental pressure or incapability when faced with a verbal math problem, resulting in a lack of motivation to reach a solution, or to monitor the problem-solving process. Thus, evaluation of one's personal ability influences evaluation of the task, its requirements, the knowledge required for implementing the task, and the implementation strategies (Borkowski, Carr, Rellinger and Pressley, 1990). Paris and Winograd also included another two essential components in their definition of metacognition (Paris and Winograd, 1990):

a) Self-appraisal – reflection on one's personal knowledge states, abilities and emotional states which relate to one's knowledge, abilities, motivation and learning characteristics.
b) Self-management – relating to metacognition in action, including mental processes that help to orchestrate aspects of problem-solving (Paris and Winograd, p. 18).

Villar's explanation (Villar, 1994) that reflection influences one's affective condition coincides with my feeling of release on developing my metacognitive thinking. In his opinion, reflection enables the passage from states of uncertainty, doubt, confusion and embarrassment to a state of control over complex situations and a sense of satisfaction as a result of coping with dilemmas. In light of this, it appears that the definition of the concept of metacognition should include several components: Knowledge of the personal knowledge, the processes, the cognitive state and the affective state, the ability of conscious, directed monitoring and the ability to manage these states.

The teacher's function is also clarified here – to develop the students' awareness of their abilities as an essential condition for metacognitive thinking cultivation. Also – to accustom the students to consider a range of aspects, while connecting them: Their personal learning characteristics, content knowledge – what they already know and what they still need to learn, available strategies and the various learning task requirements. The teacher also needs to accustom the students to coordinate the range of aspects via processes of monitoring and regulation of the cognitive processes. The teacher must possess a high level of metacognitive ability to develop metacognitive thinking among the students, and must be a model for reflective thinking, in addition to having expertise in the content, pedagogical and methodological research fields.

Another of the teacher's major functions is to design the learning environment. Many researches show that exposure to an environment conducive to thinking may improve people's inherent abilities (Greensfeld, 1997; Perkins and Salomon, 1989; Zohar, 1999, Zohar and Dori, 2003) and use of metacognitive thinking may improve students' implementation of thinking (Costa and Garmston, 1994; Costa and Kallick, 2000; Schoenfeld, 1987).

CONCLUDING REMARKS

I embarked on an experiential learning journey, a once-in-a-lifetime-experience and fraught with risks. I started out as researcher of science, immersed in quantitative research paradigms. I relied on my success as a teacher educator of Natural Sciences, but my reservoir of knowledge contained only a hazy perception of metacognition. I entered unforeseen situations and was inspired to think about questions for which I had not yet reached answers. It was, in the words of Calvino (1978) a journey to the invisible cities. As one session followed another, I was continually learning something new. As my students learned, so did I. I discovered that the learning occurred when we were all functioning as learners. I had started to share my deliberations with them in any case. Thus my content knowledge, pedagogical knowledge, methodological research knowledge and metacognitive thinking ability progressed.

The action research was the learning trigger. It can be assumed that had it not been for commitment to the research, my personal learning awareness would not have surfaced as it did following my observation as a researcher. The research obliged me to connect the new knowledge to my prior knowledge as a learner, a content specialist, a facilitator and a researcher, with the result that I developed within each of these functions. The development process that I described is similar, to an extent, to processes described in action research literature (Delaney, 2001; Elliott, 1997, Keiny, 1996; Kember, 2002; Zeichner and Noffke, 2001), but it is unique in that the research object was metacognitive thinking.

I finished the journey as a different person. My current knowledge of metacognition was created by an integration of theoretical knowledge and practical knowledge applied in the classroom. This is phronesis: Practical knowledge dependent on context (Eisner, 2002; Kessels and Korhagen, 2001). As a researcher, I underwent a perceptual turnaround. I learned to evaluate the qualitative paradigm for educational research (Greensfeld and Elkad-Lehman, 2007) and understood the power of self-study-type action research as a metacognitive thinking development tool. I succeeded in constructing meaningful instruction, with emphasis on process and focused teaching for developing the students' metacognitive thinking skills. I underwent a change in my own teaching practices, with a readiness to enter constructivist teaching processes in earnest. I learned how to consider the students' knowledge and to listen to their needs, and to questions that arose during the learning process, even if this meant acquiring new personal knowledge during the very act of teaching. I now understand Eisner's viewpoint (Eisner, 1983, 1992). It connects the development of educational expertise with the ability to cope with opaque situations, and with research ability combined with the development of intellectual and critical curiosity, out of the aim of achieving the educational goals. Since completing the experimental course, I have applied my insights within the framework of thinking courses and of courses in other disciplines.

Nora, a student from the experimental course, said: *I discovered that this course affects all aspects of my life*. Unexpectedly, this course has also affected all aspects of my own life – as teacher educator, human being and researcher.

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Chapter 16

TRACES AND INDICATORS: FUNDAMENTALS FOR REGULATING LEARNING ACTIVITIES

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ABSTRACT

The work reported here takes place in the educational domain. Learning with Computer Based Learning Environments changes habits, especially for teachers. In this paper, we want to demonstrate through examples how traces and indicators are fundamental for regulating activities. Providing teachers with feedback (via observation) on the on going activity is thus central to the awareness of what is going on in the classroom, in order to react in an appropriate way and to adapt to a given pedagogical scenario.

In the first part, the paper focuses on the description of different ways and means to get information about the learning activities. It is based on traces left by users in their collaborative activities. The information existing in these traces is rich but the quantity of traces is huge and very often incomplete. Furthermore, the information is not always at the right level of abstraction. That is why we explain the observation process, the benefits due to a multi-source approach and the need for visualisation linked to the traces.

In the second part, we deal with the classification of the different kinds of possible actions to regulate the activity. We also introduce indicators, deduced from what has been observed, reflecting particular contexts. The combination of contexts and reactions allow us defining specific regulation rules of the pedagogical activity.

In the third part, we illustrate these concepts into a game based learning environment focused on a graphical representation of a course: a pedagogical dungeon equipped with the capacity for collaboration in certain activities. This environment currently used in our University offers both observation and regulation process facilities.

Finally, the feedback about these experiments is discussed at the end of the paper.

Keywords: *Traces, Observation, Collaborative Activities, Regulation, and Awareness*

INTRODUCTION

Learning with Computer Based Learning Environments changes habits, especially for the teachers. Most of the time, a teacher prepares his/her learning session by organizing the different activities in order to reach a particular educational goal. This organization can be rather simple or complex according to the nature of this goal. For instance, the teacher can decide to split the classroom into groups, ask the students to search an exercise in parallel, put different solutions on the blackboard, have a negotiation debate about the proposed solutions, and ask the students to write the chosen solution in their exercise-books. The organization of the different sub-activities in an educational session is called "learning scenario".

In traditional teaching, namely in an environment with no computers, a teacher tries to be as aware as possible of his/her students' performance, searches for indicators that allow him/her to know a student's understanding status and what activity of the learning scenario this student is performing. The teacher then adapts his/her scenario, e.g. by adding further introductory explanations or by keeping an exercise for another session. Once the training session is finished, the teacher often reconsiders his/her learning scenario and annotates it with remarks in order to remember some particular points for the next time. For instance, he /she can remark that the order of the sub-activities must be changed or that splitting into groups was not a good idea. In that case, the teacher is continuously improving his/her learning scenario, thus following a quality approach.

In educational platforms, formalisms exist to allow the teacher to describe learning scenarios with IMS-LD (Koper et al., 2003), (Kinshuk et al., 2006). Once the scenario is described, it can be enacted in the platform. The different actors can perform the predicted activity. At that time, the teacher would like to have the same possibility as in traditional teaching, to be aware of what is going on in the classroom, in order to react in an appropriate way. Of course, he/she cannot have the same feedback from the students, since he/she lacks human contacts. However, in such environments, participants leave traces that can be used to collect clues, providing the teacher with awareness of the on-going activity. These traces reflect in depth details of the activity and can reveal very accurate hints for the teacher.

This observation features in learning environments let provide tools to the teacher allowing her/him to react to a particular situation, for instance: one student is in trouble; there are two many interactions among a group of people; there is not enough communication in a collaborative task. Being aware of these particular situations helps the teacher to adapt her/his following actions that is to say the learning session. For instance, he/she can communicate with a student and help her/him or s/he can deactivate the communication tools within the group of participants. This adaptation of actions in a collaborative activity is also called "regulation".

In this chapter, we want to point out the different aspects enabling the regulation of the collaborative activities. We propose to split these aspects in two different classes: the ones linked to "observation" and the ones linked to "(re) action".

In the first part, we present the problems linked to observation through traces. Although this approach is very powerful, we will see that observation is a tricky task, with a lot of problems to be solved in order to obtain relevant observation allowing decision making for improvement of the collaborative process.

In the second part, we classify the different kinds of possible actions to regulate the activity. We also introduce indicators, deduced from what has been observed, reflecting particular contexts.

We also introduce a third part where the regulation of the pedagogical activity is illustrated in a "pedagogical dungeon", through a learning game where groups of students embark on a quest for knowledge acquisition.

OBSERVATION PART

The tracing activity is an appropriate way for reflecting in depth details of the activity and for revealing very accurate hints for the teacher.

Unfortunately, traces are objects very difficult to manage and understand. We propose to first demonstrate the kind of problems linked to observation and to expose them through a pragmatic approach (experimentations).

Pragmatic Approach to Observation Problems

Fact 1: Log Files are Rich but Correspond to a Difficult Way to Exploit Information

A first aspect to consider, central to the observation area, is the form of the traces. Many e-learning Platforms or Learning Management Systems are based on Web Servers (Zaïane et al., 2001) (Burton et al., 2001). These servers easily supply logs (information concerning the connections on this server) stored in specialised files. We first used this information in an experiment carried out at the University of Savoie. As we needed to analyse the new usages induced by the use of our local e-learning platform ("the electronic schoolbag"), we decided to work from the traces left by thousands of users. The source of these traces was a web server providing data in the SQUID format, as for instance,

193.48.120.76 22/04/2003 04:25:31 POST TCP_MISS/200 http://www.univ-savoie.fr:443/Portail/logged_in FIRST_PARENT_MISS/www3-ssl2.univ-savoie.fr text/html.

It is obvious that these traces are not directly interpretable. They should be transformed, rewritten, in order to make their understanding possible. For instance,

193.48.120.??? => "Connection to the e-learning platform from the university".

Here, we want to identify connections matching the *193.48.120.???* address, meaning an access from the university site, where the ??? can be replaced by any number from 1 to 255.

The traces were analysed a posteriori by a researcher in the "information and communication" field. From this experiment, new practices were revealed such as the use of the platform at home, but without using collaborative tools (Chabert, 2005). The experiment also pointed out the need for addressing the problem of treating the huge amount of data available in the log files.

Fact 2: Traces Need to be Transformed in an Organised Way

In order to better manage this huge and fine-grained information, we specified a transformation chain allowing the manipulation of traces (figure 1). The main purpose is to

reach a good level of granularity, allowing a better comprehension of the user behaviour (Loghin, 2005).

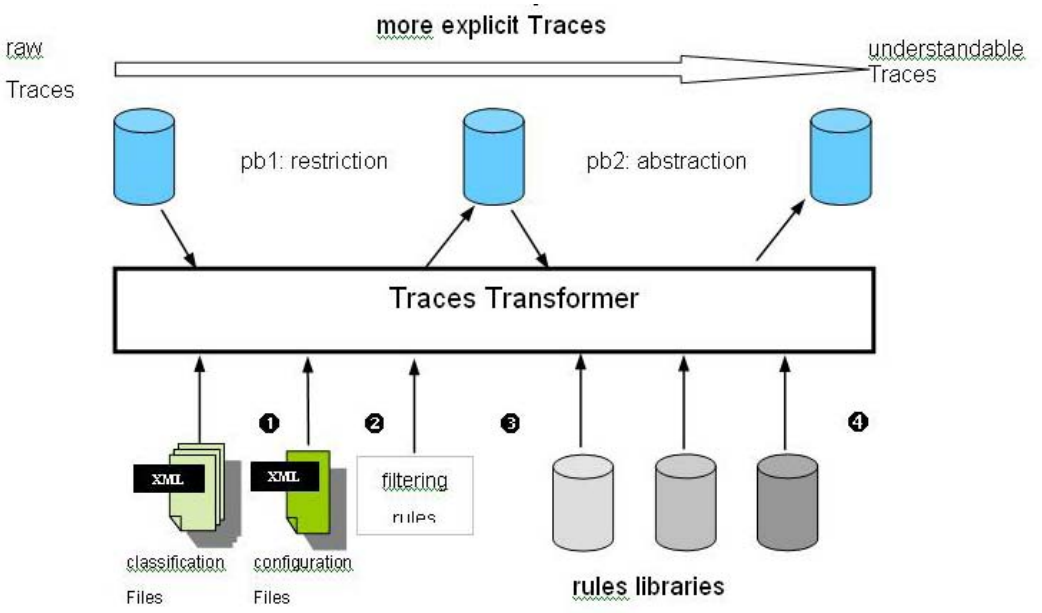

Figure 1. Transformation chain for manipulation of traces.

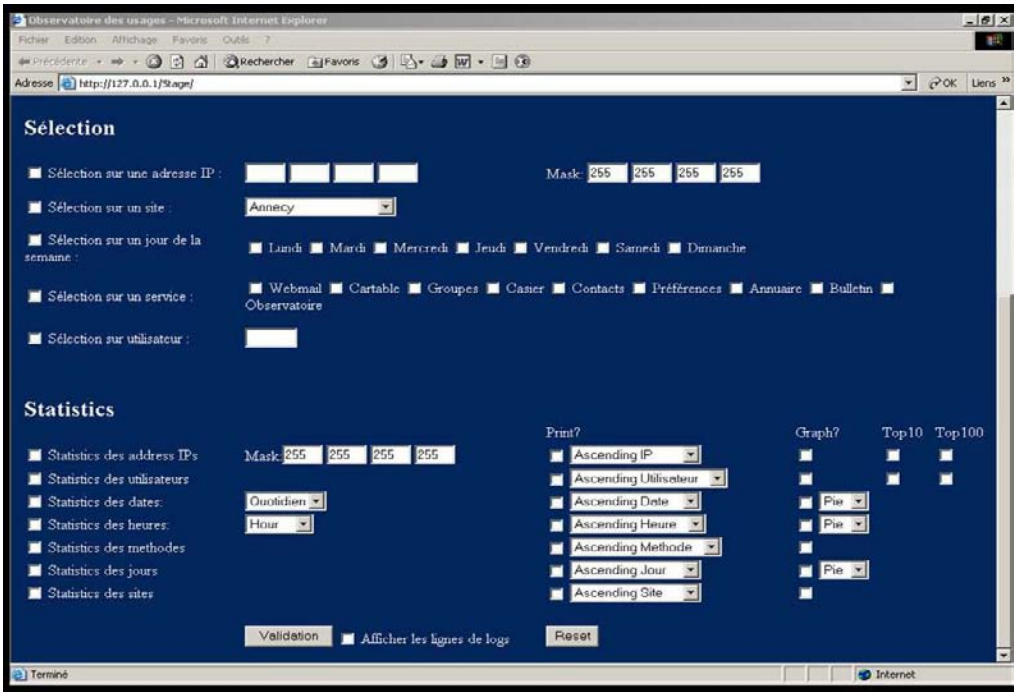

Figure 2. Requests through the “observatory” tool.

This chain proposes several functionalities to manipulate the traces: filtering in order to reduce the huge quantity of logs, aggregation in order to change the level of granularity (abstraction) of the traces, transformation into a uniform format in order to take into account several log formats (SQUID, APACHE, I2S), or storage in a database and use of a Data Base Management System through SQL requests.

An experiment enacting this transformation chain allowed us to make an “observatory” tool, dedicated to non-computer scientist users. This tool allows gathering statistics on the usage of the “electronic schoolbag”, such as the number of connections, the types of users connected, the kind of preferred tools.

Visualization functionalities were added to this tool for obvious reasons of classical representations of statistical data (graph representations, figure 3), thus adding a visualisation step to the transformation chain.

Fact 3: Traces Contain Hidden Information; Searching into Traces Can be an Interesting Research Track

The approach presented above is valid, since the analyst exactly knows what s/he is searching and if s/he is able to express it through the proposed interface. From the usage of the tool, we can say that there is a need for other approaches, especially when the analyst or the teacher does not know precisely what s/he would like to observe. This is the case, for instance, when the analyst tries to discover new usages. In that case, we are faced with a new problematic, where the information included in the traces contains hidden behaviours to be revealed.

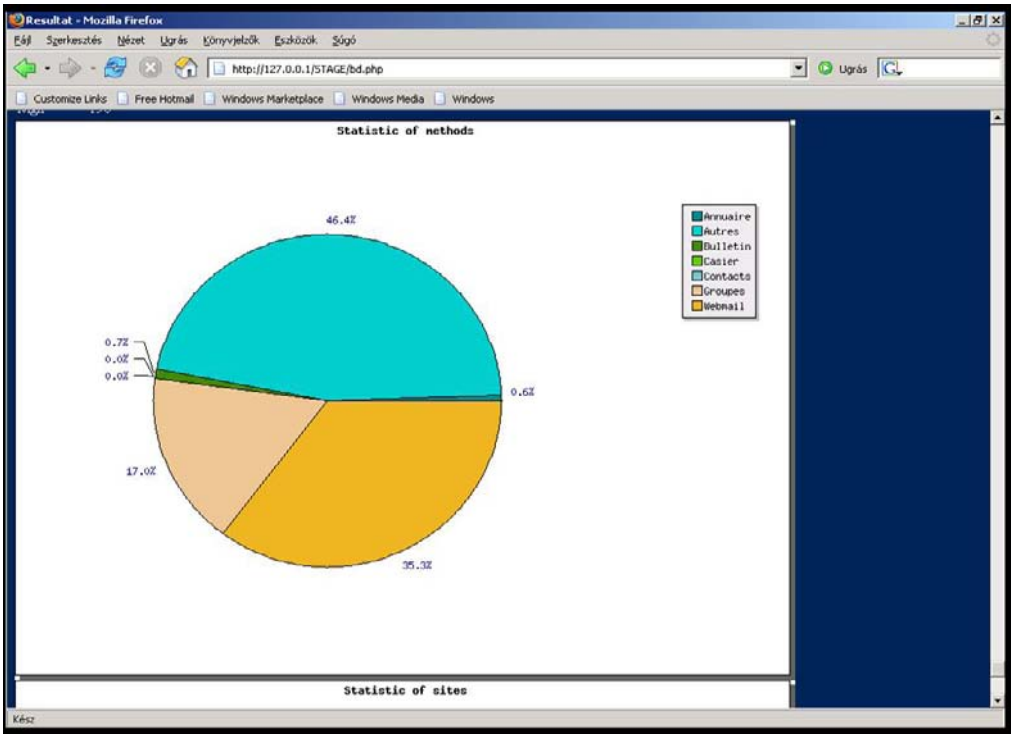

Figure 3. Visualisation Interface: Computation of indicators.

The considerable volume of data generated by an e-learning platform enacted in a real situation (e.g. 1 Go per week for approximately 15000 people using the “electronic schoolbag”) causes real exploration problems, as in data mining. It is sometimes extremely difficult to extract or analyse significant patterns from this data, making sense for the analysts. For that purpose, we developed a tool called “Analog”, implementing “sequence mining” algorithms, and providing significant patterns. Using “Analog”, we found out the combined use of different tools integrated in the “electronic schoolbag”, as the frequent switching from the web mail to the telephone directory. This kind of facts can be used for ergonomic purpose; it clearly suggests a re-conception of the platform, with a close integration of the directory into the web mail. In the same vein, we pointed out the necessity for launching automatically the web mail, since most of the users first accessed this tool when they connected to the “electronic schoolbag”. By coupling “Analog” with a weighted graph tool, it was possible to represent the most frequent path followed by the users, thus defining a “standard use case” of the platform.

Although these tools compute their results from a significant amount of data obtained through the platform, they are sometimes useless to obtain precise information for some observation goals. In that case, it is necessary to combine them with other sources of data.

Fact 4: In Order to Better Understand the Activity, and the Links with Predefined Learning Scenarios, Multi Sources for Traces Should be Considered

As mentioned in the introduction, a certain amount of research works linked to pedagogical platforms concerns the formalisation of educational scenarios (Koper et al., 2003). The teacher frequently foresees a sequence of activities to be performed during the learning session. This sequence, also called scenario, guides the session, and it becomes crucial to compare the learners’ activities and the predefined scenario (France et al., 2005). This comparison allows providing the teacher with awareness of the activities going on, and allows improving the scenario itself (Marty et al., 2004).

This is not an easy task, since the users can use simultaneously tools that are not integrated in the educational platform (forums, web sites, chat). We do not want to restrict our understanding to the tasks included in the predicted scenario. We want to widen the sphere of observation, so that other activities performed by a student are effectively traced. Even if these activities are out of the scope of the predicted scenario, they may have helped him/her to complete the exercise or lesson. We thus need to collect traces from different sources. It is therefore interesting, from a general point of view, to be able to take into account more than one source of data. Such an approach allows deducing, from the multi sources traces, non-foreseen behaviours.

Through an experiment described in (Heraud et al., 2005), we have observed non-foreseen students’ behaviours. It is then possible to pick among the collected logs from different sources to precise, annotate or better explain what happened during the session (see Fig 4), through a “trace composer” (Marty et al., 2007).

To help the user to better understand the generated trace, a graphical representation is a good support to make links between the learning scenario and the traces. We also take the different sources into account, in order to refine the understanding of the effective activity. We propose a metric to see how much of the activity performed by students is understood by the teacher, which is graphically represented on a "shadow bar".

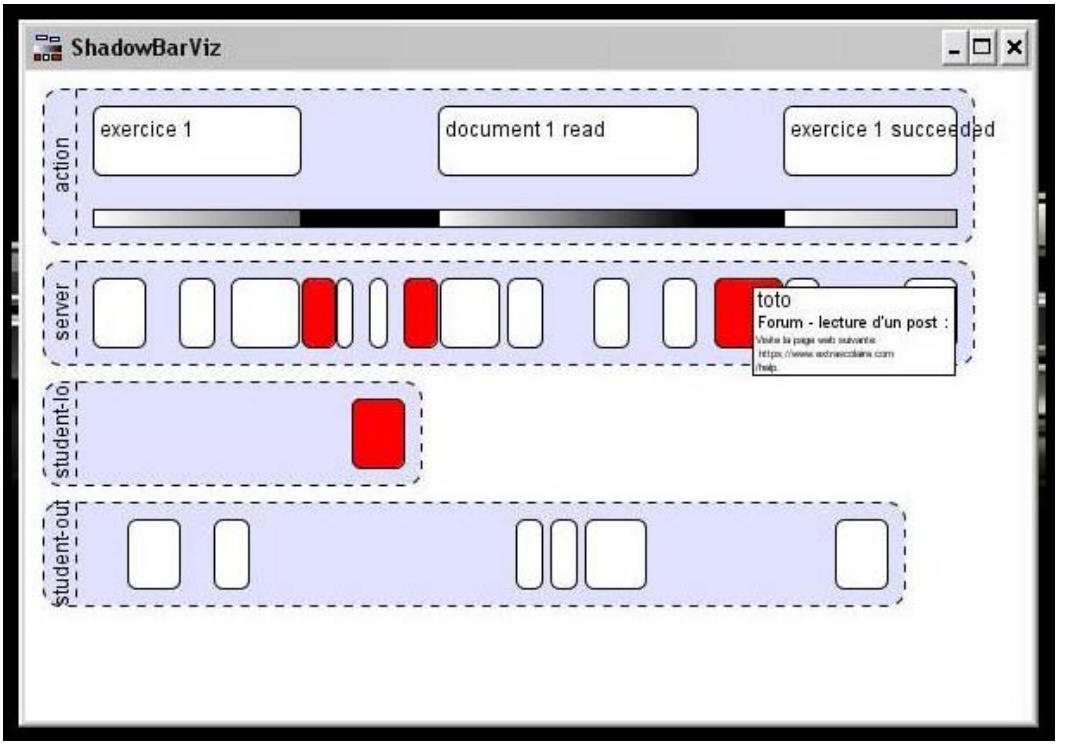

Figure 4. Tool visualising traces from different sources.

The comprehension of a general activity implies to situate non-foreseen behaviours with foreseen activity sequences, as shown in figure 4 with exercise 1, document 1 read. It is thus useful to be able to reposition the users' actions on the pedagogical scenario. In this experiment, we suggested a scenario improvement, since we pointed out that all the students that finished the learning session communicated with the teacher at the end of the first exercise in order to validate it. This validation making them more confident can thus be proposed in the scenario itself.

Our approach concentrates on the links between the performed activity and the recommended scenario. We can take advantage of the interpretation of the traces (Egyed-Zsigmond et al., 2003) in order to improve the scenario itself (Marty et al., 2004). Indeed, in the framework of reusing learning scenarios in different contexts, the quality of a learning scenario may be evaluated in the same manner as software processes, for instance with the CMM model (Paulk et al., 1993). The idea is to reconsider the scenario where some activities are systematically added or omitted by the users.

This study thus allows addressing problems that are linked to the scenario and the necessity to follow the activity. Analysing the traces after the session provides the analyst with interesting results but does not solve the problem of giving the teacher the necessary awareness to react immediately to particular situations.

Fact 5: Immediate Analysis Enables Reaction. Visualisation Improves the Teacher's Awareness

Detecting potential problems as soon as possible is a crucial issue. In order to alert the teacher on the fact that the collaborative activity is not progressing as expected, we need to compare the traces representing the actual activities with the ones mentioned in the predefined scenario and try to establish links between them. It is essential for the teacher to have a view of what is going on, in order to be able to react to given situations. The a posteriori analysis remains valid but can be expanded by analysis during the activity. New observation goals can also appear during the session. For instance, it can be useful to observe the status of the students during the first part of the session and to synchronise them before starting the second part of the session, being sure that everyone acquired the required concepts.

This adaptive observation, needing high flexibility from the system, can be implemented through agents. A set of "pedagogical observation agents", set up on the students' computers, inspects some users' actions (the ones that are on focus for the observer) and notifies an awareness agent before invoking a visualisation agent to provide the teacher with the appropriate information. This distributed system is thus able to collect the significant logs directly on the machines through specialised agents (Carron et al., 2006).

The visualisation agent interprets the traces sent by the observer agents in order to display them on a dashboard for the teacher. An example of such an agent, called "classroomviz" has been developed (figure 5). Indicators are computed from activity traces and from a predictive scenario, offering the average realisation time for each activity (France et al., 2006). The teacher can thus easily follow the students that are late for some activities (red faces).

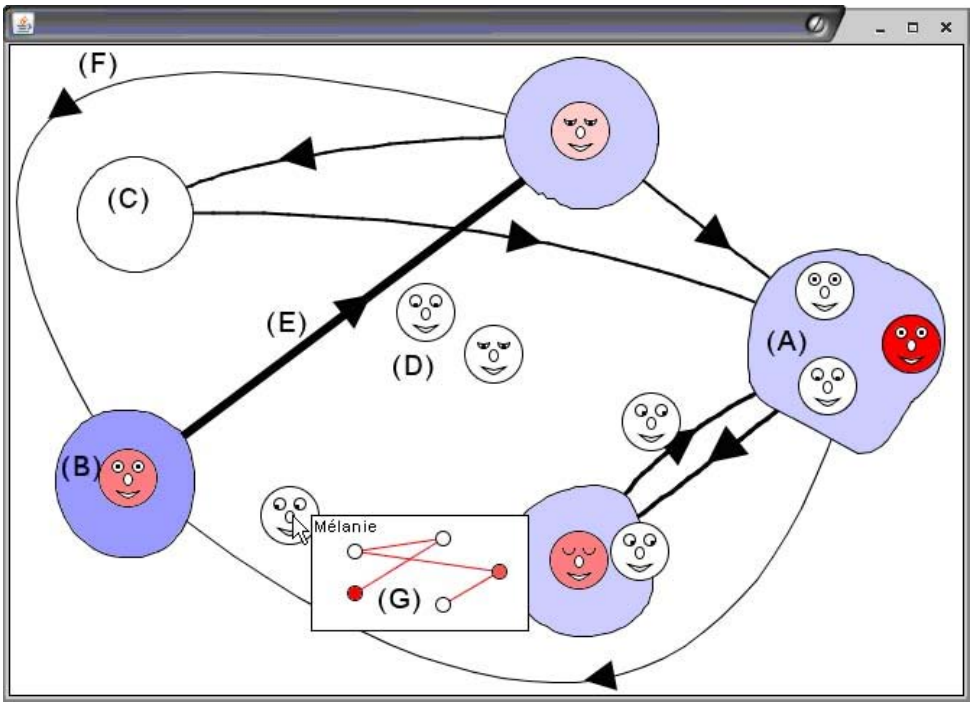

Figure 5. Screenshot of the visualisation tool for the teacher.

ARCHITECTURE OF THE OBSERVATION SOFTWARE

From the facts pointed out in the previous section, we propose an architecture suited for taking these points into account.

Summary of the mentioned experiments

Experiment	Approach	Source	Transformation of the traces	Visualisation	Analysis Type	When
Analysis of usages (electronic schoolbag)	Centralised	Mono	Filtering, Renaming	Statistical	Quantitative	a posteriori
Transformation Chain	Centralised	Mono	+ Rewriting Rules	Statistical	Quantitative	a posteriori
Searching into traces : "analog"	Centralised	Multi	+ Aggregation	Statistical + graphical (oriented graph showing the most frequent path)	Quantitative	a posteriori
Multi Trace Composer	Centralised	Multi	+ Annotations	Links with the pedagogical scenario	Qualitative	a posteriori
Visualisation of the classroom	Distributed	Multi	Computation relating to scenario constraints (being late in an activity)	Display Dashboard Observation reconfiguration	Qualitative	During the activity

Suggested analysis viewpoints reinforce the established phases linked to the observation lifecycle. These phases can be described as follows:

- A collecting phase, where relevant traces are identified and collected before being treated by a dedicated agent (structuring or visualisation);
- A transformation phase (structuring, abstraction) of collected data in order to make more explicit the rough traces and to make these traces understandable from the observer (researcher, teacher, or student);
- And, a visualisation phase, where visualisation techniques will be used in order to reveal the semantic from the traces, make it easier to understand and help an analysis from a particular viewpoint. The phase is aiming at facilitating the interpretation of the on-going activity from a non-specialist.

MODEL OF A TRACE BASED SYSTEM

We ground our work on a model elaborated in collaboration with the SILEX Team of the LIRIS laboratory. This model called Trace Based System (TBS) defines the different modules associated with the different phases mentioned previously.

The figure 6 illustrates the process allowing the observer interacting with a traced e-learning platform in order to visualise and regulate the activity using the traces. The observer plays the role of a "trace composer". S/he furnishes both the pedagogical scenario possibly expressed with IMS-LD (Koper et al., 2003), and the description of the experiment pointing out the analysis needs (Carron et al., 2006). S/he thus sets up the e-learning platform by adjusting collecting and transformation tools. Then, the experiment can be enacted, providing the analysts with usage feedback.

Collecting Phase

As demonstrated in figure 6, the collecting phase is prepared before using the TBS and consists of gathering the traces generated in the e-learning platform. The trace collecting is a complex computer science problem, due to the large volume of rough traces that one can possibly collect. This collect can be made through instrumented software according to the trace composer's intentions (Talbot et al., 2008) or through files generated by the operating system, or through dedicated spy software, as key loggers. Another problem related to the trace collection is the heterogeneity of rough traces that requires studying a way to model them (Iksal et al., 2005).

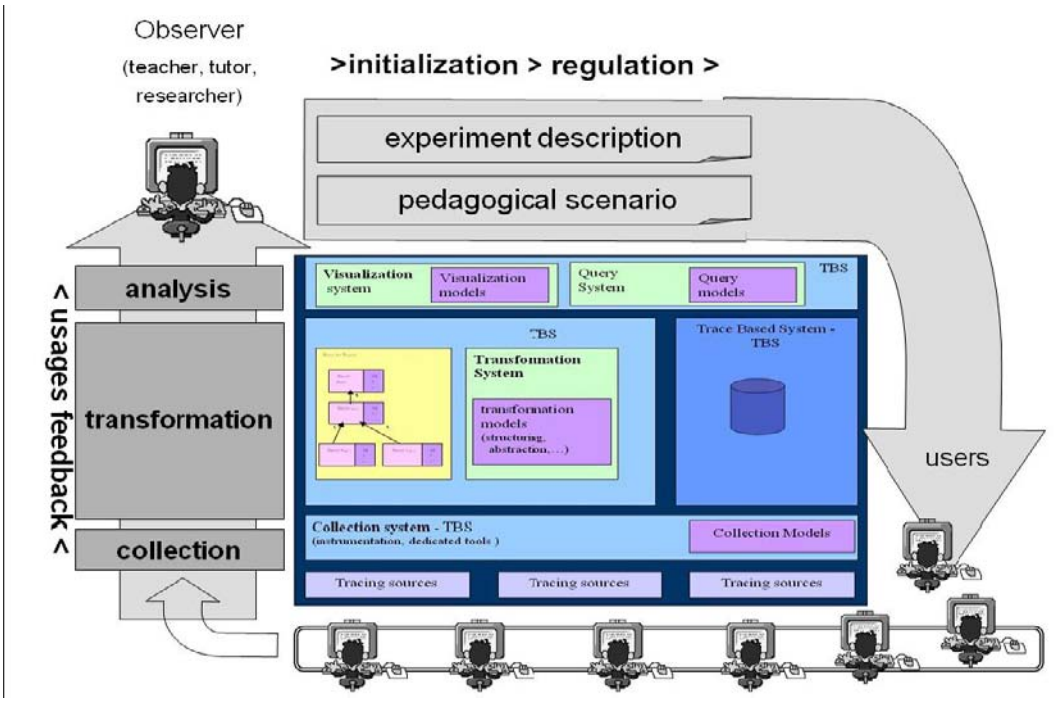

Figure 6. Process for a TBS Model.

Transformation Phase

The transformation phase is performed inside the TBS. The trace being an object in itself, the notion of Trace Based System has emerged these last years, in order to allow and facilitate the exploitation and the interpretation of traces (Laflaquiere et al., 2006). The functionalities of such systems therefore concern the traces manipulations. From the rough traces, a TBS offer a set of operations among these objects: filtering, joining or abstracting them. When the results of these operations are still traces, they remain inside the TBS and they can possibly be used for other manipulations. A TBS also offers services allowing trace organisation, such as storage or historical mechanisms. Research questions related to this phase meet trace cleaning (Cooley et al., 1999), trace aggregation according to temporal (Marquardt et al., 2004), semantic or syntactic constraints (Tanasa et al., 2004), trace rewriting or modelling (Laflaquiere et al., 2006), (Champin et al., 2004).

Trace Visualisation

Visualisation phase consists of making request among traces and of visualising traces. These visualisation tools are part of the interface between the TBS and the trace composer. We decide to situate the visualisation and the request system out of the TBS, since these tools do not fit the definition of trace manipulation as defined in (Laflaquiere et al., 2006). Indeed, visualisation techniques produce results that are not traces. Visualisation consists of elaborating a graphical representation, adapted to the analyst objective, from traces contained in the TBS. This representation can take many forms, such as a temporal 2D visualisation of a trace (France et al., 2006), of several traces (Mazza et al., 2005), or a spatial 3D visualisation (Cugini et al., 1999). The visualisation system relies strongly on the analyst objective. For instance, the visualisation system must be able to provide the analyst with a real time visualisation of the enactment of the users activities, and particularly to detect and show the users in trouble. The system must also provide him/her with information about activities causing problems to these users. Finally, a visualisation of individualised paths showing the path of activities for each user must allow the analyst to make an intermediate assessment of the users' progression.

This model guided us to set up an architecture dedicated to the observation problem. We also took into consideration that a centralised approach could not offer adequate functionalities for diverse observations.

DISTRIBUTED APPROACH: AN AGENT ORIENTED ARCHITECTURE

Reasons for Multi Agent Architecture

The observation of collaborative activities has several salient characteristics that give good reasons for an agent approach.

- First, the problem is geographically and functionally distributed. Indeed, each student works on his/her own workstation and some information must be collected locally before being sent on other stations (for instance the teacher's station) in order to be treated or displayed.
- Furthermore, it is not possible to foresee which machine will receive or send the information. This depends mainly on the observation goal and on the students' actions. This is thus highly context dependant. There is no a priori solution to this problem because one cannot discover in advance the students' behaviour.
- Each machine must remain autonomous in order to keep the progress of the pedagogical activity unchanged. It must also be able to communicate with each of the other machines, either to ask for information or to furnish itself some information if necessary.
- Finally, the set of collected traces possibly comes from different software and can be quite heterogeneous. It is thus difficult from a practical point of view to transfer the whole set of data coming from all the workstations to a unique station dedicated to the treatment of this data.

All these points justify the multi-agent approach. It would be however possible to add other advantages of such an approach, as for instance the necessity for an observation system to be open or fault tolerant. The enactment of this kind of system must take into account the deployment context and the constraints imposed by the experiment in particular classrooms.

Multi Agent Systems offer solutions for distributed systems in which autonomous software entities, the agents, can cooperate by means of interactions between them or with the environment. The choice of a multi agent approach is thus particularly well adapted for such observation software. The general idea is to enact observer agents, autonomous software installed on each station, and that are in charge of collecting the relevant (according to a particular goal) actions performed on the station. This provides the teacher with a powerful means for being aware of the status of each student and thus being able to react in an appropriate way.

Multi Agent System (MAS) Enactment

In order to set up the experiments described above, we have developed and used such a system. As we have already highlighted it, the observation goal of the pedagogical experiment is central for the technical choices. The enacted architecture is represented on figure 7.

It contains 3 types of agents that are possibly installed on the machines: the collector agents (C), the structuring agents (S), and the visualisation agents (V). From a technical point of view, some agents (not represented in the figure) are only dedicated to the system functionalities. It is the case for instance for the facilitator agent (directory service: white and yellow pages), or the deployment agent (launching and killing agents).

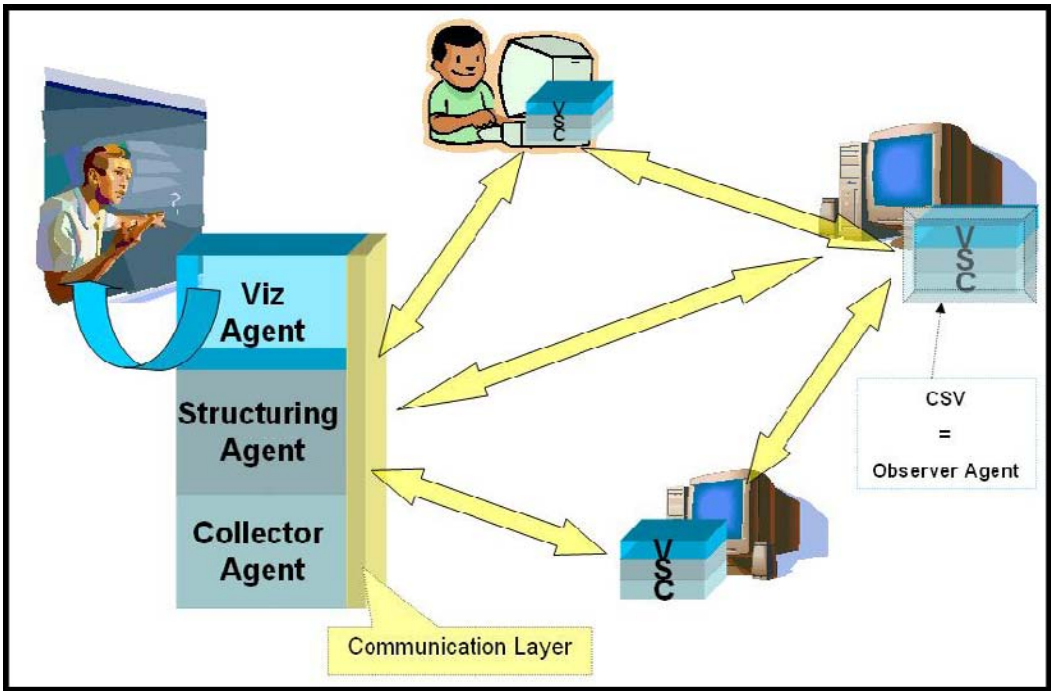

Figure 7. MAS Architecture for observation.

Generally, the MAS are grounded on multi agent platforms (Pesty et al., 2004). Our objective is however to keep our solution as simple as possible, and to be able to deploy it with a minimum of constraints. That is why we have chosen JAVA agents, that are platform independent and that can be launched easily on each station by a simple click. From a conceptual point of view, this solution is open and allows us developing new agents when needed, without changing what is already working. Agents with specific functionalities (useful in particular situations) can thus be enabled or disabled when needed.

From a technical point of view, this observation features must work on any pedagogical platform. The software environment becomes a trace generator. The agents are developed in such a way that they can be considered as a probe on any trace source. The main constraint is of course that the educational platform provides traces and their interpretation model. This "equipment" phase involves having access to the software of this platform, in order to have precise and rich traces.

Experimentations led us to consider other functionalities concerning the management of the traces: Each user has access to his/her traces and can disable the traces collect when s/he wants. For ethical reasons, each user must own his/her traces.

ACTION PART

We can obtain a great amount of heterogeneous trails or traces from various means. This information lets us have an idea of the on-going pedagogical activity.

Coupled with the observation, the reaction is the other aspect of the regulation of the activity. Through this reaction, the teacher can maintain, adapt or improve a particular

pedagogical session. The elements on which a teacher can act to regulate the general activity are all the elements involved in the pedagogical session.

ELEMENTS OF A PEDAGOGICAL SESSION

In pedagogical platforms, the creation of a pedagogical session leads to the creation of a scenario, usually written with IMS-LD described in (Koper, 2003) or more flexible languages like LDL proposed by (Ferraris, 2007). Whatever the formalism is, the pedagogical scenario represents a sequence of activities. In figure 8, an example is given where *the students start with activity 1; they continue either with activity 2 or activity 2' and they finish with activity 3*.

More precisely, an activity is a set of pedagogical resources composed of exercises and pedagogical contents. We can see the exercises as goals and pedagogical contents as means provided to achieve the goal. Moreover, an activity may be composed of tools. These tools allow acquiring some knowledge, testing some hypothesis, communicating, searching and finding information. The figure 9 shows this model.

Several actors may be involved into a pedagogical session. Most of the time, five roles are involved in the description, enactment, or analysis of the pedagogical sessions: student, teacher, tutor, pedagogical engineer and researcher as shown in figure 10.

This short description of the different elements concerning a pedagogical session allows us proposing actions on these elements in order to maintain, adapt or enhance the pedagogical session. This description has shown different levels of granularity for the elements therefore we can exhibit different levels of reaction concerning the pedagogical session.

Let us start with the higher level of the scenario: it is possible to act directly on the list or the sequencing of the activities of the pedagogical scenario. For example, a teacher may want to add a specific activity "verification of cognitive prerequisites at the very beginning of the learning session as (Ausubel, 1968) proposes.

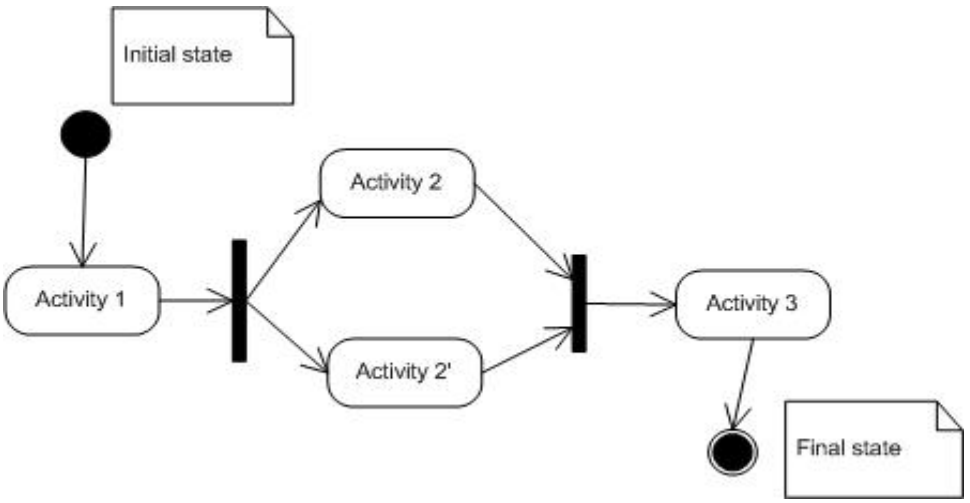

Figure 8. Example of model of pedagogical scenario (sequence of activities).

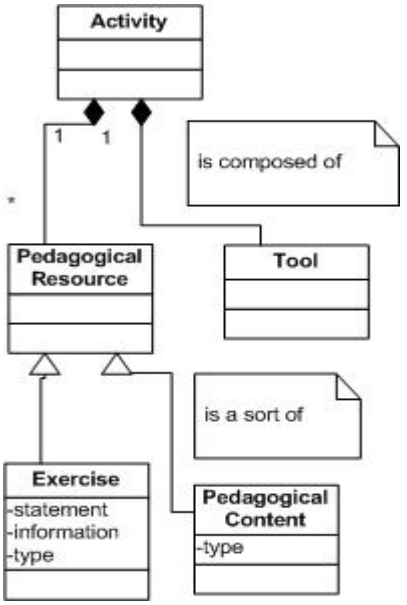

Figure 9. Model of activity related to a pedagogical scenario.

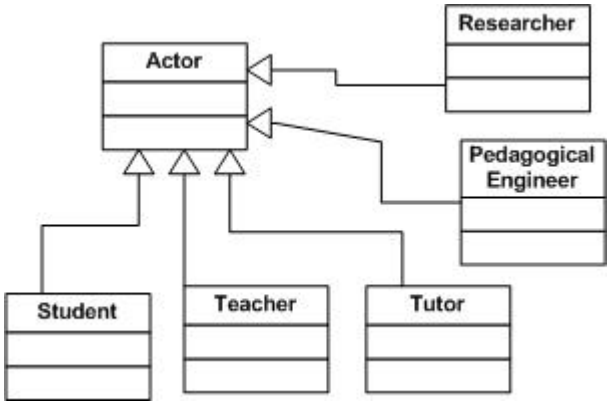

Figure 10. Model of actor involved in a pedagogical session.

It is also possible to remove some activities or just to change their sequencing: swapping two activities; or placing an activity before another one for pedagogical purpose; or even putting some activities in parallel to offer non-linearity or more flexibility in the achievement of the learning session, as already shown in the example in figure 8.

At a sublevel, it is rather possible to act on an existing activity. For example, we may want to change (add or remove) an exercise, a pedagogical content or a tool. For example, the teacher may decide to complement an activity with a new and more difficult exercise, and add a communication tool in order to improve collaboration between the classmates (Slavin, 1987), (Miller, 1990), and force reformulation for a better memory acquisition (Woods, 1989).

At a lower level, each of these entities (exercise, pedagogical resource or tool) is specifically internally adapted:

Regarding the exercises, the statement of an exercise may be simplified in order to split it into easier parts. The pedagogical objective is for example to reduce the cognitive overload of such an exercise (Ausubel, 1975). Another possibility is to change the way to answer this exercise (type). For example, to change an open question into a multiple-choice questions (quiz) because at this moment of the pedagogical session, the teacher is generally overloaded (Plowman, 1997) and is not able to answer quickly to the proposed answers by the students. Another field of an exercise is related to the associated information (see Figure 9). It may include "accepted answers" for automatic correction or "typically wrong answers" in order to help the student and may naturally be also modified, completed or simplified.

Similar actions may be applied to pedagogical contents: it is also possible to modify, complement or simplify the content of a resource. For instance, in order to increase the impact on student's mind (Caine et al., 1990), we may change the modality of a pedagogical resource, if the environment allows it,: text to read, spoken text, diagram, figure, sound only or video.

Slightly different actions are available on tools, since we need to enable or disable functionalities and to modify/adapt the graphic user interface according to the user profile (Brusilovsky, 2001).

All these actions impact directly the global pedagogical scenario at different levels of granularity. Nevertheless, during the pedagogical session, we may want to limit the use of some elements only to specific roles. For example, we could forbid the students from communicating via the chat tool but we could let the teacher and tutors still use it. Some other actions (modify access rights) are thus dedicated to the roles. In a differentiated pedagogy approach, it is required to apply these actions directly on a specific student (on an instance).

All these actions offer different ways to adapt the activity to specific situations detected through observations, participating at the heart of the regulation process. A non-exhaustive summary of the described regulation actions is shown on figure 11. The organisation of the different levels of actions is highlighted: the main generic actions are coloured: the darker, the higher level.

REGULATION AS RULES LINKING OBSERVATION AND ACTIONS

In the first part, we have demonstrated how to obtain facts in order to be aware precisely of each on-going situation. In the second part, we have shown that many regulation actions are available at different levels. The regulation consists in linking observations about a particular situation with a regulation action or set of regulation actions, thus defining regulation rules.

As said before, it is possible to get from different means a great amount of traces that are most of the time heterogeneous. Although it is necessary to equip the stations with as many observation functionalities as possible in order to increase the observation possibilities, only few sharp information is really interesting for the different actors of the learning process at a time. Therefore it is crucial to raise the abstraction level according the concerned user in order to provide synthetic adapted information.

For that purpose, we define *indicators* based on observed traces to present a specific view on the on-going activity. Indicators can be considered as signals enabled when a particular and interesting situation happens. For example, the teacher can use an indicator to know which students are late in an activity (see Fact 5 in the first part).

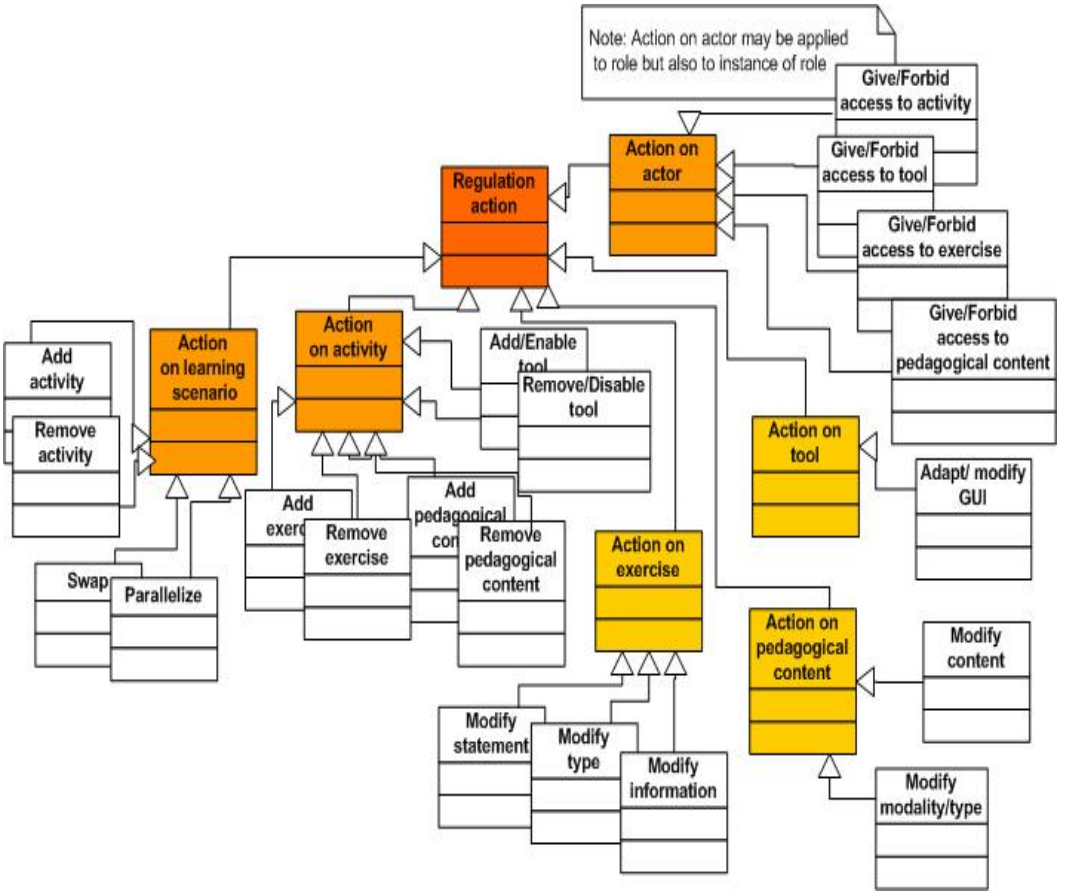

Figure 11. Model of regulation actions for a pedagogical session.

The indicator is here the result of a calculus from the trace 'entering in an activity' and the expected duration of this activity. In this particular situation, the teacher may want to accomplish a specific action and thus to regulate the activity, as for example, making a new help file available for these students with an associated notification.

More complex indicators may be defined by specifying whether these students have previously consulted the available help resources, in order to react in a personalised way. An indicator thus results from a calculus based on a set of observable elements. It reflects particular situations and it may be built from the composition of pre-existing indicators.

REACTING ON PARTICULAR CONTEXTS

A difficult part of the regulation specification is related to the description of the situation when a regulation action must be considered. These situations are quite difficult to describe since they are often complex situations, where a single indicator is not enough. That is why, several indicators are activated and a set of several complementary indicators allows us defining a context representing a more accurate view of the situation (see Figure12). In the previous example, we are able to extend and complement the information, realizing that

almost the whole set of students are late in this activity. In that case, the regulation action must be changed: the difficulty of this activity, the intelligibility of the statement or even the quality of the provided resources must be reconsidered. The final regulation process will not be same: several other possibilities of regulation actions are now possible and adapted for such a situation.

All roles (see Figure10) are concerned by observation, even the students for reflexivity purpose (Feather, 1982), (Paris et al., 1990). Each role or person may define or select their own observation contexts and associate some actions to them. It is a general way to create its own regulation context. A tutor can create a particular set of rules under which the students will work. But, we can easily imagine that a student can also create regulation rules (if the rights are enabled) in order to perform a subtask in a specified way. This is the case for instance when a student is designated as responsible for a particular collective task (tutor role for this subtask). Naturally, each rule is adapted to a specific goal: increase collaboration, develop metacognition, enhance memorisation, verify prerequisite, and magnify the transfer between knowledge and learned abilities.

Now, we present an application of these concepts on a real digital learning environment that we have developed and that we use currently in our university.

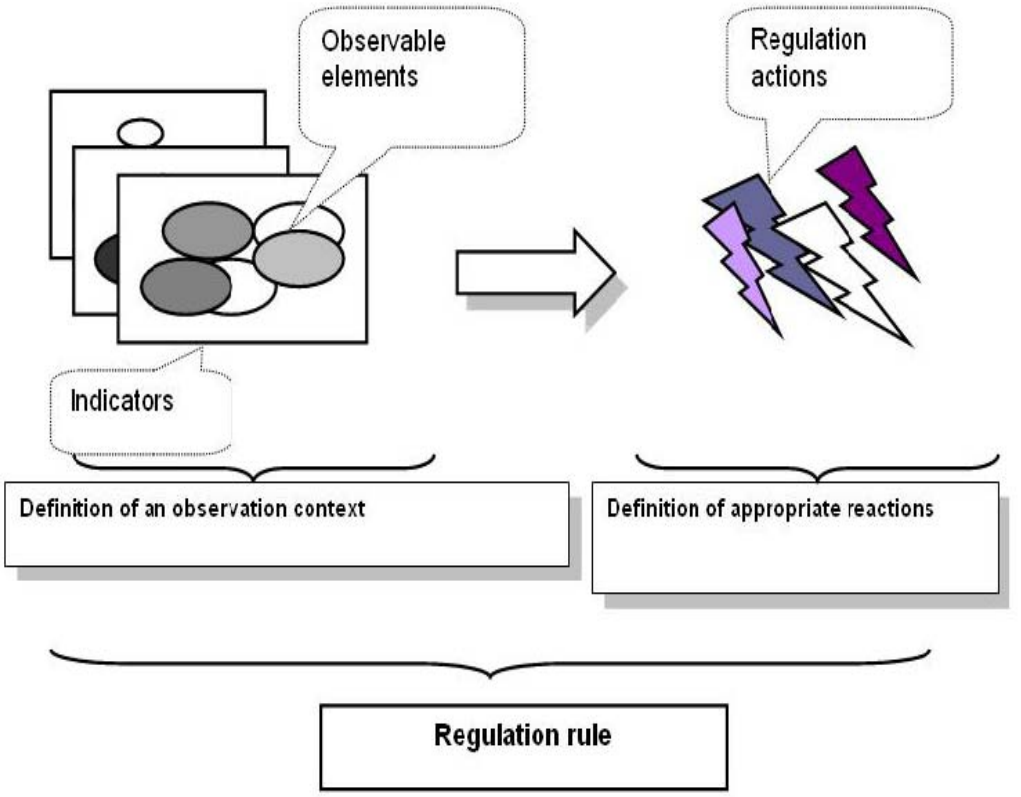

Figure 12. Description of a regulation rule.

EXAMPLES OF REGULATION IN A PARTICULAR EDUCATIONAL PLATFORM: THE "PEDAGOGICAL DUNGEON"

Description of the Platform

Principles of a Game Based Platform

We propose to demonstrate our purpose through a Game Based Learning Management System called a *pedagogical dungeon* equipped with cooperation abilities for particular activities (see Dillenbourg et al., 1996 for a list of cooperation abilities).

We agree with Vygotski's school of thought and activity theory, and we consider that the social dimension is crucial for the cognitive processes implied in the learning activity. Consequently, the question was how to enhance the social dimension in such environments. Observing the emergence and success of online multiplayer games with our students –the so-called "digital natives"-[Summit on educational Games, October 2006 (http://www.fas.org/gamesummit/)], more generally in the world (Rosenbloom, 2004) and even in education (Purdy, 2007), (Scott, 2007), it was decided to use it as a support for our course. This led us to apply the metaphor of exploring a virtual world, a dungeon, where each student collects knowledge related to a learning activity. It is our view that the way to acquire knowledge during a learning session is similar to the exploration of a dungeon. This approach reveals advantages such as a recreation-type process, a large usability of the tool or its adaptation to the student's speed. Such game based learning environments can thus be proposed as a way of implementing learning sessions, in which teachers can prepare and follow a pedagogical scenario (Kinshuk et al, 2006).

In the Activity Theory (see Dunne, 1996 for a definition of Activity Theory), the social dimension is crucial for the cognitive processes involved in the learning activity. A learning activity consists of one or more (sub) activities linked and ordered to achieve a given pedagogical goal. Actors (students or teachers) can perform these (sub) activities when their associated conditions (or prerequisites) are satisfied. They carry out these activities in collaborative spaces called arenas, through social interactions or through personal actions. An activity is mediated by tools (such as communication tools or evaluation tools) and uses artefacts (defined in Dunne,1996).

To enhance this social dimension, we have chosen to put the students together in a common virtual environment during the entire learning process. In order to link the game world to the learning one and according to Hainley (2006), we propose to link the objects used in our game based framework with the concepts that we usually find in a learning system. Table 1 summarizes these links.

Table 1. Correspondence between AT Concepts and Game based LMS Representation

Classical concept in the activity theory	Corresponding representation in our Game Based LMS
Arena / Collaborative space	Dungeon for the learning activity Room for an activity
Link between activities	Corridor
(sub) Activity (Exercises)	Crystals (Exercises)

Table 1. (Continued)

Classical concept in the activity theory	Corresponding representation in our Game Based LMS
Condition / Requisite	Room Door
Resources (pedagogical contents)	Knowledge Spheres
Assessment, Validation	Door Key
Communication tool	Chat window
Persons	Avatars (teachers, students)

Decomposition of a Learning Session: Rooms and Topology

The learning session (or learning activity) is very often split into different activities. It is the case when the teacher proposes to her/his students a set of exercises linked together in order to reach a pedagogical goal. Each activity has its own local goal, generally a concept to acquire. For a student, performing all the activities ensures that s/he has reached the general goal of the session, i.e. s/he has gained the knowledge associated with the session.

The dungeon represents the place where the learning session takes place. A particular dungeon is dedicated to a particular learning activity, for a particular subject. Each room of the dungeon represents the place where a given (sub) activity can be performed. The dungeon topology represents the overall scenario of the learning session, i.e. the sequencing between activities. There are as many rooms as actual activities, and rooms are linked together through corridors, showing the attainability of an activity from other ones. An example of a scenario seen as a dungeon topology is presented in figure 13.

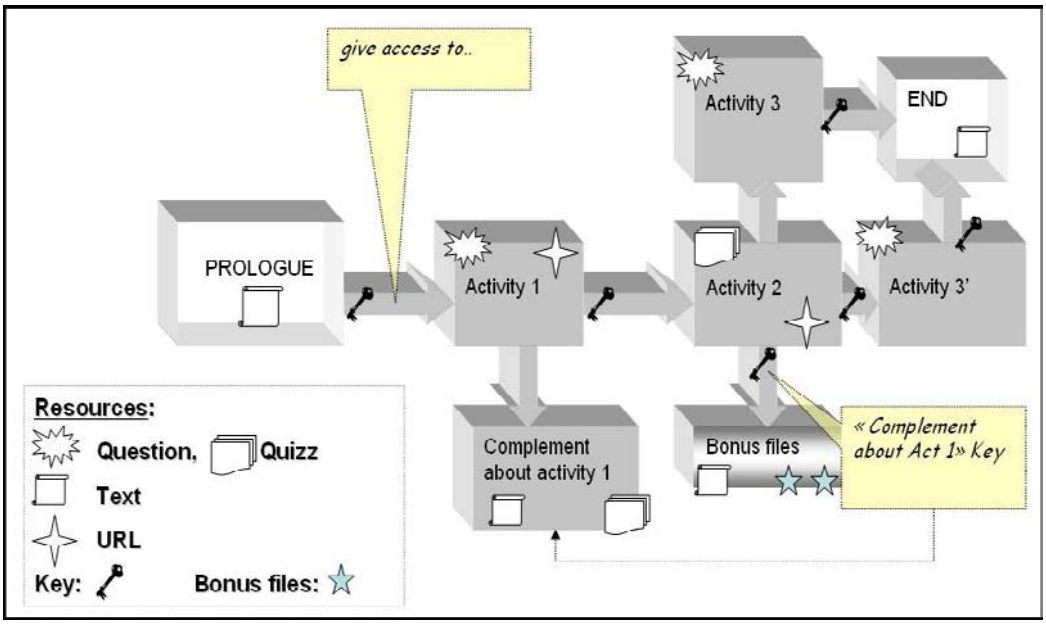

Figure 13. An example of a scenario seen as a dungeon topology.

Actors (Students or teachers) can move through the dungeon, performing a sequence of sub activities in order to acquire knowledge. Activities can be carried out in a personal or collaborative way: you can access knowledge through documents, via help from teachers, or from work with other students. The dungeon can be flexible. For instance, "teleportation portals" can lead to new rooms created dynamically.

Achievement of Activities

Each room is dedicated to an activity. You can find explanatory resources such as texts, links, and videos. These provide the student with useful information. The student reaches the local goal of the activity if s/he answers a quiz successfully. This quiz is thus also located in the room. In Figure 14, we can see an example of a room in the dungeon.

As users move through the dungeon, they can meet other students or teachers involved in the same session. When a student is in the same room as another student, it only means that these students are performing the same activity. They can of course access the resources at the same time.

The teacher may want several activities to be collaborative. In that case, the rooms associated to these activities are collaborative places. Currently, a chat facility is provided in the dungeon rooms, but we can easily imagine other collaborative tools available in these rooms (shared space, forums, etc.). If the teacher uses collaborative work in a session, s/he must set up teams of students: students belonging to the same team are supposed to carry out collaborative activities together. In collaborative rooms, the quiz is also collaborative. Students in the same team must all be present in the room. They may exchange via the chat before answering the question.

As in "traditional classrooms", a student may also collaborate with a teacher, for instance when s/he needs help from her/him.

Sequencing of Activities

Each room can be accessed through doors. These doors are the guards of the activity. They ensure that the student has the necessary prerequisites to perform the activity correctly. When users answer a quiz correctly, the associated key is obtained. In the event of a correct answer given for a collaborative quiz, a collaborative key is provided to all the members of the team.

Activities must not necessarily be ordered in the dungeon. However, most of the time, they are well ordered: it is quite rare for a teacher to provide the students with a set of exercises without any order. By ordering the activities, teachers may want either to define an order representing a progressive approach to the general goal of the session (logical order), or simply to force the group to carry out the activities in the same order with the purpose of following the students more easily (temporal order). When users play out a session in the dungeon, this ordering is ensured by the fact that they have to have obtained the key of previous activities before entering a new room.

In figure 14, three persons are present in a room; the avatar on the bottom (with the helmet) is the teacher. The other one (a student) has his nickname written above his avatar (Antony), and the user is the third one. The name of the activity (prologue) is written on the floor of the room. Touching a sphere/globe item (a resource) opens a text window with explanations or provides a web link, a file, etc. Touching a crystal item proposes an exercise,

a test or a quiz. A correct answer to a crystal question generally gives the student a key to open the door and lets him/her continue the quest.

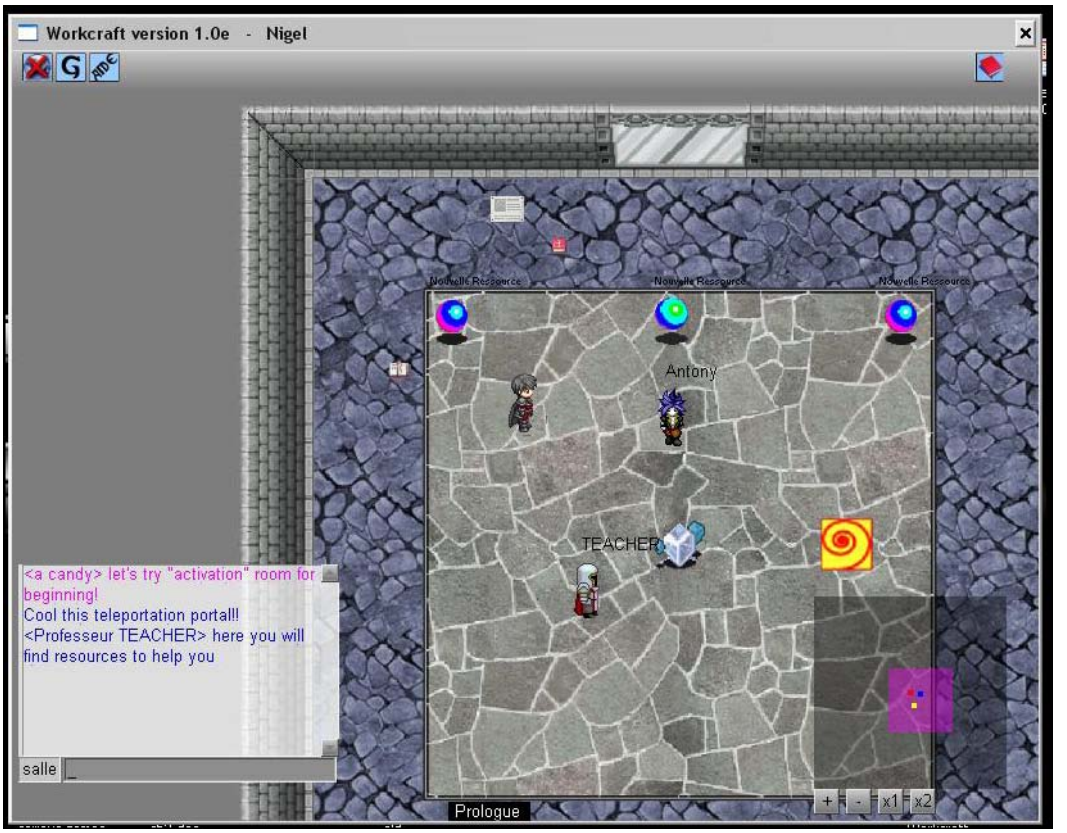

Figure 14. Student view of the dungeon.

The translucent white area is a chat window for collaborative features. Each person present in this room can see what is said. Clicking on a specific avatar may open some private chat windows.

It is not the purpose of this chapter to describe in details how a teacher can create a new pedagogical session (definition of activities, links between activities, evaluation of activities). This information is described in (Carron, 2008).

EXAMPLES OF REGULATION IN THE PEDAGOGICAL DUNGEON

This Game Based Platform is attractive for the users. But, for usability purposes, it is essential that Computer Based Education offer the possibility of monitoring the activity performed by the students and of obtaining information or feedback about it. Loss of perception for the teacher in these environments can make the tool unusable for him/her, because s/he cannot regulate the collaborative activity anymore.

In order to understand well how our approach allows a better regulation, let's expose 3 case studies.

Case Study 1:

A certain concept is particularly important. The teacher wants that all the students succeed in the associated room. As a regulation, s/he needs to introduce dynamically new sub activities for those who failed. These sub activities can be similar to the one that caused a problem and will be proposed only to the students who were unsuccessful.

Case Study 2:

The teacher wants to know which exercises his/her students are failing. Most of them have difficulties to solve some problems. In that case, the teacher can regulate the activity by adding new resources for helping these students, by modifying existing ones or by opening a dialogue session with these students providing them with hints to solve the problem.

Case Study 3:

The students are chatting a lot through the collaborative tools, but the results are poor, according to the teacher. S/he needs to regulate the activity by disabling the chat tool and let the students continue individually the other activities.

IMPLEMENTATION OF THE REGULATION IN THE PLATFORM

The whole pedagogical dungeon is equipped to be fully observable. This implies the definition of an API of required basic observations. Currently, 17 elementary (low-level) probes are available and may be flagged at any moment by any client of our application (Carron, 2008). These probes may be enabled or disabled in order to select what to be aware of. For instance, in the dungeon, actions such as “entering a room”, “correctly answering a quiz”, “chatting” or “help consulting” may be traced and thus collected by specific elementary probes. The indicators are defined thanks to these probes that may be combined. For example, we define an indicator which computes who is “chatting too much” (more than 10 messages) in the “exercise 3” room.

These probes and these indicators are central to the regulation process. We can apply this approach to see how regulation rules are concretely enacted in the pedagogical dungeon for the 3 case studies presented above.

The *case study 1* is high level. It is thus grounded on the structure of the pedagogical session. The regulation rule is rather easy to define: when a student gives a wrong answer then an access to a new room is available.

The observation context is here a simple indicator based on one elementary probe WorkshopCorrectlyAnswering=(user,”activity_X”,”false”). It is based on the success rate of an activity.

The *regulation action* is add(activity_Y,activity_X). You can see the result in figure 14: a teleport (spiral icon) appears in this case and let the user access to the new activity_Y.

The *case study 2* deals with the modification of the content of a specific activity during the session.

The *observation context* depends on the time spent for doing the same activity. It is constituted of an indicator which allows observing the time of all activities. It especially shows during the session that more than 50% of the students are late in one activity as explained in the fact 5 (see Figure 5). The teacher is thus warned of this situation and decides to modify the help file.

The *regulation action* is composed of two actions: to modify the help file and to warn the students that a new help file is available. Furthermore, it is possible for the teacher to interact directly with a user via the interface by clicking on his/her avatar. A private chat session is thus initiated.

The *case study 3* concerns the possibility to act on a tool via its interface.

The *observation contex***t** deals with the quantity of messages exchanged in the same activity. The indicator "chatting too much" has already been described just before.

The *regulation action* is to disable the chat access for the students concerned by the indicator and thus to act on tools available in the learning environment.

These 3 case studies illustrate different levels of regulation that can be exhibited on a learning environment. The different experiments that we carried out in our university in real situations showed that such an environment is well perceived by the students. Involved in an immersive pedagogical session, they are not exactly aware of the regulation process. They are most of the time amused by the appearing of new pedagogical resources. The disabling actions on tools are very efficient but more disturbing if no satisfying explanation is given. We did not focus on this fact here, but each regulation action should be used with a notification message. Regarding the teacher, the cognitive overload prevents him/her from being able to develop from scratch and add a new activity during the session. Currently, the content of such high level regulation actions must be prepared before the start of the learning session.

CONCLUSION

In this paper, we have demonstrated through examples how traces and indicators are fundamental for regulating activities. We explained how to get relevant information about a specific expected situation and how to react through different levels of regulation actions directly during a pedagogical session.

These concepts have been illustrated through a Game Based Learning Management System called a pedagogical dungeon.

More precisely, we defined the term of "observation context" in order to gather all indicators suited to bring the most relevant information to evaluate a given pedagogical situation. For future work, we will try to categorise the observation contexts according to expected pedagogical goals.

In the same way, we described many actions on modelled elements of a pedagogical session that are relevant for regulation of the activity. We think that these actions or set of actions should be seen as a mean to resolve particular disturbing situations and could be classified as well with this point of view.

Combining these two concepts offers large possibilities: libraries of regulation rules according to pedagogical aims can be set up. This implies extended work on the definition and classification of collaborative indicators and on a classification of the possible collaborative actions.

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Chapter 17

PROFESSIONAL LEARNING AND TECHNOLOGY TO SUPPORT SCHOOL REFORM

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ABSTRACT

Research suggests that teacher expertise is one of the most influential factors affecting student achievement, and that continuous, on-the-job professional learning is the most effective strategy for teachers to develop this expertise. School reform efforts that ignore these research findings are unlikely to succeed. In this chapter, I discuss the importance of teacher learning in sustaining innovative classroom use of technology and provide a framework for supporting ongoing teacher professional learning. The framework, called PD*LEARN, is built upon established principles of effective teacher professional learning.

INTRODUCTION

As school districts struggle to develop strategies to improve student learning the focus is typically on short term, quick fix solutions such as introducing technology into classrooms. After an initial period of enthusiasm about the technology interest begins to wane as the expected gains in achievement often do not materialize. Teachers teach as they always have and the technology sits collecting dust (Cuban, Kirkpatrick, and Peck, 2001). More often than not, the reason technology fails to have an impact is because the central role teachers play in fostering student achievement is ignored. Teachers are not provided with the continuous, on-the-job professional support and learning opportunities they need to change their practice.

In this chapter, I will argue from the existing literature base that teacher expertise is one of the most influential factors in determining student achievement and that continuous professional learning is the best strategy to develop needed expertise. Then I will illustrate how critical professional learning is to support classroom innovation and student learning

with technology. To do this I will draw on a sub-study that I conducted within the Second Information Technology in Education Study – Module 2 (SITES-M2) which examined innovative pedagogical uses of technology in 28 countries (Kozma, 2003). I will conclude with a framework for professional development that derives from research linking student achievement with teacher professional development.

TEACHER EXPERTISE AND STUDENT ACHIEVEMENT

Teachers do make a difference. This is something that parents have known for generations when they ask to have their child moved from one teacher to another because the child cannot learn in the former teacher's class. However, only within the last 10 to 15 years have researchers been able to quantify the magnitude of the effect teachers have on student achievement (OECD, 2005). This has been done using three different research strategies. The first compares teacher expertise to a host of other socio-economic factors influencing achievement; the second compares the achievement of students in classes of high- and low-performing teachers; and the third analyzes international achievement data.

Several significant studies have compared teacher expertise relative to other socio-economic factors. Ferguson (1991), who examined the records of over 2.4 million students in 900 school districts in Texas, found that teacher expertise is the largest single factor affecting student achievement scores, accounting for 43% of the variance. Teacher expertise was measured by amount of education, scores on a teacher licensing exam, and experience. Other significant factors were a combination of home and school factors, including parent income, language background, race, and location (49% of the variance), and class and school size (8% of the variance). Greenwald, Hedges, and Laine (1996) conducted a meta-analysis of 60 primary research studies on student achievement and a variety of school factors. Their findings were similar, only they expressed them in terms of the effectiveness of spending on those factors. They found that for every $500 spent per student, gains of 0.22 test units occurred for increasing teacher education. Lesser amounts were found for increasing teacher experience (0.18), increasing teachers' salaries (0.16), and lowering pupil teacher ratios (0.04). In another meta-analysis, Rice (2003) came to the same conclusion on the importance of teachers in determining student achievement, but noted that the effects of specific teacher attributes were not the same for elementary and high school teachers. Rivkin, Hanushek, and Kain (2005), in another study of Texas school data, found "large differences in the quality of instruction…that rule out the possibility that the observed differences [in student achievement] are driven by family factors" and that "teachers matter importantly in student achievement" (p. 449). The authors note, however, that the teacher effects are more concentrated with beginning teachers and with younger students.

Sanders (1998) and Sanders and Rivers (1996) carried out one of the most significant studies comparing achievement scores of students in classes of high and low performing teachers in Tennessee. Through statistical modeling they estimated teacher effects on achievement of grade 3 students who were in classrooms of highly effective teachers with those in classrooms of the least effective teachers. After just one year students in classes of effective teachers scored 40 percentile points higher than their counterparts on the Tennessee mathematics proficiency tests. Additionally, the data show slightly smaller but significant

differences for middle and high-achieving groups of students. When the researchers looked at the data longitudinally, by the end of grade 5 students with effective teachers were scoring 50 percentile points higher in mathematics than those in the least effective teachers' classes. As the researchers point out, differences of this magnitude can represent the difference between students being placed in remedial or accelerated school tracks. Other studies conducted in Dallas and Boston show similar longitudinal results and that the effect occurs at the secondary school level as well (Haycock, 1998).

Further evidence of the effect of teacher expertise comes from international comparative studies. Darling-Hammond and Ball (1998) examined teacher education requirements and in-service support of teachers in countries scoring higher than the U.S. on the Third International Mathematics and Science Study (TIMSS). They concluded that in those countries achieving higher than the U.S. "teaching is not only better supported, but it is guided more thoughtfully and adapted more consciously to students' learning needs" (p. 11). More recently, Akiba, LeTendre, and Scribner's (2007) analysis of the TIMSS 2003 mathematics data found that higher achieving countries have a higher proportion of teachers meeting their country's full certification criteria, have a mathematics or mathematics education major, and have at least three years teaching experience.

The above studies demonstrate the significance of the influence teacher expertise has on student achievement. Moreover, the effect appears to be cumulative, so that students who do not have strong teachers early on may never recover from this deficit. Teacher expertise may be acquired in many ways: through formal academic education, teacher education courses, workshops, and informal learning. Typically, these strategies have little impact on student achievement, and as Fullan (2007) states they can "never be powerful enough, specific enough, or sustained enough to alter the culture of the classroom and school" (p. 35). Research is starting to emerge, however, on the kinds of professional learning that can have a direct impact on student achievement (Cohen and Hill, 2001; Garet, Porter, Desimone, Birman, and Yoon, 2001; Hawley and Valli, 2000; Hiebert, Gallimore, and Stigler, 2002). This will be described in the final section of this chapter. Next, I will discuss how central a role professional learning plays in supporting teacher innovation in the classroom using technology.

PROFESSIONAL LEARNING AND TEACHER INNOVATION USING TECHNOLOGY

The SITES-M2 study of innovative pedagogical uses of technology examined 174 schools worldwide. Overall, the schools in the study reported a substantial positive impact of their technology based innovations on students: 62% reported increased subject matter acquisition; 68% of schools reported increased student positive attitudes toward learning; and 63% improved collaborative skills (Kozma, 2003). Central to these outcomes was the classroom teacher who—depending on the particular school—designed, implemented, and led the innovation.

I conducted a sub-study of the SITES-M2 data to identify underlying factors that led to some teachers being able to sustain their classroom innovation and others not (Owston, 2003, 2007).

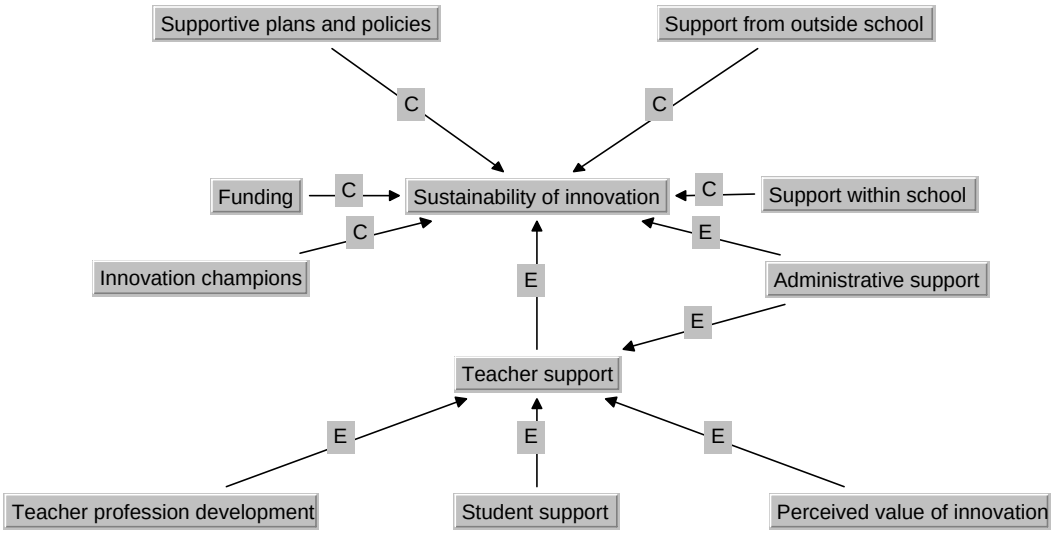

Figure 1. Essential and contributing factors for sustainable innovation (Adapted from Owston, 2003).

From the set of 174 schools, I identified 59 that were able to sustain their innovation beyond two years. The case write-ups of these schools became my data source for the sub-study. Through a qualitative analysis of these data, two sets of factors emerged that explained why these innovations were sustainable—one set labeled *essential*, the other *contributing*. Essential factors were defined as those that my analysis found were necessary, but not sufficient, for innovations to be sustained. Evidence of these factors was found in *all cases* in the sample. Contributing factors were those that appeared in *50% or more* of the cases. These are represented by "E" and "C" respectively in the figure below that shows the factors and their relationships.

Most fundamental to sustaining an innovation is teacher support, for without this, the innovation simply cannot occur. The model posits that when teachers see that students are supportive of the innovation and that it benefits their learning, they tend to invest more time and effort into ensuring its success. As they invest more into the innovation, teachers find that they need to learn more about the pedagogical approach they are using (e.g., project based learning) and the technology itself. This learning came from a variety of sources including formal professional development courses, learning in informal groups with colleagues, or self-study. The model does not distinguish among these types of learning. Indeed, there was evidence of all types of professional learning occurring in the cases I studied. The salient point is that ongoing teacher learning or professional development is essential for classroom innovation to succeed and for students to benefit from technology.

Important to note for the present discussion is that in the above model supportive policies and plans are a contributing factor for sustainable innovation, rather than an essential one. The SITES-M2 study as a whole reported that 63% of cases were linked to a school technology plan or policy, 73% to a national ICT policy, and 62% to a national education policy (Kozma, 2003). That a gap exists between national policies and classroom practices which they are intended to influence is not unexpected. The key to closing this gap and increasing student achievement appears to lie with building systemic capacity for change (Fullan, 2005). Centrally informed and prescribed strategies for change can carry a reform

initiative only so far and eventually a leveling off of improvement is seen, as witnessed in England's national initiative to boost literacy and numeracy achievement (Barber, 2002). In order to move beyond this plateau effect, Barber (2002) believes that reform efforts need to move from an era of "informed prescription" to an era of "informed professional judgment." Characteristics of this era would include removing demands on teachers that are not central to teaching and learning, and providing teachers with more time to engage in professional learning and collaborative preparation and assessment.

EFFECTIVE PROFESSIONAL LEARNING STRATEGIES

Given the centrality of teacher professional learning in promoting student achievement, with or without technology, the question remains as to what kinds of professional learning strategies are most effective in this pursuit. Research on the relationship between professional development practices and student achievement is now unequivocal: professional development is most effective when it is long-term, collaborative, school-based, focused on the learning of all students, and linked to the curricula that teachers have to teach (Cohen and Hill, 2001; Garet, Porter, Desimone, Birman, and Yoon, 2001; Hawley and Valli, 2000; Hiebert, Gallimore, and Stigler, 2002). The term PD*LEARN serves as a guide to all of the elements which must be included in professional learning programs for them to have impact on student achievement.

P(ermanent):	Professional learning is not an activity that is carried out only several times per year: it must be an ongoing, permanent part of a teacher's professional responsibilities.
D(riven)	Professional learning must be driven or guided by an analysis of the gap between student learning expectations and students' actual performance.
L(earning)	Consistent with adult learning principles, professional learning must involve teachers in decisions about their own learning. This will increase teacher motivation to learn and decrease cynicism and detachment.
E(mbedded)	Professional learning must be "job-embedded" i.e., part of a teacher's everyday job. This principle does not deny out-of-school learning, but emphasizes that the most powerful learning opportunities are those linked to authentic and immediate problems in the classroom.
A(ssessed)	Professional learning programs should be assessed to determine their impact on teachers and, ideally, their impact on student learning. Not only does this improve accountability of program expenditures, assessment provides feedback on design of future learning programs.
R(elevant)	Professional learning must be relevant to their needs by focusing on the subject matter they will be teaching. Information about general instructional strategies (e.g., cooperative learning) or unrelated content enrichment is not effective.

N(etworked) While professional learning should relate to individual needs, it should also involve collaboration or networking with other teachers. When teachers work together they can break down isolation and create a shared understanding of good practice within a school.

Technology fits into this framework in two ways. First, when an analysis is undertaken of the gap between where students are in terms of their actual learning and expectations, teachers should give careful thought to how technology can be used to address this gap. Too often technology is used indiscriminately in classrooms with no serious consideration given to whether it will help achieve essential learning objectives (Cuban et al., 2001). By following this strategy teachers will begin to develop a more precise practice-based understanding of when technology may be used effectively in their curriculum. If teachers share their experiences with their colleagues, a common understanding of how technology can be integrated successfully into the curriculum can also be developed.

A second way technology can support the PD*LEARN framework is to use it to foster teacher learning through online professional learning communities (Dede, 2006). Fully online communities are difficult to implement successfully because of significant challenges in organizing and maintaining environments in which participants develop the sense of belonging, trust, and support, the prerequisites to learning in a community (Charalambros, Michalinos, and Chamberlain, 2004). Consequently, a blended approach that combines online experience with face-to-face components offers greater likelihood of developing strong social cohesion and of developing a collective momentum for implementing meaningful change in teaching practices (Owston, Sinclair, and Wideman, 2008; Wideman, Owston, and Sinitskya, 2007).

SUMMARY AND CONCLUSION

There is now compelling research evidence to suggest that teacher expertise can have an immediate as well as a long-lasting effect on student achievement. Moreover, teacher expertise is the single most significant factor, after the combined effects of school and home, which affects student performance. Teacher expertise also plays a critical role in successfully implementing and sustaining classroom pedagogical innovation using technology. Teachers may acquire expertise in many ways; however the supporting of professional learning is one step that school districts can take to help teachers increase their expertise. To be effective this support must be directed toward implementing professional learning programs that are on-going, school-based, and focused on areas of the curriculum in which students are having difficulties. Districts that invest in teacher learning of this kind will benefit from a more sustainable reform initiative and ultimately improved student achievement.

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Chapter 18

COLLABORATIVE KNOWLEDGE CONSTRUCTION DURING STRUCTURED TASKS IN AN ONLINE COURSE AT HIGHER EDUCATION CONTEXT

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ABSTRACT

This chapter presents a study that explored how two different tasks developed for supporting student groups' collaborative activities in a web-based learning environment enhanced students' collaboration during web-based discussion. Furthermore, the aim was to study what challenges were faced during online interaction from the perspective of collaborative learning. The subjects of the study consisted of two small groups of teacher education students studying the pedagogy of pre-school and primary education in a web-based learning environment.The students' web-based discussion was analyzed in terms of communicative functions (Kumpulainen and Mutanen, 1999) and contextual resources (Linell, 1998). The results of the study indicate that the educational value of the students' discussions was not very high. Neither of the groups used such functions as argumentation and counter argumentation in their discussion. The knowledge was more cumulatively shared and constructed than critically evaluated. Whereas Group 1 relied more on theoretical and practical background material, Group 2 relied more on their own experiences as resources in their knowledge sharing and construction. There were both changes in the participatory roles as well as in content-based roles between the tasks. Participation in Task 2 was more equally distributed in both groups compared to Task 1. It also seemed that in Task 2 both of the groups were engaged in content-based activity, whereas in Task 1 the discussion of Group 2 did not focus on sharing and constructing knowledge but on organizing and commenting on the process of working on the document to be written. Thus, the discussion forum was not fully successful as a context for problem-solving and knowledge construction as was intended. The study demonstrates that the teacher cannot be easily replaced by even the most advanced technology or pedagogical pre-structuring. Despite the pre-structuring of the tasks the students would have needed the teacher's support in engaging them to participate more

equally, in deepening their discussion and in guiding them to use the resources as was intended – that is, in supporting collaborative knowledge construction.

INTRODUCTION

Computer-Supported Collaborative Learning

In many definitions, collaboration has been regarded as similar to co-operation, which is a typical activity for example in school projects where students work towards a shared goal, usually a shared product, but the actual work is divided. Students may divide the task into sub-tasks which individuals then complete on their own. In the literature this kind of activity is typically referred to as co-operation instead of collaboration (Cohen, 1994). In this study, collaboration is defined as a shared knowledge construction, which requires that participants are together equally engaged in a co-ordinated effort to construct knowledge or solving problems related to the task in hand (Baker, 2002; Barron, 2000). For collaborative knowledge construction to occur, it is not enough that participants cumulatively (Mercer, 1996) share knowledge among themselves, but the knowledge has to be constructed by building on ideas and thoughts presented by the participants and developing them further (Arvaja, 2007). Yet, it may be that in collaboration students complement or continue each other's ideas, but do not engage in any deep reasoning in relation to the subject. Thus, in such a situation the participants do not produce critically grounded knowledge. However, it is suggested that effective learning through shared knowledge construction presupposes cognitively high-level discussion (Fischer et al., 2002). According to Mercer (1996), different types of talk represent different ways in which the participants in a dialogue engage in the joint construction of knowledge. Exploratory talk, which is beneficial for collaborative knowledge construction, occurs when the participants explore critically but constructively each other's ideas. In exploratory talk, statements and suggestions are offered for joint consideration. These are challenged and counter-challenged with justifications and alternative hypotheses. Thus, within collaborative discourse it is possible to identify different kinds of activities that are beneficial to learning, such as elaboration (e.g. van Boxtel, van der Linden and Kanselaar, 2000) or argumentation (e.g. Weinberger and Fischer, 2006).

Lipponen (2001) has made a distinction between the collaborative use of technology and collaborative technology. The collaborative use of technology refers to situations where the computer can serve in a face-to-face event as a referential anchor, coordinate joint attention and interaction, and be an object for manipulation and thus support collaboration (Lipponen 2001). In the case of computer-mediated communication, technology may be used collaboratively, for example to restore people's thoughts and ideas on a common platform which then serves as a public memory, making the contributions available and visible for reflection in the long term. Alternatively, participants can engage in asynchronous (e.g. discussion boards) or synchronous (e.g. chat) discussions. According to Lipponen (2001), collaborative technology refers to specific technological support for collaboration built in computer networks. These different forms of technological support can also be called scaffolds (Arvaja, Häkkinen and Kankaanranta, in press). For example Knowledge Forum (formerly known as CSILE, see Scardamalia and Bereiter, 1984) is an attempt to structure collaboration in a CSCL environment through the use of thinking types, which are intended to

scaffold students' inquiry processes. Also other forms of scaffolds built into technological systems, such as graphical argumentation tools (e.g. Belvedere, see Suthers, Weiner, Connelly and Paolucci, 1995), can support high-level interaction.

Possibilities provided by instructional technology for facilitating collaborative learning through computers have been described in a number of studies (e.g. Koschmann 1996; Fischer, Bruhn, Gräsel and Mandl 2002; Schellens and Valcke, 2005). However, in the general climate of rather overoptimistic expectations for technology-based learning environments (Fabos and Young 1999), empirical studies have also revealed more pessimistic findings about the quality of interaction and shared knowledge construction on the web (e.g., Arvaja, Rasku-Puttonen, Häkkinen and Eteläpelto, 2003; Hämäläinen and Arvaja, in press; Järvelä and Häkkinen 2002). The problem has been that simply offering online learning environments for students to use does not guarantee that they interact in a way that promotes learning. It is hence argued that the promotion of collaborative use of technology requires approaches that help structure collaborative learning situations since free-form collaboration does not systematically produce learning (Dillenbourg, 2002). Structures are intended to facilitate collaborative learning processes and guide the learners' activities. Structuring the interaction process may favor the emergence of productive interactions. At its best, some amount of structuring may help manage collaborative learning situations and enable teams to achieve effective collaboration (Dillenbourg, 1999; Kollar, Fischer and Hesse, 2003). One way to structure interactions is to design collaboration scripts into CSCL environments (Kobbe et al., 2007). These scripts are sets of instructions prescribing for example how students should form groups, how they should interact and collaborate, and how they should solve problems (Dillenbourg and Jermann, 2006).

This study explored how two different tasks developed for supporting student groups' collaborative activities in a web-based learning environment enhanced students' collaboration during web-based discussion. Furthermore, the aim was to study what challenges were faced during online interaction from the perspective of collaborative learning. The focus of this study was on collaborative use of technology in computer-mediated communication (Lipponen, 2001). Thus, supporting students' collaboration by some technological tool was not the aim here, but the focus was on supporting students' asynchronous discussion through the task assignment. This study used scripting as a pedagogical method to facilitate collaborative learning. Macro-level scripts (see, Dillenbourg and Tchounikine, 2007) were employed to offer learners guidance with which they were expected to carry out their group work. During the tasks the students were asked to complete general steps or phases to trigger collaboration. However, the scripts did not instruct or control the groups' interaction in any detailed manner.

METHODS

Participants and Context

The subjects of the study consisted of two small groups of teacher education students studying the pedagogy of pre-school and primary education in a web-based learning environment. The students participated in three different tasks, the first (Task 1 in this study)

and the last (Task 2 in this study) of which were the focus of this study. In Task 1, Group 1 consisted of four students, three female and one male, in Task 2 one female student had dropped out of the course. Group 2 consisted of five students – four female and one male – in Task 1, whereas in Task 2 two female students had dropped out of the course. In both of the tasks, the main idea was to solve an authentic learning problem (e.g., Brown, Collins and Duguid, 1989) through complementary knowledge construction (e.g., De Laat and Lally, 2004). The pedagogical framework behind both of the tasks was designed as a joint effort by two research groups (see Häkkinen et al., 2005), while the content of the tasks was designed by the teacher (an expert with a doctoral degree in education and many years' teaching experience). Both of the tasks took about four weeks to complete, during which time the students were supposed to proceed through different steps. Moving to the next step required that the previous task was completed. The students were not penalised in any way, however, should they fail to go through all the phases.

In the Case task (Task 1), the learners worked in small groups to prepare an individualised teaching plan for one particular learner (Matti or Timo). Matti and Timo have different kinds of needs in terms of the teaching plan. The Case had different phases. Firstly, the students needed to familiarise themselves with an authentic learning problem concerning learning readiness (of two different learners, Matti and Timo). At this step each group read a comic where Matti and Timo were presented working together. Secondly, they were to read theoretical background material about such cases. After this they were to enter a shared web discussion about constructing a shared plan for a personal curriculum for Matti or Timo. Based on this discussion the students were to proceed to accomplish a shared plan for this personal curriculum as a group.

In Task 2, the students were set a so called ‘Open problem’, meaning that they had to create and resolve a problem relating to the theme ‘Differentiation in teaching reading’. Course material was provided in the form of documents and web-based links in the learning environment and the students’ task was first to read the material. After this the students were to choose a problem relating to a given theme and to discuss it in an asynchronous discussion forum and, finally, to prepare a lesson plan for teaching reading. The lesson plan was then to be written to a document base in the learning environment. Thus, the steps in this task were quite similar to the ones in Task 1. The two groups that were the focus of this study chose the same problem to be discussed and solved in the forum: “How to differentiate teaching reading in a classroom where pupils are on different levels as regards reading ability”.

Data Collection

This study concentrated on studying the asynchronous web-based discussion that each group had in one of the phases of the given tasks. The data thus consists of students’ web-based messages. Moreover, all the material that was used in the course (lecture notes, web-based documents and links) was used in interpreting the students’ knowledge construction activity.

Data Analysis

The students' knowledge construction activity was analyzed in terms of communicative functions (Kumpulainen and Mutanen, 1999) and contextual resources (Linell, 1998). Communicative functions were adapted from the framework for analyzing language functions developed by Kumpulainen and Mutanen (1999). However, these language functions were not used as predefined categories but the specific context of the data was taken into account in interpreting the function of communication. Thus, the communicative functions were contextual in nature, depending on the topic of the discussion and the interpretations made by the participants involved in these discussions. The functional analysis of the web-based messages focused on the purposes for which language was used in the given context. The communicative functions were not identified on the basis of their linguistic form as such, but they were rather identified in terms of their content and form as well as their effect on and relation to the discourse of which they were part. The analysis of communicative functions focused on the nature of the exchanges between the students. Thus, the interpretation of the communicative function was partly made in relation to the preceding message(s). The function of communication was analysed mainly at the utterance level. However, in some cases several utterances served the same function. Similarly, in some cases one utterance served multiple functions. From the data nine categories of communicative functions were detected. These are presented below (Table 1) with descriptions:

Secondly, Linell's (1998) notion of *contextual resources* was adapted and used as an analytical tool in studying the resources students used in negotiating meanings from the point of view of knowledge construction. Contextual resources refer to those aspects of the potential context that the participants make relevant in the on-going activity.

Table 1. Communicative functions in web-based discussion

Communicative function	Description
Interrogative	Asking for an opinion, information, suggestion or clarification
Responsive	Answering a question or giving clarification
Knowledge providing	Giving a suggestion, information or a concrete example relating to the topic of discussion
Elaborative	Developing further a previously offered piece of information, suggestion or example
Reasoning	Justifying a piece of information, suggestion or example or reasoning about knowledge
Commenting	Giving positive/negative feedback, expressing (dis)agreement on or summarizing a previously offered piece of information, suggestion or example
Social	Giving comments with a social function, e.g. greeting or encouragement
Organizational	Organizing work in the discussion forum or generally on the task
Technical	Technical comment relating to the web-based environment

Relevant contextual resources are those referred or oriented to in the discourse (e.g. Buttny, 1998). From the data ten broader categories of contextual resources were detected. These are described below (Table 2):

Table 2. Contextual resources in web-based discussion

Contextual resource	Description
Task description	In discourse students refer to the given task assignment. Specific resources include for example written *task instructions* in the web-based environment
Course material	In discourse students refer directly, for example, to lectures, articles or web-based links which serve as theoretical background material for the task, or the discussion may be identified as being based on the course material. Specific resources are mainly *concepts* and their *theoretical description or definition* (e.g. methods and their features)
Case	In discourse students refer directly to the case material (only in Task 1), the comic about Matti and Timo, which serves as a practical material for the task, or the discussion may be identified as being based on the case material. Specific resources are mainly *activity or character descriptions*, *examples or concepts* based on the material
Message	In discourse students refer directly to other students' thoughts presented in previous messages. Thus, the student may not refer directly to the message itself (e.g. "as you said in your message"), but to the content of the message. This shows in comments on other students' thoughts
Document	In discourse students *refer to the document to be written* as a result of discussion. References may include evaluations of the document or ideas suggested to be included in the document
Own opinion	In discourse students use their own opinions, for example, in evaluating other students' suggestions. Opinions are either *positive or negative evaluations or judgements*
Own idea	In discourse students use their own ideas, which are usually manifested in practical or concrete suggestions. Specific resources are mainly *concepts* and their *practical application* (e.g. differentiation and its concrete means), which are usually manifested in *action* and *activity descriptions*
Own conception	In discourse students use their own conceptions of either practical or more abstract issues or knowledge. Specific resources are students' *interpretations* of issues or knowledge presented by oneself or other students (e.g. the consequences of a practical suggestion or the application of theoretical knowledge). In discourse this shows in reasoning and justifying
Own experience	In discourse students use their own experiences, which are either directly referred to as such or can be identified as such. Specific resources are mainly *case descriptions* or *examples*

Contextual resource	Description
Co-text	Co-text refers to the fact that students build their thoughts on other students' thoughts. In discourse students directly or indirectly refer to *concepts, interpretations, case descriptions or examples presented by others* by developing them further. This shows in elaborating on, reasoning about or justifying other students' knowledge further and answering questions. However, co-text can co-occur with other resources. For example, a student may use information from articles in developing further previous thoughts or ideas. It is important to differentiate between the message and co-text as resources. Whereas in referring to a message students usually comment on the content of the other students' thoughts, in co-textual references they build the content further

Contextual resources were extracted from the web-based messages by examining students' contextual references and the content of the messages, which directly or indirectly reveal the 'source of the resources'. This means that in analysing whether the resource used was, for example, course material depended on whether it was directly referred to as course material ("In the article I read…") or whether the content was identified as course material even though not directly referred to as such. As in the case of communicative functions, contextual resources were analysed at the utterance level. (For a more specific discussion about the methodology and its theoretical grounds see Arvaja, 2007; Arvaja et al., 2007).

RESULTS

Individual Similarities and Differences in the Web-based Discussion in Two Tasks

In the next two Tables (Table 3 and 4), the frequency of communicative functions and contextual resources used in the students' web-based discussion in the two different tasks are presented. The focus is on the individual differences and similarities in communication as well as the possible roles individual students have in their group discussions.

Table 3. Frequency of functions of communication and contextual resources used by students in Group 1 in two different tasks

	Task 1				Task 2		
Communicative functions	Iina	Alisa	Otto	Elina	Iina	Alisa	Otto
Interrogative	4	0	0	5	15	8	6
Responsive	1	0	0	0	6	4	3
Commenting	4	2	3	4	13	10	6
Knowledge providing	8	3	0	12	4	11	13
Elaborative	5	0	1	5	11	5	3
Reasoning	8	2	1	12	9	8	7
Social	3	1	3	3	8	3	6

Table 3 (Continued)

	Task 1				Task 2		
Contextual resources	Iina	Alisa	Otto	Elina	Iina	Alisa	Otto
Technical	0	0	0	0	0	0	0
Organizational	6	2	3	3	5	5	7
In total	*39*	*10*	*11*	*44*	*71*	*54*	*51*
Task description	5	0	0	0	1	4	2
Course material	2	1	1	1	8	5	6
Case	7	2	0	10	-	-	-
Message	3	1	0	3	7	9	6
Document	3	2	4	2	8	3	3
Own opinion	4	2	3	3	11	6	7
Own idea	8	1	0	6	10	7	11
Own conception	5	2	0	7	5	6	3
Own experience	0	0	0	6	0	0	0
Co-text	8	0	1	8	17	9	4
In total	*45*	*11*	*9*	*46*	*67*	*49*	*42*

As can be seen from Table 3, in Task 1 Iina and Elina were the most active participants in the discussion. They both mostly provided knowledge by reasoning it. They also elaborated other students' thoughts. Alisa was also providing reasoned knowledge, but to a lesser extent than Iina and Elina. Otto and Alisa were mostly commenting on other students' thoughts and organizing activities. From the use of contextual resources we can see that Iina and Elina were building their discussion on the case description, their own ideas (Iina) and conceptions (Elina). They were also constructing knowledge based on each other's thoughts (co-text). However, the course material based on theoretical knowledge was hardly at all referred to in the discussion. Otto and Alisa were using their own opinions as resources and referring to the written document in their discussion. All in all, it seems that Iina and Elina had reciprocal roles in their knowledge construction activity and they were responsible for knowledge construction (co-text) and sharing (no co-text) in the forum. Alisa's and Otto's role in the discussion was minimal from the perspective of knowledge sharing and construction. For example Otto‘s contributions for the most part focused on supporting other students' activities: evaluating or judging other students' suggestions, organizing activities and giving social support.

In Task 2, Elina was not participating in the discussion, but had dropped out of the course. Iina was the most active participant, but also Alisa and Otto were contributing actively. Out of the three most frequent communicative functions used, Alisa and Otto were providing knowledge by reasoning it. Iina, however, provided hardly any new knowledge, but in turn elaborated the knowledge provided by Alisa and Otto and also justified and reasoned (reasoning) her elaborations. Both Iina and Alisa were also commenting on other students' messages, asking questions and asking for opinions or clarifications (interrogative). The organizational function was among the three most frequent functions for Otto. As regards contextual resources, one can see that presenting one's own ideas was among the three most frequent resources for all students. This indicates that the knowledge offered was quite practical in nature, consisting of practical and concrete suggestions, for example. Iina and

Alisa were both developing the ideas presented by others further (co-text), that is, they were building their discussion on each other's thoughts. Also one's own opinions (Iina and Otto) and messages (Alisa and Otto) were frequently used contextual resources. Referring to other students' messages indicates that students were commenting on each other's knowledge even though they were not developing it further. Thus, both the use of co-text and references to messages, as well as the commenting and elaborative function of communication show that the discussion was quite cohesive in nature in this second task. All the students were using also course material, even though it was among the three most frequent resources only for Otto.

There were changes in participatory roles between the two tasks. In Task 1, Otto and Alisa were passive, whereas in Task 2 they participated actively in the group's activities. For Alisa, the main functions of communication remained the same between the two tasks (commenting, knowledge providing, reasoning). Iina maintained her role as an active contributor to knowledge sharing and construction, even though her role changed from a knowledge provider in the first task to a knowledge elaborator in the second task. Otto's role changed the most between the two tasks; he changed from a commentator in the first task to a knowledge provider in the second one. Iina's main resources in the two tasks remained the same (own idea, co-text).

Table 4. Frequency of functions of communication and contextual resources used by students in Group 2 in two different tasks

	Task 1					Task 2		
Communicative functions	Jaana	Mari	Jussi	Minna	Sanna	Jaana	Mari	Jussi
Interrogative	3	4	0	7	3	3	11	2
Responsive	1	1	0	1	0	2	2	0
Commenting	8	4	5	9	1	9	9	8
Knowledge providing	7	3	0	0	3	16	16	2
Elaborative	0	0	1	5	1	3	6	2
Reasoning	3	0	4	3	5	14	1	4
Social	1	6	1	9	3	4	11	2
Organizational	7	8	3	8	2	8	8	5
Technical	1	0	2	0	3	0	0	0
In total	*31*	*26*	*16*	*42*	*21*	*59*	*64*	*25*
Task description	1	1	0	0	3	2	5	1
Course material	1	1	0	4	0	1	0	0
Case	2	1	0	0	2	-	-	-
Message	2	1	2	3	0	8	8	4
Document	7	9	4	11	2	8	5	4
Own opinion	0	0	3	1	0	7	8	3
Own idea	5	2	3	0	0	6	4	3
Own conception	2	0	0	3	5	10	1	4
Own experience	0	0	0	0	1	8	11	2
Co-text	2	1	3	7	4	5	7	2
In total	*22*	*16*	*15*	*29*	*17*	*55*	*49*	*23*

The third main resource in the first task - case description - was only available as a resource in the first task. All the resources Alisa drew on changed between the two tasks, whereas for Otto, the two resources used by him – course material and his own opinion – remained the same.

As can be seen from Table 4 presenting the communicative functions and contextual resources used in the discussion in Group 2, in Task 1 Jaana (31) and Minna (42) were the most active participants. However, only Jaana and Sanna provided knowledge related to the content of the task judging by their most frequent functions of communication. Other students were quite inactive in providing knowledge, although Minna elaborated the knowledge presented. However, it was not among her most frequent functions of communication. Jussi and Sanna were justifying or reasoning the knowledge presented. Both organizational and commenting functions of communication were among the most frequently used for four students: Jaana, Mari, Jussi and Minna. Also the social function of communication was among the most frequent functions for Mari, Minna and Sanna. Judging by the most frequent functions of communication it seems that the students had quite similar roles. The content of the task was not widely discussed, the main focus being on organizing activities, commenting on the suggestions, information or examples presented by the other students, or making comments with a social function. Technical comments given by three students were related to the technical difficulties the students faced during their activity.

The contextual resources used in the students' activity supports the interpretations made based on the communicative functions used (Table 4). The document was the most referred resource for Jaana, Mari, Jussi and Minna. The case, however, was not among the most referred resources except for Jaana and Mari, and the frequency was low. Minna was referring to course material, but again the frequency was low. This finding indicates that in the discussion forum the students focused more on commenting on the content of the written document than discussing and constructing knowledge based on the case. However, even though the knowledge was infrequently discussed in the forum, when it was discussed, it was based on co-construction of knowledge as the figures for co-text indicate. The co-text was among the most frequently used resources for all students, although the frequency was low. One's own ideas were the most widely used (Jaana, Mari and Jussi) resources in knowledge construction, except for Sanna who used her own conceptions.

Minna and Sanna did not participate in Task 2. In this task, Jaana and Mari were the most and equally active participants, whereas Jussi was clearly a non-active participant. Jaana and Mari both contributed actively to knowledge sharing. However, whereas Jaana provided reasoned knowledge, Mari frequently requested the other students to present their ideas or provide support for her knowledge (interrogative). Mari also frequently contributed socially for example by maintaining a good atmosphere. All the students were also actively judging and evaluating suggestions, information or examples presented by the other students (commenting) and organizing activities. Jussi's role remained the same between the two tasks; he was mostly providing support for the content-based discussion carried out by the others, commenting and organizing activities. Thus, he made more a social contribution than a content-based one in both of the tasks. Jaana's role as a knowledge provider and commentator remained the same between the two tasks, whereas Mari activated in her role as a knowledge provider in the second task. However, interrogative and social functions remained the most frequent functions.

As regards contextual resources used for knowledge sharing and construction, one's own experiences were among the most widely used resources for Jaana and Mari. The course material was barely referred to at all. Jaana and Jussi were also using their own conceptions. References to the document as the main resource indicate that the forum was also used for commenting on the written document. In this task, co-text was not among the most widely used resources for anyone, although Jaana and Mari built to some extent their contributions on other students' ideas. However, the students were mostly sharing knowledge as the high frequency of the knowledge providing function and the low frequency of the elaborative function demonstrate. The most remarkable change in resources as regards all students was that whereas one's own experiences were used as the main resource in this task, in Task 1 they were not used at all.

Differences and Similarities in the Web-Based Discussion Between the Groups in Two Tasks

Table 5 presents the differences and similarities between the two groups in the use of communicative functions and contextual resources in the two tasks.

Table 5. Frequency (*f*) and percentage (%) of the functions of communication and contextual resources used by Group 1 and 2 in two different tasks

	Task 1				Task 2			
Communicative functions	Group 1		Group 2		Group 1		Group 2	
	f /	%	*f* /	%	*f* /	%	*f* /	%
Interrogative	9	9	17	13	29	16	16	11
Responsive	1	1	3	2	13	7	4	3
Commenting	13	13	27	20	29	16	26	18
Knowledge providing	23	22	13	10	28	16	34	23
Elaborative	11	11	7	5	19	11	11	7
Reasoning	23	22	15	11	24	14	19	13
Social	10	10	20	15	17	10	17	11
Technical	0	0	6	4	0	0	0	0
Organizational	14	13	28	21	17	10	21	14
In total	*104*	*100*	*136*	*100*	*176*	*100*	*148*	*100*
Task description	5	5	5	5	7	4	8	6
Course material	5	5	6	6	19	12	1	1
Case	19	17	5	5	0	0	0	0
Message	7	6	8	8	22	14	20	16
Document	11	10	33	33	14	9	17	13
Own opinion	12	11	4	4	24	15	18	14
Own idea	15	14	10	10	28	18	13	10
Own conception	14	13	10	10	14	9	15	12
Own experience	6	5	1	1	0	0	21	17
Co-text	17	15	17	17	30	19	14	11
In total	*111*	*100*	*99*	*100*	*158*	*100*	*127*	*100*

In Task 1, the main function of communication as regards students in Group 1 was to provide well reasoned (22%) knowledge (22%) as well as to organize activities (13%) and give comments (13%) to other participants (Table 5). As can be seen from the use of contextual resources and, more specifically, the figure for co-text (15%), the knowledge was co-constructed. Thus, the students built on each other's thoughts. The knowledge was mainly constructed by discussing the case (17%) and by using one's own ideas (14%). From the task aim point of view, this group shared and constructed knowledge by using the case description as their main resource as was intended.

In terms of the discussion and activities, Group 2 differed notably from Group 1. The main functions of Group 2 were organizing activities (21%), commenting on other students' thoughts (20%) and maintaining a good atmosphere (15%). Thus, instead of focusing on content-based goals, they had a strong social orientation in their work. Their main reference was clearly the document base (33%), which indicates that the discussion forum was used for commenting on the ideas to be included in the document and organizing the process of writing the document. Thus, the forum was not extensively used for developing ideas. However, the knowledge provided (10%), elaborated (5%) and reasoned (11%) in the forum was co-constructed as the figure for co-text (17%) shows. One's own ideas (10%) or conceptions (10%) were also used. However, the case, the main resource in terms of the aim of the task, was hardly referred to (5%) in the discussion. This supports the notion that content-based activity mainly took place during the document writing.

As regards Task 2, a notable difference in the activities of Group 1 compared to Task 1 was that even though one participant had dropped out of the course the frequency of discussion increased (104/176). Again, the participants in Group 1 mainly provided knowledge (16%) and commented on other students' thoughts (16%). If the content-based functions – knowledge providing, elaboration and reasoning – are added up, it can be seen that the Group's orientation towards the content decreased slightly from 55% in Task 1 to 41% in Task 2. However, in Task 2 the use of the interrogative function increased (9% / 16%). This indicates that the students faced a real problem in solving the task. They needed each other in solving the problem and constructing the knowledge in hand as the figure for the main resource – co-text – demonstrates (19%). Thus, even though the knowledge-based discussion decreased, there was a slight increase in the construction of knowledge by building on thoughts presented by other participants. The knowledge was constructed mainly by using one's own, practical ideas (18%). However, they also relied more on the theoretical course material (12%) in their discussion compared to Task 1 (5%).

In Task 2, the number of the participants in Group 2 had decreased from five to three. However, the frequency of discussion slightly increased (136/148). The activities of Group 2 in this task were quite similar compared to Group 1. The main communicative functions in the group's discussion were to provide knowledge (23%) and to comment on other students' thoughts (18%). However, there was a notable change from Task 1 to Task 2 in the content of the discussion. Whereas in Task 1 Group 2 hardly provided knowledge (10%), in Task 2 it was their main function (23%). Thus, there was a shift from more socially oriented activity towards more content-based activity in the discussion forum. If the content-based functions (knowledge providing, elaboration and reasoning) are added up, the change is clear: from 26 % in Task 1 to 43% in Task 2. However, even though Group 2 shared more knowledge in this task it was less co-constructed as the figure for co-text (11%) demonstrates. In Task 1, the percentage for co-text was 17, which indicates that there were more instances of co-

constructing knowledge. This is also an opposite tendency compared to Group 1, which co-constructed more in Task 2. The main difference between the groups as regards the contextual resources used was that Group 2 used their own experiences (17%) as a main resource in their knowledge construction activity, whereas Group 1 did not use them at all.

All in all, it seems that the activities of Group 1 remained more similar from task to task compared to Group 2. Group 1 used the discussion forum for sharing and constructing knowledge. It also used the material that was supposed to be used in the tasks. In Task 1, Group 1 used the case (17%) as their main resource and in Task 2 it used the theoretical background material (12%). In Task 1, Group 2 was not using the discussion forum to share and construct knowledge based on the case (5%), but to guide and comment on the process of the document writing. In Task 2, it used the forum for knowledge sharing and construction, but did not draw on the course material (1%). Thus, from the task perspective Group 1 'succeeded' better in using the discussion forum as was intended by the teacher.

CONCLUSION

The aim of this study was to explore how two different tasks developed for supporting student groups' collaborative activities in a web-based learning environment enhanced students' collaboration during web-based discussion. Furthermore, the aim was to examine what challenges were faced during online interaction from the perspective of collaborative knowledge construction activity.

Based on the communicative functions, it was possible to some extent to evaluate the cognitive quality of the collaborative interaction and hence to make some assumptions about the learning in interaction (Mercer, 1996; Weinberger and Fischer, 2006). The elaborative function of communication, which has been demonstrated to be beneficial for collaborative learning (Van Boxtel et al., 2000), was not among the most widely occurring functions of communication at the group level, even though in Group 1 it was one of the most widely used functions for two students. Most notable from the point of view of collaborative learning is that neither of the groups used such functions as argumentation and counterargumentation in their discussion. Thus, the knowledge was more cumulatively (Mercer, 1996) shared (no co-text) and constructed (co-text) than critically evaluated. This type of interaction can be referred to as a conflict-avoiding co-operation style (Fischer et al., 2002), which is not considered as beneficial for collaborative learning. Thus, the results of the study indicate that the educational value of the students' discussions was not very high. An asynchronous web-based discussion tool, such as the one used in this study, can be regarded as a challenging tool for argumentation, because it does not allow for a very rapid exchange of ideas. Instead, synchronous discussion tools, such as chat, have been proved to be efficient in supporting argumentative discussions (e.g. Marttunen and Laurinen, 2007).

The notion of co-text (Linell, 1998) was used to indicate whether the students were building their discussion on other students' thoughts. Thus, it can be regarded as an indicator of the occurrence of co-construction of knowledge (Arvaja, 2007). In both of the tasks the use of co-text as a resource varied between 11-19% in both groups. This demonstrated that the discussion forum was not a very efficient tool for the co-construction of knowledge. An asynchronous discussion tool can also be regarded as a challenging tool for shared knowledge

construction, as it is for argumentation, because it allows for long monologues which are not easy to 'grab' as a whole and to develop further by others. However, an asynchronous discussion tool as a 'public memory' (Lipponen, 2001) allows for more careful and perhaps deeper reflection on the other students' thoughts than a synchronous tool. Thus, in this task it well served the function of providing and developing knowledge and thoughts and restoring them for later use in the document writing task.

Whereas Group 1 relied more on theoretical (Task 2) and practical (Task 1) background material, Group 2 relied more on their own experiences (Task 2) as resources in their knowledge sharing and construction. As our earlier study based on qualitative analysis of this data (Arvaja, 2007) has demonstrated, the students' different backgrounds influenced the way the task was interpreted as well as the choice of resources considered to be relevant in accomplishing the task. The use of one's own experiences instead of background material was related to the former teaching experience the students in Group 2 had (Arvaja, 2007). It might be that the students in this group faced no challenges as such and the task was not a real problem-solving task for them, as it might have been for students in Group 1, who had no teaching experience. Thus, even though the interaction took place only through the computer, the knowledge construction activity was still grounded into wider contexts and mediated to the discussion by the histories of individual students in the form of experiences and prior knowledge. Thus, in supporting collaborative learning, more attention should be paid to differences in the students' prior knowledge and experiences. Moreover, the diverse needs that different individuals as well as groups have in terms of resources should be taken into account in designing collaborative tasks.

One of the biggest challenges in web-based discussion is how to maintain interaction and knowledge construction. Jeong and Chi (1997) point out that in order to facilitate co-construction over computer networks, there has to be a social obligation for the participants to engage in active interaction. They build their argument on Clark's and Schaefer's (1989) claim that for co-construction to occur, it is not enough to make a contribution but the contribution also has to be accepted by the partner. Jeong and Chi criticise computer-mediated learning environments where responding is based merely on the person's own interest particularly for lacking this obligation for co-construction of knowledge. In this study, students were not in any way obligated to participate in the web-based discussion. It also seemed that due to the nature of the tasks themselves, they did not guarantee participation and engagement. Thus, it was relatively easy for individual participants to 'free-ride' (Hämäläinen and Arvaja, in press; Kreijns and Kirschner, 2004; Srijbos et al., 2007) in the web-based discussion as for example Jussi did. He was supporting other students' knowledge construction in both of the tasks by evaluating ideas presented by the others and organizing activities, but showed only little effort for content-based work. Furthermore, the dropout rate among the students indicated that the web-based activity was not considered a very motivating way of completing the course.

It is also noteworthy that even though the roles of some students remained the same between the two tasks, for some students the roles changed. There were both changes in the participatory roles as well as in content-based roles between the tasks. Participation in the last task (Task 2) was more equally distributed in both groups compared to Task 1. It also seemed that in the last task (Task 2) both of the groups were engaged in content-based activity, whereas in Task 1 the discussion of Group 2 did not focus on sharing and constructing knowledge but on organizing and commenting on the process of working on the document to

be written. Thus, the discussion forum was not fully successful as a context for problem-solving and knowledge construction as was intended. This may again relate to the issue of the tasks lacking the obligation for co-construction of knowledge (Jeong and Chi, 1997). To engage students to participate equally in collaboration, the notion of cognitive diversity has been utilized to make use of contradictory perspectives and interdependency by giving students different learning materials (Dillenbourg, 2002) or by assigning students reciprocal roles (Arvaja et al., 2003; Hämäläinen et al., 2006; Weinberger, Ertl, Fischer and Mandl, 2005). Thus, to really engage students in collaborative activity in a web-based environment there has to be a real need to make contact and to collaborate with other participants (Mäkitalo, Häkkinen, Leinonen and Järvelä, 2002).

The tasks were carefully structured beforehand to decrease the teacher's workload during the course. This structuring was able to guarantee that, at a general level, both of the groups succeeded in finishing the tasks step-by-step as was intended and in finding the resources needed (Hämäläinen, Arvaja and Häkkinen, 2007). However, a closer look at one of the steps, namely the web-based discussion in this study, demonstrated that the quality of the students' collaboration and participation varied. This study along with some earlier studies demonstrates that the teacher cannot be easily replaced by even the most advanced technology or pedagogical pre-structuring. As Pöysä and colleagues (2007) have shown, students need the teacher's support in working in web-based learning environments, and even the mere presence of the teacher may be enough. In this study, the students would have needed the teacher's support in engaging them to participate more equally, in deepening their discussion and in guiding them to use the resources as was intended – that is, in supporting collaborative knowledge construction. However, Groups 1 and 2 would have benefited from different kinds of support. While Group 1 would have benefited from support in engaging in the activities, Group 2 would have benefited from support both in engaging in the activities and in combining their own experiences to the theoretical background.

The findings of this study demonstrate that, although carrying out the same tasks, the groups differed in their knowledge construction. Along with the need for the teacher's support a more careful pre-structuring of the students' activity and the task itself in the web-based learning environment would have been needed in order to engage students in productive collaboration (Mercer, 1996; Fischer et al., 2002). So far empirical studies of scripts have mainly focused on a very detailed level scripts (e.g. Schellens, Van Keer, De Wever and Valcke, 2007; Stegmann, Weinberger, and Fischer, 2007; Weinberger, Ertl, Fischer and Mandl, 2005), in which all the groups are instructed similarly. Since collaboration is a complex phenomenon, including elusive and unpredictable elements (Resnick, 1991; Gillies and Ashman, 1996), in future flexible scripts which can take into account the diverse needs of different groups are needed. It has been stated that scripting collaborative interactions is a complicated challenge with a danger of too much or too little guidance (e.g. Dillenbourg, 2002). If there is not enough guidance, students may not reach the goals set for interaction, or in the worst case there is no real interaction at all. If there is too much guidance, it may prevent natural collaboration from emerging in all its richness (Dillenbourg and Tchounikine, 2007).

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Chapter 19

CHALLENGES OF MULTIDISCIPLINARY AND INNOVATIVE LEARNING

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ABSTRACT

The purpose of this chapter is to explore how higher education institutions can promote the synergic and multidisciplinary learning to increase their innovativeness and the external impact on the region. The organization of the Turku University of Applied Sciences was developed to support the multidisciplinary and innovative activities. The organizational change is described in the chapter using the Balanced Scorecard approach, which was used to communicate the strategic objectives and support the implementation of the new multidisciplinary organization. The Balanced Scorecard approach is not only a tool for the communication and implementation of the strategic plans, but it can also be used to consistently define the objectives of the organizational change. The empirical results of the study show that the multidisciplinary faculties can be successfully formed to create innovative research and development.

Keywords: *innovations, regional development, higher education, organization research, multidisciplinary education, research and development*

1. INTRODUCTION

The production of knowledge and innovation is currently a broadly discussed topic, because knowledge is crucial for the high quality learning and the development of the regions, where higher education institutions have a remarkable role. Higher education

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institutions are operating in a post-industrial environment and they are characterized by turbulent change, information overload, competitiveness, uncertainty and sometimes organizational decline (Cameron and Tschirhart, 1992). Therefore the institutions must constantly develop their internal processes and structures to respond the needs of the environment.

Gibbons et al. (1994) propose a universal classification for the system of knowledge production. Their purpose is to explore the present close relationship between science and technology. They studied the diversity of researcher backgrounds in developed countries and drew a conclusion that the technological development is result from the conversion from mode 1 to mode 2 research. The old mode 1 represents the style of the knowledge production performed in each field of study. In the new style, mode 2, multidisciplinary knowledge production is performed in a social context.

The knowledge production in mode 2 is more heterogeneous than in mode 1. The purpose of knowledge production in mode 2 is practical. Often both the information producers (researchers, teachers and students) and the recipients of the information work together. This knowledge is socially shared, multidisciplinary, problem-oriented and produced in the context of application. The need for producing information arises from social and financial contexts. The mode 2 knowledge is produced as collaboration between the actors of science, technology, industry, entrepreneurs and practitioners.

The mode 2 knowledge requires heterogeneity, organizational diversity, enhanced social accountability and the broadly defined quality control. These requirements are interconnected in the organizational structure and culture with cognitive and social practices. According to Gibbons' theory, there should be a clear connection between the expansion of research and development (R&D) and the increasing of mode 2 knowledge production in the projects of the universities of applied sciences. The combination of mode 2 research and teaching is a challenging potential, because most of the research personnel are teachers.

The study by Ando (2001) indicates that there are two factors which prevent teachers from participating in mode 2 research. Mode 1 research is academically significant and mode 2 research is socially significant. Academically and socially significant research approaches are fairly different from each other. Mode 2 is characterized by the concept of individuality and disagreed by the concepts of universality and reproducibility, which characterize traditional scientific research. The gap between academic research and socially significant research is narrowing when the academics are beginning to accept the concept of individuality. The question of identity and academic tribes is closely related to the realization of mode 2 knowledge.

The purpose of this study is to show that the higher education institution is able to create the structure of a knowledge-intensive organization which supports mode 2 research and regional development. Most of the research at the Finnish universities of applied sciences is carried out using external funding. The innovativeness and usefulness of each project is evaluated, when the funding decision is made. Therefore the volume of R&D can be used as the proxy of the innovativeness of the faculties having a different kind of structure. The single- and multi-field faculties are evaluated using the empirical data of R&D projects.

The case study is carried out at the Turku University of Applied Sciences (TUAS), which is one of the largest higher education institutions in Finland. The institution is operating in eight different campuses in Southwest Finland. The organization of the TUAS underwent three major organizational changes after the establishment of the institution in 1992.

Multidisciplinary education was started in 1996 after the single-field phase of technology and transport. The organization was merged in 2000 to another institution and in this way the institution became the largest university of applied sciences in Finland. The amount of faculties was reduced in 2004 from ten to six and an R&D manager was hired for each faculty.

This chapter is organized as follows: The next section first describes the higher education system and the organizational structure, which was designed to support innovations and regional development. The Balanced Scorecard approach is used to define the objectives of the organizational change. In addition, the section briefly describes some results of the organizational change. Then the chapter describes the cooperation between faculties and degree programs within the institution in R&D. Finally, the results of the study are summarized and discussed in the concluding section.

2. KNOWLEDGE PRODUCTION IN THE SOCIAL CONTEXT

The Finnish Higher Education System

The Finnish higher education system consists of two complementary sectors, which are universities and universities of applied sciences. The mission of universities is to conduct scientific research and provide postgraduate education based on it. The universities of applied sciences train professionals in response to the labor market needs and conduct applied R&D, which supports instruction and promotes regional development. The universities of applied sciences were formerly called polytechnics in Finland, but they assumed the new name at the beginning of 2006 following the European practice.

The sector of the universities of applied sciences is still fairly new. The first universities of applied sciences started to operate on a trial basis in 1991-1992 and the first institutions were regularized in 1996. By 2000 all the universities of applied sciences were working on a permanent basis (Ministry of Education, Finland, 2008). The universities of applied sciences were established by merging vocational schools and improving the quality and status of vocational education. Before the organizational change the different fields of vocational education were separated to unconnected vocational schools, but the establishment of the universities of applied sciences collected the fields of education under the same roof.

The Finnish universities of applied sciences are aimed to be multi-field regional institutions focusing on cooperation with working life. The universities of applied sciences are municipal or private institutions, which are authorized by the central government. The authorization determines their educational mission, fields of education and location. The universities of applied sciences have autonomy in their internal affairs. They conduct applied R&D mainly geared to the needs of business and industry and usually linked to the structure and development of the regional economy.

Education at the universities of applied sciences is provided through degree programs, which are categorized into the fields of educational. They have been defined for the statistical purposes and to plan the amount of study places in the various parts of the country at the Ministry of Education. The newly established universities of applied sciences challenge the traditional science universities and do not use the fields of education as a basis of their

organization. The universities of applied sciences want to be innovative and serve their regions.

According to the legislation, the universities of applied sciences provide education in the following fields of education:

- Arts and Media
- Humanities and Education
- Health Care, Sports and Social Services
- Natural Resources and the Environment
- Natural Sciences
- Social Sciences, Business and Administration
- Technology, Communication and Transport
- Tourism, Catering and Hospitality Management

These fields of education are not suitable for the basis of faculties at the TUAS, because some of the fields are very large in comparison with the smallest fields. In addition, the institution wanted to promote the multi-field education and innovative R&D. The importance of multidisciplinary activities and team learning has been acknowledged in several studies (Drucker, 1998, Edmondson, 2003, Fong, 2003, Dyer and Hatch, 2006, Koskinen, Pihlanto and Vanharanta, 2003, Ruuska and Vartiainen, 2005).

The purpose of the organizational change at the TUAS was to implement the legislation of the universities of applied sciences which introduced a new task for these institutions. The new task of applied R&D was defined so that it should support the regional development. The purpose of the organizational change was also to strengthen the applied R&D to be an integral part of curriculum development so that the institution could increase its external impact on its region.

Social Networks

The R&D projects of the universities of applied sciences usually involve several partners, who seek to add value to their conventional activities in their background organizations. The purpose of the collaboration is to find new ways of working in social networks. Innovation requires skills to operate in the networks and tacit knowledge which can be gained or transmitted through interactions in the networks. The density of interaction and the likelihood of change promote conditions to create innovations (Burt, 2002). Better and more adequate results can be achieved through enhanced cooperation with other partners in the region.

The universities of applied sciences are closely linked to the social networks in their regions. The collaboration in social networks has implications for all the perspectives of strategic planning. It can even be interpreted that the strategy process of a higher education institution is the dimension of creating social capital in the region. The dimensions of social capital have been presented by Nahapiet and Ghoshal (1998). Strategic thinking is needed in the networked collaboration (Mintzberg, 1995). Social capital provides a useful framework together with strategic thinking to plan the future of higher education institutions in networked collaboration.

The management of higher education institutions can use the Balanced Scorecard approach and take into account the social capital and social networks. The internal strategic planning can be extended to take into account the networked external partners of the institution. Networks are important elements of social capital when the institution wants to increase its external impact on the region. The creation and maintaining of social capital should be taken into account in the strategy process.

The Balanced Scorecard approach developed by Kaplan and Norton (2001, 2004) is a useful tool, when the institution is combining strategic planning with the development of social capital. The Balanced Scorecard approach is used in this study rather as a philosophy than strictly a measurement system. The ability to integrate different knowledge of the institution to ensure the best possible outcomes is a clear advantage in strategic planning. Strategic plans can be communicated and implement taking into account the social dimensions of the organization. The combination of social capital and strategic management narrows the cap between the concepts of management and leadership.

3. ORGANIZATIONAL STRUCTURE TO SUPPORT INNOVATIONS

If management cannot describe the objectives of an organizational change, it is difficult to make a notable difference. The Balanced Scorecard approach was originally planned to translate the strategic plan into strategic objectives and tangible measures that can be communicated to the personnel and external stakeholders (Kettunen, 2004a,b, 2005, 2006a,b, Kettunen and Kantola, 2006, Kantola and Kettunen, 2008, Kettunen, Kantola and Hautala, 2007a,b). The Balanced Scorecard approach can also be used as an efficient tool for the organizational change. The specification of the objectives of the organizational change should include the balanced mix of objectives placed in the different perspectives to articulate the purpose of the change.

The strategic objectives of the Balanced Scorecard approach are typically defined in four perspectives, which are balanced between the external measures for customers, the financial measures that are aligned with the measures of internal processes and structures, and the learning measures that drive future performance. This section shows how these perspectives can be applied to specify the objectives of the organizational change. The objectives of the organizational change were defined from the legislation and overall strategic plan of the institution and placed to the perspectives of the Balanced Scorecard. The board of the TUAS set clearly defined objectives for the organizational change using the Balanced Scorecard approach as follows:

1. Customer perspective. The customer perspective describes the added value of the organizational change created for the customers. It also describes the external effect of the institution on its environment. The Board of the TUAS defined the objective in this perspective as the “support of working life and regional development”. This reflects the declared mission and the legislation of the universities of applied sciences.
2. Financial perspective. The financial perspective includes the financial objectives of the organizational change. The Board of the TUAS defined the objective to be in this

perspective “economic and efficient activities”. This reflects the fact that the central government did not allocate extra funding even though the new task of R&D was assigned to the institutions. The purpose of the institution was to increase its cost-efficiency activities to release resources for R&D.

3. Internal processes and structures perspective. This perspective includes the objectives that are aligned with the objectives of the financial perspective. The Board of the TUAS defined four objectives in this perspective: “potential for new innovative products”, “structure where R&D serve education”, “multidisciplinary activities” and “the creation of synergies.” These objectives emphasize the innovative activities and the purpose of the institution to support the regional development.
4. Learning perspective. The learning perspective includes the objectives that are drivers for future performance described in the internal processes. The Board of the TUAS defined the objective “strengthening the capabilities of research, development and management” in this perspective. Without capabilities for R&D, the activities cannot be innovative. These capabilities can be achieved by recruitment and internal training and supervision.

The objectives of the organizational change were achieved by forming larger faculties. The number of faculties decreased from ten to six. Another lower level organizational change was that the number of degree program managers decreased from 44 to 27. This change increased the responsibilities of the managers. Before the change each manager was responsible for one degree program, but after the change they could take responsibility of several degree programs and create synergies among them. Another advantage of the organizational change was that the institution was able to appoint full-time deans to the faculties. The third advantage was that the institution could engage an R&D manager for each faculty.

Figure 1 presents the organization of the TUAS. The organization has functional activities and six faculties. The rector and two vice rectors assume responsibility for functional activities with the managers of the development unit. The rector and two vice rectors have centralized responsibilities for the administration services, R&D services and student services in the development unit. The institution has six faculties. Four of them are multi-field and two of them are single-field faculties. Each faculty has 5-10 degree programs.

The R&D managers were hired in August 2004. The managers assumed the new responsibility and it soon became evident that there was plenty of potential to raise the volume of R&D. The expenditure and external revenue started to boost. In addition, the number of publications doubled in three years after the organizational change. The organizational change is a success story, which also produced plenty of fresh contents to education.

Soon after the organizational change there emerged a concern that the resources for education decreased, because internal funds were allocated to R&D. An innovative solution was found. The R&D activities were effectively integrated into education. An increasing number of students could participate in R&D projects. The students could earn credits and promote their studies in practically-oriented development projects. The institution could create many new learning environments for students.

Figure 2 describes the rapid increase of R&D after the organizational change in 2004 at the TUAS.

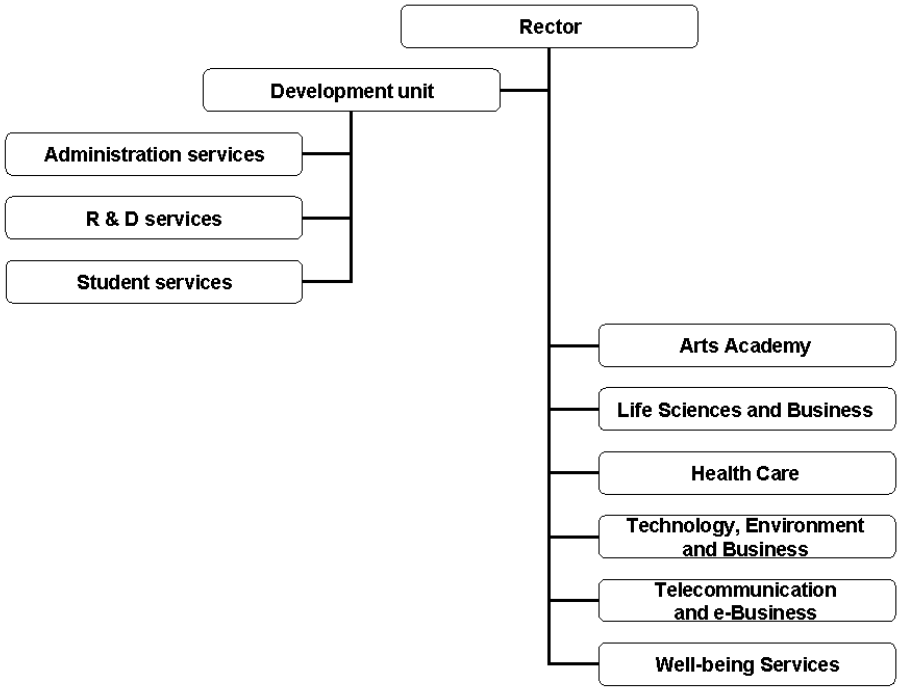

Figure 1. The organization of the TUAS.

The TUAS accomplished an organizational change which produced the structure of R&D managers and the multidisciplinary faculties. Each faculty has a R&D team which supports the teachers to integrate R&D with education. The experience of the organizational change supports the argument that the clearly defined and communicated objectives of organizational change help the institution to create an organizational structure, which supports innovative R&D and regional development.

4. THE COOPERATION IN R&D AT THE TUAS

The structural network analysis (Scott, 1990) is used in this study as the tool of analysis in the empirical part of the study. The network analysis exercised the information of 895 R&D projects of the TUAS from the years 2001-2007. The R&D database of the institution is the data source, which contains information about all the projects implemented at the TUAS. Each project in the database has one responsible founder from a known degree program and faculty. In addition, all other degree programs and faculties which participate in the project are registered in the database.

The faculties were categorized into two groups using the fields of education. In the single-field faculties, all degree programs are categorized into one field of education. In the multi-field faculties, degree programs are categorized into several fields of education.

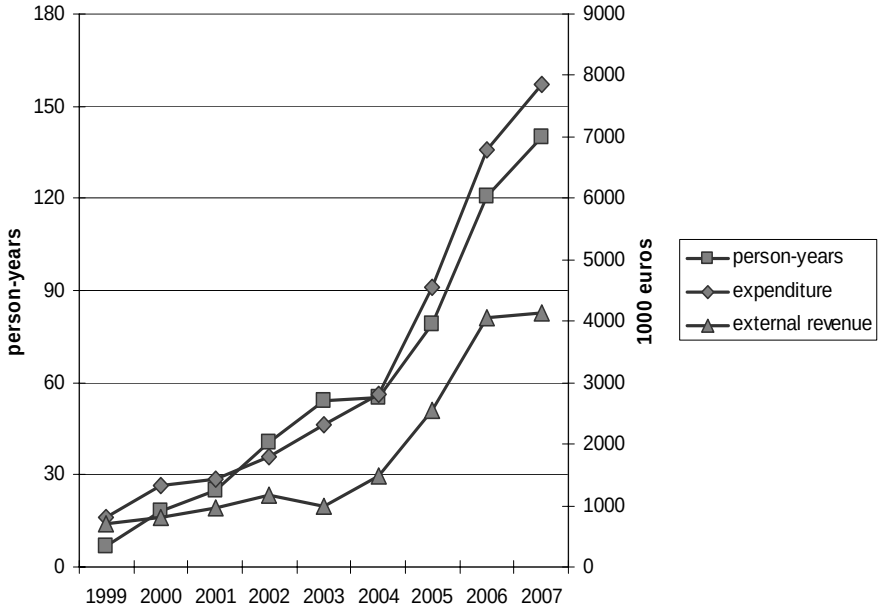

Figure 2. The increase of R&D at the TUAS.

The projects were categorized by two dimensions: firstly by the amount of degree programs participating in projects and secondly by the amount of fields participating in projects.

Table 1 describes the shares of projects, teachers, publications and students by the faculty type at the TUAS. It describes the differences between single- and multi-field faculties. The part-time teachers have been calculated in this case as the annual full-time equivalent. Every person has a defined primary unit at the institution based on their workloads. When the share of teachers is compared with other factors, the proportions of students and projects are relatively high in multi-field faculties. This indicates that there are smaller study groups and even individual teaching and supervision in the single-field faculties. The low proportion of projects could also indicate that the single-field faculties have fewer contacts with the surrounding working life.

The figures of the table are greatly influenced by the fields of education in the single-field faculties, but as we point out later in this study, the combination of fields of education in multi-field faculties has a great strategic importance to co-operation between the institution and working life. The share of R&D projects is not strongly related to the share of publications. The teachers in the single field faculties are only slightly more active to produce publications than the teachers in multi-field faculties.

Table 2 describes the share of single- and multi-field R&D projects by the faculty type. There are 205 projects in single-field faculties and 690 projects in multi-field faculties. The share of single-field projects is 79 % and the share of multi-field projects is 21 %. The difference between the single- and multi-field faculties is significant. There are 10 percentage units more multi-field projects in multi-field faculties than in single-field faculties. This finding supports the argument that multidisciplinary faculties favor multidisciplinary projects.

This also supports the argument that the multidisciplinary faculties are able to promote innovativeness, which responds to the needs of customers.

Table 3 describes the share of one and several degree programs in the R&D projects by the faculty type at the TUAS. It can be seen that the single- and multi-field faculties have no remarkable differences when we are looking at the number of degree programs involved in the R&D projects. This finding supports the argument that the multi-field composition of faculties favors more the multidisciplinary and innovative projects than the amount of partners. This finding is interesting, because it is often argued that the higher education institutions should be large to promote the innovations.

Table 1. The share of projects, teachers, publications and students by the faculty type at the TUAS

The faculty type	Share of R&D projects, % (N=895)	Share of teachers, % (N=396)	Share of publications, % (N=151)	Share of students, % (N=8397)
Single-field faculties	23	41	46	28
Multi-field faculties	77	59	54	72
Total	100	100	100	100

Table 2. The share of single- and multi-field R&D projects by the faculty type at the TUAS

Faculty type	Share of single-field R&D projects, %	Share of multi-field R&D projects, %	Total
Single-field faculties	87	13	100
Multi-field faculties	77	23	100
Average	79	21	100

Table 3. The share of one and many degree programs in R&D projects by the faculty type at the TUAS

Faculty type	Share of one degree program in the R&D projects, %	Share of several degree programs in the R&D projects, %	Total
Single-field faculties	88	12	100
Multi-field faculties	85	15	100
Average	85	15	100

Cooperation between the degree programs in R&D is active at the TUAS. The degree programs have on average 17 projects, which have several degree programs as a partner. Another indication of the active cooperation is that 12 degree programs of all the 46 degree programs take part in more than 17 multi-field projects. The projects of the TUAS have cooperation between the business life and public sector. There is also active academic cooperation between the other higher education institutions in Finland and other countries.

Table 4 describes the share of R&D projects by faculties at the TUAS. In most cases a single-field R&D project is able respond to the customer needs. The single-field faculties are less active than the multi-field faculties in multi-field projects. The large multidisciplinary faculties are less active than the small multidisciplinary faculties in multi-field projects. These findings support the argument that small multidisciplinary faculties are able to provide better communities of practice (Wenger and Snyder, 2000) and promote innovation activities.

Table 4. The share of R&D projects by the faculties at the TUAS

Faculties	Share of R&D projects, %	Share of single-field R&D projects, %	Share of multi-field R&D projects, %
Single-field faculties			
• Arts Academy	9	81	19
• Health Care	14	91	9
Multi-field faculties			
• Life Sciences and Business	8	71	29
• Well-being Services	17	72	28
• Telecommunication and e-Business	19	78	22
• Technology, Environment and Business	33	81	19
Total	*100*	*79*	*21*

Figure 3 describes the expenditure and external revenue from R&D in 2006-2007 by faculties at the TUAS. The figure indicates that the external revenue did not increase remarkably in 2007, but the expenditure of the multidisciplinary faculties increased. The expenditure and revenue from R&D are higher in the multi-field faculties than in the single field faculties. The multi-field faculties expect that they still can increase their revenues in the future, because they are able better to meet the customer needs.

5. CONCLUSIONS

This study emphasized mode 2 R&D at higher education institutions. Mode 2 R&D supports the outreach and engagement of the institution in the regional development using social networks. It produces socially significant research, which is important for the economic growth, employment and welfare of the regional. On the other hand, mode 1 research is academically significant producing plenty of publications, which is not necessarily significant for business life and the development of the public sector in the short run. A future challenge is to combine effectively mode 1 and mode 2 research.

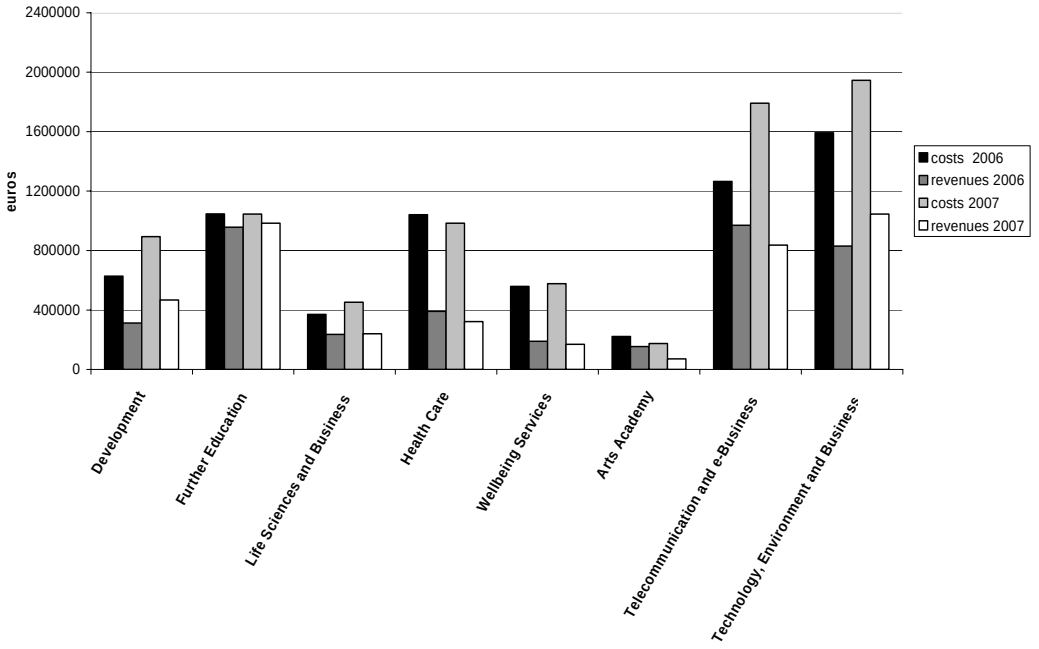

Figure 3. Expenditure and revenue from R&D in 2006-2007 by faculties at the TUAS.

The results of this study show that the structure of the knowledge-intensive organization has a great importance on the results achieved. The hiring of R&D managers for faculties and forming multi-field faculties to promote innovative R&D are able to remarkably increase the volume of R&D and the external impact of the institution on its region. This study challenges the management of higher education institutions to construct knowledge-intensive organizations to support innovations.

The empirical results of this study indicate that the multi-field faculties are able to promote the multidisciplinary and innovative projects. This is an important finding when the higher education institution aims to develop its innovative activities and aims to increase its external impact on the region. The composition of the faculty does not seem to affect the number of partners in R&D projects. This supports the argument that the number of partners is determined on the basis of customer needs and other factors.

The empirical results of this study support the argument that the small multidisciplinary faculties are more active than the large multidisciplinary faculties to take part in multi-field projects. This finding supports the argument that small multidisciplinary faculties are able to promote innovations. One plausible explanation is that small multi-field faculties have stronger social pressure to take part in the multidisciplinary projects. This interpretation needs, however, more research. The effect of the size of the multidisciplinary faculty is an important result, because politicians often argue that small units should be combined to bigger units to strengthen the innovative activities and external impacts of the higher education institution.

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INDEX

A

absorption, 285
abusive, 119
academic, viii, xi, xii, xv, 5, 6, 18, 20, 29, 31, 46, 52, 53, 56, 116, 128, 129, 130, 135, 147, 149, 151, 187, 188, 191, 208, 214, 246, 254, 283, 284, 286, 287, 288, 289, 301, 308, 314, 317, 320, 353, 358, 378, 385, 389
academic growth, 128, 130
academic performance, viii, 6, 29, 31, 214
academic settings, xi, 187
academics, 378
access, 58, 67, 107, 108, 141, 142, 147, 150, 159, 167, 232, 325, 335, 338, 343, 345, 346, 357
accommodation, 284
accountability, xiii, 229, 252, 254, 355, 378
accounting, 352
accreditation, 130
accuracy, 35, 53, 126, 150, 156, 242
achievement, vii, 1, 6, 13, 15, 17, 18, 19, 20, 25, 27, 32, 39, 40, 50, 52, 66, 102, 190, 226, 230, 232, 233, 234, 236, 246, 252, 254, 255, 337, 351, 352, 353, 355, 356, 358
achievement scores, 352
acid, 175
action research, xv, 111, 165, 283, 284, 287, 288, 290, 297, 298, 301, 304, 306, 308, 310, 313, 314, 315, 317, 319, 321, 322
activation, xv, 44, 50, 283
activity theory, 341, 342
actual output, 215
acute, 269
adaptation, 324, 341
administration, 109, 382
administrative, 107, 111
administrators, 191, 193, 204, 247, 254
adolescents, 27
adult, xiv, 34, 45, 59, 72, 225, 278, 283, 284, 321, 355
adult education, 59
adult learning, xiv, 283, 284, 321, 355
adults, 27, 189
advertisements, 36
advocacy, 4, 102
affective experience, 240
Africa, 102, 104, 105, 130, 131
African Americans, 54
afternoon, 196
age, 4, 11, 59, 173, 239, 268
agent, 19, 267, 330, 331, 333, 334, 335, 347
agents, 140, 330, 334, 335
aggregation, 47, 327, 333
aid, 262, 275, 277, 302
AIDS, 5, 19
air, 114
allergy, 237
alternative, xv, 3, 4, 10, 13, 29, 60, 92, 96, 140, 159, 160, 167, 268, 280, 283, 290, 311, 360
alternatives, 5, 9, 11, 19, 95, 140, 159, 160, 161, 163, 167
ambiguity, 161
American Association for the Advancement of Science, 87, 184
American Educational Research Association, 27, 29, 254, 255, 320, 321
American Psychological Association, 152, 255, 376
amino, 17
amino acid, 17
Amsterdam, 53, 348, 349, 375
analog, 331
analysis of variance, 35, 250
analysts, 50, 328, 332

analytical models, 50
anatomy, 23
anger, 41
animal tissues, 78
animals, 13, 77, 78
ANOVA, 197, 199, 251
anthropology, 152
anxiety, 271, 288
apathy, 128, 129
application, vii, xv, 1, 41, 47, 58, 65, 66, 93, 118, 128, 211, 223, 232, 284, 286, 299, 301, 307, 312, 340, 345, 364, 378
aptitude, 26
aquatic, 77
argument, xvi, 3, 19, 22, 28, 44, 138, 139, 151, 192, 216, 219, 220, 281, 359, 360, 361, 371, 372, 376, 383, 384, 385, 386, 387
arrest, 107
arthropoda, 78
articulation, 33, 129
artificial, 77, 176, 376
artificial intelligence, 376
Asia, 73
aspiration, 208
assessment, xiii, xiv, 8, 16, 17, 18, 26, 38, 56, 58, 59, 60, 61, 62, 65, 72, 81, 87, 88, 98, 103, 108, 112, 114, 118, 146, 184, 197, 204, 211, 226, 227, 229, 230, 231, 232, 233, 234, 235, 236, 241, 242, 261, 265, 279, 333, 355, 358
assessment tools, 231
assignment, 23, 78, 116, 124, 125, 159, 289, 290, 296, 301, 306, 307, 308, 361, 364
assimilation, 5, 26, 28, 208, 284
assumptions, xi, 7, 95, 108, 156, 158, 159, 162, 167, 187, 188, 191, 192, 371
asynchronous, 360, 361, 362, 371, 374, 375, 376
asynchronous communication, 375
atmosphere, xiv, 15, 26, 39, 63, 111, 112, 237, 245, 249, 253, 267, 306, 307, 313, 368, 370
attention, xiii, xiv, 24, 25, 42, 43, 59, 63, 67, 102, 103, 108, 112, 116, 118, 127, 135, 141, 142, 143, 150, 151, 157, 159, 162, 167, 190, 194, 207, 208, 216, 217, 223, 230, 257, 258, 263, 265, 270, 274, 278, 286, 294, 305, 310, 314, 360, 372
attitudes, 16, 29, 36, 117, 118, 129, 258, 259, 260, 278
attribution, 34, 35, 41
attribution theory, 34, 35, 41
auditing, 235
Aurora, 255
Australia, 157, 165, 280
authenticity, 172, 249
authority, 3, 4, 5, 7, 14, 20, 53, 127, 149, 156
autonomous, 35, 254, 334
autonomy, 58, 59, 162, 167, 246, 281, 379
availability, xi, 188
avoidance, 129
awareness, xv, 39, 50, 108, 194, 196, 202, 203, 239, 285, 291, 293, 296, 300, 303, 307, 308, 311, 315, 316, 317, 323, 324, 328, 329, 330, 374

B

Balanced Scorecard, xvi, 377, 379, 381
bank account, 196
barriers, 297, 388
beginning teachers, 274, 319, 352
behavior, 5, 33, 34, 35, 42, 78, 91, 92, 152, 190, 226, 233, 240, 241, 302
behavioral change, 246
behaviours, 72, 112, 120, 327, 328, 329
beliefs, xiv, 5, 27, 29, 34, 36, 39, 40, 97, 128, 150, 246, 249, 250, 254, 257, 258, 259, 260, 263, 266, 268, 273, 274, 276, 277, 278, 279, 280, 281, 291
belongingness, xii, 207, 213
benchmark, 152
beneficial effect, 52
benefits, xv, 5, 11, 29, 58, 85, 102, 143, 144, 146, 147, 149, 151, 323, 354
Best Practice, 88, 184
bias, 20, 35
Bible, 4, 12, 287
biological, 3, 5, 24, 26, 56, 77, 85, 88, 160, 168, 215, 216
biological activity, 77
biological processes, 160
biological systems, 216
biology, vii, 1, 6, 7, 12, 14, 17, 18, 23, 27, 36, 76, 79, 87, 111, 119, 160, 173, 182, 193, 194, 200, 211, 216, 225, 262, 264, 319
biomedical, 231
black, 5, 195, 269
blame, 129, 290
blocks, 14, 92, 136, 138, 237, 268
blood, 35, 216, 237
blood pressure, 237
Bohr, 92, 95
Boston, 87, 88, 155, 185, 318, 321, 353, 388
Botswana, 131
bounds, 160
boys, 62, 116, 125, 138, 271
brain, 284
brainstorming, 161
Brassica rapa, 77
British, 54, 73, 107, 171, 278
buildings, 107, 136

business, 11, 36, 210, 349, 379, 385, 386, 388

C

calculus, xiii, 207, 339
California, 88, 133, 169, 292
campaigns, 164
Canada, 57, 207, 351, 375
cancer, 20, 29, 243
candidates, 194, 198, 200, 203, 236, 249, 278
capacity, xv, 24, 44, 54, 77, 108, 114, 163, 165, 166, 167, 274, 323, 354
capacity building, 108
capital, 5, 111, 380, 381, 389
capital punishment, 5
carbon, xiii, 5, 174, 207
carbon dioxide, xiii, 6, 207
cardiac risk, 242
cardiac risk factors, 242
career counseling, viii, 31, 32
Carnot, 225
case study, 111, 279, 345, 346, 378
cast, 57, 193
catalytic, 165
categorization, viii, 31, 280
cathode, 98
cats, 213
causal attribution, 39
causality, 39, 54, 214
cave, 5
Central America, 163
centralized, 160, 382
certainty, 5, 19, 293
certificate, 287
certification, 130, 353
chaotic, 252
cheating, 193
chemical, 97, 183
chemistry, ix, xii, 81, 89, 90, 91, 92, 95, 96, 97, 98, 111, 119, 173, 188, 191, 194, 200, 205, 211, 226
Chernobyl, 5
Chicago, 29, 97, 169, 227, 280, 321
child rearing, 34
child-centered, 102
childhood, 152, 157
children, 32, 35, 42, 50, 54, 56, 59, 60, 61, 62, 63, 67, 69, 107, 108, 113, 139, 140, 144, 147, 152, 157, 208, 271, 274, 375, 376
China, 194
Chinese, xii, 30, 188
chloride, 175
Christianity, 12
circulation, 23
citizens, vii
citizenship, 56
civil engineering, 388
civil society, 165
class period, 7, 112
class size, 115, 231
classes, xii, 14, 27, 33, 35, 45, 81, 114, 115, 117, 120, 125, 127, 129, 147, 159, 160, 164, 188, 191, 196, 200, 237, 280, 311, 324, 352
classical, 327
classification, xv, 58, 214, 323, 347, 378
classified, 193, 346
classroom activity, 156
classroom culture, 147, 252
classroom environment, xiv, 90, 104, 245, 246, 247, 248, 249, 251, 252, 253, 254
classroom management, 108, 111
classroom practice, 114, 129, 354
classroom settings, 113, 192
classroom teacher(s), 99, 353
cleaning, 113, 115, 145, 149, 333
clients, 102
clinical, xiii, 229, 230, 232, 233, 234, 236, 237, 238, 239, 240, 241
closure, 146
coactors, 42, 43
coal, 5
coding, 160
cognition, vii, 2, 6, 19, 27, 35, 52, 53, 104, 152, 275, 318, 320, 376
cognitive, vii, viii, 1, 2, 3, 5, 26, 27, 31, 32, 33, 34, 35, 38, 39, 42, 44, 45, 51, 52, 53, 54, 127, 143, 208, 216, 225, 240, 254, 259, 267, 271, 285, 286, 291, 292, 293, 294, 313, 316, 318, 319, 320, 336, 338, 341, 346, 349, 371, 373, 376, 378
cognitive abilities, 39, 44
cognitive activity, 292, 293
cognitive development, vii, 1, 26, 34, 35, 45, 51, 54, 127, 285
cognitive dimension, 32
cognitive dissonance, 3, 5, 34
cognitive function, viii, 31, 42
cognitive performance, 42, 44, 53
cognitive process, 286, 291, 293, 316, 341, 376
cognitive processing, 291, 376
cognitive psychology, 216
cognitive research, 318
cognitive system, 291, 292, 293, 294
cognitive tasks, 44
coherence, 274
cohort, 18, 64, 76, 163

collaboration, xv, xvi, 30, 45, 48, 64, 67, 111, 258, 260, 261, 276, 277, 279, 323, 332, 337, 340, 356, 359, 360, 361, 371, 373, 375, 376, 378, 380
collaborative learning, 374, 376
college students, vii, 2, 4, 27
colleges, 36, 388
colors, 137
combined effect, 356
comfort zone, 145
commodity, 128
communication, xi, xii, xvi, 22, 35, 45, 52, 72, 146, 149, 150, 183, 187, 188, 195, 196, 198, 200, 202, 205, 216, 227, 230, 232, 237, 238, 240, 320, 324, 325, 337, 341, 360, 361, 363, 365, 367, 368, 369, 370, 371, 377
communication abilities, 198
communication skills, xi, xii, 187, 188, 200, 232, 237, 240
communication systems, 35
communities, 26, 45, 47, 114, 129, 147, 240, 259, 260, 356, 357, 376, 386, 389
community, ix, x, 3, 18, 23, 45, 47, 89, 91, 93, 96, 98, 133, 135, 143, 145, 146, 150, 151, 162, 165, 166, 167, 240, 247, 252, 259, 260, 313, 319, 356
commutativity, 139
compassion, 239, 240
compensation, xi, xii, 187, 188, 195, 196, 197, 198, 199, 203
competence, xi, xii, 46, 104, 181, 187, 188, 190, 195, 197, 198, 199, 202, 230, 234, 235
competency, xiii, xiv, 229, 230, 231, 232, 233, 234, 236, 241, 243
competition, 38, 39, 253
competitiveness, 378
complement, 58, 236, 273, 337, 338, 339, 360
complementary, xiv, 231, 257, 339, 362, 379
complexity, xv, 17, 57, 64, 96, 97, 129, 134, 157, 163, 164, 167, 181, 219, 247, 283, 293, 374
components, xv, 107, 108, 126, 139, 163, 194, 218, 259, 260, 262, 283, 285, 293, 295, 298, 310, 312, 313, 314, 315, 316, 356
composite, 84
composition, 213, 217, 339, 385, 387
comprehension, 6, 7, 29, 127, 152, 193, 195, 201, 202, 203, 284, 286, 326, 329
computer, 6, 27, 29, 52, 81, 82, 319, 327, 332, 360, 361, 372, 374, 375, 376
computer science, 6, 27, 332
computer software, 29
computer technology, 81
computerization, 235
computers, 133, 226, 324, 330, 349, 361, 376
computing, 124
concentrates, 329
concept map, 79, 84, 208, 209, 210, 211, 214, 215, 225, 226, 227
conception, 96, 259, 328, 364, 366, 367, 369
conceptualization, 285
concrete, ix, xiv, xv, 6, 23, 26, 35, 75, 105, 136, 150, 233, 257, 260, 281, 283, 285, 314, 363, 364, 366
concreteness, 214
confidence, 64, 65, 66, 67, 93, 159, 161, 167, 181, 254, 265, 272, 277, 288, 297
conflict, 5, 12, 20, 25, 42, 43, 45, 50, 53, 259, 268, 270, 371
confrontation, 95
confusion, 65, 316
conjugation, 95
consciousness, 53
consensus, ix, x, 89, 90, 94, 111, 133, 135, 136, 138, 139, 140, 143, 144, 145, 146, 147, 149, 150, 151, 176, 308
constraints, 24, 102, 140, 184, 191, 200, 274, 331, 333, 334, 335
construct validity, 249
construction, viii, xvi, 7, 15, 31, 33, 39, 45, 46, 85, 92, 95, 96, 112, 125, 146, 149, 209, 210, 213, 215, 216, 217, 218, 222, 223, 226, 258, 259, 263, 268, 271, 278, 279, 306, 313, 317, 359, 360, 366, 367, 368, 369, 370, 371, 372, 373
constructivist, xv, 95, 208, 259, 262, 280, 283, 284, 286, 317, 318, 321
consulting, 345
consumer goods, 11
consumers, 105
consumption, xiii, 163, 207
contamination, 175
content analysis, 196, 198
contextualization, 157
contingency, 10
continuing, 63, 166, 183, 319, 388
continuity, 274
control, xiv, 18, 40, 41, 46, 50, 111, 125, 127, 129, 148, 160, 164, 175, 176, 177, 178, 179, 180, 181, 183, 211, 227, 245, 246, 247, 248, 249, 250, 251, 252, 253, 254, 269, 316, 318, 320, 361
control group, 18, 111, 176, 177, 178, 179, 180, 211
controlled, 176, 205, 243
conversion, 378
conviction, 36
cooperative learning, 231, 255, 355
coordination, 45, 130, 374
coping strategies, 127
corporations, 226, 249
correlation(s), 15, 17, 35, 190, 214, 249, 250
corridors, 342

cortical, 44
Costa Rica, 226
cost-benefit analysis, 6
costs, 108, 134
counseling, 196
coupling, 328
course content, 13, 290, 298, 307
course work, ix, 89, 183
coverage, 191, 198
covering, 266
creationism, 4, 11, 22, 28, 29
creative thinking, 286, 299, 300, 309, 312, 321
creativity, ix, 56, 89, 95, 96, 125, 166, 167, 192, 210
credibility, xiv, 257, 303
credit, 8, 193, 219
crimes, 11
critical analysis, 20, 280
critical thinking, x, 2, 7, 10, 13, 27, 28, 155, 156, 158, 159, 160, 161, 163, 164, 166, 168, 226, 240
critical thinking skills, 240
criticism, 96, 117, 164
Croatia, 54
cross-talk, 236
crystal, 343
CSILE, 360
cues, 42, 43, 148, 195, 203
cultivation, 286, 309, 311, 316
cultural, viii, 31, 34, 36, 37, 103, 151, 152, 239, 247, 258, 259, 262
cultural psychology, 34
culture, 38, 50, 77, 78, 94, 143, 158, 165, 175, 205, 236, 252, 253, 254, 259, 286, 288, 300, 321, 353, 378
culture media, 175
curiosity, 95, 317
curriculum, ix, 2, 24, 27, 29, 33, 59, 62, 64, 72, 73, 75, 77, 86, 87, 89, 90, 94, 96, 97, 99, 103, 105, 150, 172, 190, 191, 204, 231, 235, 236, 252, 318, 319, 321, 356, 362, 380, 388
curriculum development, 318, 319, 380
customers, 381, 385
cybernetics, 227
cycles, 24, 59, 103, 216, 288, 313, 314
cynicism, 355

D

dailies, 128
Dallas, 353
danger, 373
data collection, 13, 46, 112, 312
data gathering, xiv, 257, 277
data mining, 328
data processing, 294, 297
database, 231, 319, 327, 383
dating, 270
decentralized, 130, 193
decision making, 19, 324
decision-making process, 307
decisions, 3, 5, 11, 235, 254, 285, 292, 302, 307, 355
decoupling, 18, 20
deductive reasoning, 139
defense, 234
deficiency, xiii, 229, 233
deficit, 353
definition, 17, 54, 193, 234, 286, 291, 292, 293, 308, 315, 316, 333, 341, 344, 345, 347, 364
deforestation, 163
degradation, 163
degree, ix, 12, 19, 47, 56, 58, 89, 90, 91, 148, 149, 150, 173, 175, 199, 217, 284, 362, 379, 382, 383, 384, 385
delivery, 108, 109, 158
Delphi study, 98
demand, 59, 64, 105, 119, 291, 303
density, 47, 380
Department of Education, 31, 101, 112, 245, 320
dependant, 334
dependent variable, 198
deposits, 10
desire, xiv, 15, 65, 145, 146, 232, 238, 245, 247, 251, 254, 298
desires, 146, 259
detachment, 355
detection, 195, 202, 233, 241
deterministic, 10
developed countries, 104, 378
developing countries, 103, 104
developmental process, xv, 37, 283
deviation, 21
diagnostic, 15, 44
dichotomy, 8, 12
didactic teaching, 230
differential diagnosis, 239
differentiation, 36, 62, 92, 164, 308, 364
diplomas, viii, 31, 32
direct observation, 133
disabled, 335, 345
discipline, x, 5, 66, 99, 133, 135, 139, 140, 144, 147, 149, 150, 151, 232, 233, 239, 286, 288
discourse, xi, xii, 135, 150, 151, 152, 153, 187, 188, 195, 196, 197, 198, 199, 202, 313, 360, 363, 364, 365, 374
discrimination, 36
disequilibrium, 140
disposition, 3, 19, 66, 267

dissatisfaction, 128
distance education, 45, 107, 109
distance learning, 108, 349
distortions, 94
distraction, 42, 43, 53
distribution, 10, 37, 108, 125, 163, 296
divergent thinking, 297, 299
diversity, 4, 17, 158, 164, 167, 230, 239, 373, 378
division, 108
DNA, 160
doctor, 20
dogs, 213
donor(s), 102, 103, 108, 129
doors, 343
dream, 129
drive theory, 42
drugs, 218
DSE (German Foundation for International Devlopment), 130, 131
dualism, vii, 2, 5, 7, 8, 13, 20
dualistic, vii, 1, 2, 3, 5, 6, 8, 17, 19, 23, 24
dung, 77, 78, 86
duration, ix, xii, 60, 75, 172, 188, 189, 190, 191, 192, 193, 194, 198, 199, 200, 201, 261, 339
dust, 351
duties, 115
dyeing, 78, 85, 88
dyes, 78
dynamic theory, 226

E

earth, 4, 10, 11, 13, 155, 157
ecological, 10, 86, 156
ecologists, 24
ecology, 23, 155, 160, 173, 388
economic, 5, 107, 163, 164, 165, 166, 352, 382, 386
economic growth, 386
economy, 379
Education for All, 102, 131
education reform, 77, 357
educational institutions, 388
educational practices, 33, 38, 39, 49, 50, 51
educational programs, 185
educational research, 288, 317
educational settings, 77, 189, 210
educational system, 36, 246
educators, xiii, xv, 22, 46, 151, 152, 191, 193, 216, 229, 231, 241, 249, 255, 278, 283, 286, 319
efficacy, 246, 248, 254, 297, 303, 315
ego, 47
Einstein, 19
elaboration, 42, 44, 48, 129, 360, 370, 376
e-learning, 34, 45, 46, 47, 48, 50, 51, 325, 328, 332, 348
electric charge, 99
electricity, 5, 62, 114, 225
electromagnetic waves, 214
electronic, 45, 231, 325, 327, 328, 331
elementary particle, 99
elementary school, 38, 66, 151, 176
elementary teachers, 55
emancipation, 94
emotional, 44, 143, 146, 158, 167, 250, 271, 279, 315, 316
emotional information, 44
emotional state, 315, 316
emotions, 54, 260, 271, 289
empathy, 159, 168, 313
employment, 102, 204, 205, 386
empowered, 247, 248
empowerment, xiv, 165, 169, 245, 247, 249, 251, 252, 253
encouragement, 14, 127, 299, 363
enculturation, 259
endocrinology, 15
energy, 6, 113
engagement, 27, 58, 67, 135, 231, 246, 247, 254, 277, 372, 386
engineering, viii, 2, 18, 22, 28, 29, 191, 200, 205, 388
England, 51, 56, 355, 357
English, xi, xii, 29, 56, 109, 127, 129, 187, 188, 192, 195, 203, 205
English as a second language, xi, xii, 187, 188
enterprise, 36, 93, 146
enthusiasm, 63, 103, 113, 272, 351
entrepreneurs, 378
entrepreneurship, 388
environment, xiii, xv, xvi, 6, 22, 34, 37, 39, 46, 47, 48, 78, 103, 118, 120, 126, 140, 144, 145, 160, 168, 183, 207, 210, 231, 239, 246, 247, 253, 254, 279, 285, 316, 323, 324, 334, 335, 338, 341, 346, 349, 359, 360, 362, 363, 364, 373, 378, 381
environmental, 5, 22, 78, 87, 156, 157, 163, 164, 165, 168
environmental degradation, 163
environmental stimuli, 78
environmentalists, 5
epistemological, vii, ix, 1, 2, 27, 89, 91, 92, 208
epistemological constructions, 91
epistemology, ix, 89, 90, 91, 321
equipment, 81, 107, 114, 116, 117, 126, 183, 335
equity, 153
ERIC, 153, 319, 357
essay question, 7, 9, 13

estimating, 126
ethical, 25, 28, 29, 239, 240, 335
ethnicity, 135, 239
Eurasia, 98
Europe, 169, 258
European, viii, 31, 33, 34, 46, 51, 52, 53, 54, 73, 279, 280, 349, 379
European Union (EU), 46, 53
evidence, xiii, 2, 3, 5, 10, 11, 13, 17, 19, 22, 28, 35, 40, 44, 49, 52, 54, 65, 69, 70, 78, 91, 99, 102, 103, 104, 126, 139, 140, 156, 158, 159, 167, 177, 208, 226, 231, 233, 234, 235, 236, 238, 239, 353, 354, 356, 357
evolution, vii, 1, 3, 4, 6, 7, 10, 11, 12, 13, 15, 16, 17, 18, 19, 20, 22, 27, 28, 29, 160, 205, 235, 246, 347
evolutionary, vii, 1, 3, 6, 7, 11, 13, 15, 17
evolutionary process, 13
examinations, xiii, 42, 124, 126, 128, 129, 229, 230, 233, 262
exchange rate, 165
execution, 46
executive processes, 292
exercise, x, 6, 24, 102, 119, 124, 125, 127, 158, 159, 183, 254, 267, 269, 285, 299, 300, 301, 302, 303, 304, 311, 313, 324, 328, 329, 337, 338, 343, 345
expenditures, 355
experimental condition, 219, 220
experimental design, x, 35, 83, 171, 175, 176
expert, 2, 5, 11, 20, 45, 67, 98, 191, 204, 285, 287, 311, 318, 362
expert teacher, 285, 311
expertise, xv, 39, 76, 152, 316, 317, 351, 352, 353, 356
experts, 55, 65, 106, 156, 211, 234, 288, 297
exploitation, 333
exponential, 24
exposure, 78, 128, 175, 249, 303, 316
externalization, 284
eye(s), 125, 134, 136, 195, 203, 237, 313
eye contact, 195, 203, 237

F

facilitators, 260, 263
factual knowledge, 61
failure, viii, 22, 31, 33, 36, 39, 40, 41, 53, 104, 128, 129, 233, 246, 247, 254, 269
fairness, 139
false, 7, 12, 96, 202, 267, 345
family, 78, 175, 237, 242, 352
family factors, 352
family medicine, 242
farm(s), 77, 86
fax, 377
fear, 95, 116, 160, 167, 266, 274
fears, 66, 183, 274
fecal, 86
feces, 77
fee, 36
feedback, xiii, xv, 14, 39, 40, 41, 49, 53, 59, 60, 64, 65, 67, 135, 150, 194, 196, 215, 216, 229, 230, 231, 232, 233, 234, 235, 236, 238, 240, 246, 247, 248, 250, 262, 288, 302, 313, 323, 324, 332, 344, 355, 363
feed-back, 33
feelings, 158, 247, 259, 268, 273, 290, 296, 300, 302, 312, 315
fees, 36
females, 44
fern, 77, 173
fertilization, 175
film(s), 26, 81, 161
filters, 109
financial support, 130
Finland, xiv, 73, 257, 258, 278, 279, 359, 374, 377, 378, 379, 385, 389
Finns, 280
first language, 196
fish, 267
flex, 82
flexibility, 235, 330, 337
float, 60
flood, 10
flora, 88
flow, 12, 109, 195, 202
fluctuations, 23
focus group(s), 64, 66, 119
focusing, 41, 47, 51, 113, 196, 200, 238, 299, 303, 355, 370, 379
food, 24, 78, 164, 218
forgetting, 158
formal education, 189
fossil, 5, 9, 10, 13
fossil fuel, 5
framing, 144
France, 51, 52, 323, 328, 330, 333, 347, 348
freedom, 225, 278
free-ride, 372
freezing, 174
frustration, 129, 172, 232
fulfillment, 311
functional analysis, 363
funding, xi, 107, 117, 188, 200, 378, 382
funds, 382
fungi, 87
furniture, xii, 207

futures, 169

G

games, 151, 271, 272, 341, 348
gametes, 175
gas, 114
gasoline, xiii, 207
gauge, 81
gender, 44, 54, 102, 108, 109, 125, 239
gender balance, 125
gender equality, 108
gene, 139
general education, 29
general knowledge, 291
generalizability, 143
generalization(s), 113, 139, 293, 304
generation, 5, 23, 129
generators, 3
genetic, 77, 178, 183
genetics, 12, 13, 173, 174, 239
genotype, 213
geography, 39
geology, 10
germination, 174, 175, 179, 180, 315
Gestalt psychology, 226
gift, viii, 26, 31, 37, 38
girls, 62, 116, 125
glass, 77
global networks, 320
goal attainment, 69
goals, xiv, 18, 42, 46, 67, 69, 70, 76, 86, 102, 135, 136, 148, 156, 216, 230, 233, 235, 238, 246, 247, 254, 257, 265, 267, 273, 290, 291, 296, 311, 317, 328, 330, 336, 346, 370, 373
God, 4
government, 5, 36, 56, 106, 114, 128, 129, 165, 166, 210, 379, 382
GPA, 6, 22
grades, vii, 1, 7, 8, 12, 17, 18, 112, 162, 175, 233, 268
grading, 8
graduate education, 160, 161
graduate students, x, xii, 171, 172, 188, 204
grain, 78, 158
grapes, 225
graph, 47, 48, 82, 327, 328, 331
grasses, 78
gravity, 60, 61, 157, 214
Greenland, 103, 104, 130, 131
group activities, 125
group work, 13, 57, 58, 103, 115, 116, 119, 125, 196, 361
grouping, xii, 120, 207, 213
groups, xvi, 2, 9, 13, 14, 39, 43, 44, 46, 47, 48, 51, 57, 60, 64, 82, 103, 118, 119, 125, 134, 140, 174, 175, 176, 177, 178, 179, 180, 183, 192, 230, 251, 272, 298, 307, 324, 325, 353, 359, 361, 362, 369, 371, 372, 373, 374, 376, 383, 384
growth, 23, 27, 28, 97, 107, 128, 153, 159, 163, 164, 175, 176, 177, 178, 179, 180, 239, 240, 285
growth rate, 24, 164, 175, 176
guidance, 33, 82, 104, 108, 119, 125, 175, 231, 246, 261, 262, 361, 373
guidelines, 85, 107, 151, 285, 301, 302, 309
guilt, 53

H

handling, 120, 195, 202, 260, 267
hands, 116, 119, 123, 125, 181
hanging, 281
happiness, 270
harmful, 9
Harvard, 130, 254, 280, 281, 320, 321, 357, 388, 389
Hawaii, 347
head, 107, 129, 176, 284, 322
health, 39, 70, 240, 242
health care professionals, 240
health care system, 240
health problems, 240
healthcare, 239
hearing, 237, 290, 294, 295
heart, 144, 338
heat, 214
Hebrew, 319
height, 136, 137, 139, 140, 147
herbivores, 24
heterogeneity, 332, 378
heterogeneous, 163, 334, 335, 338, 378
heuristic, 92, 95, 96, 98
high school, ix, 6, 38, 76, 87, 89, 90, 91, 191, 192, 214, 255, 287, 302, 352, 357
higher education, xv, xvi, 26, 28, 72, 73, 190, 191, 192, 200, 208, 225, 242, 284, 287, 321, 375, 377, 378, 379, 380, 381, 385, 386, 387, 388
higher quality, 102
high-level, 36, 308, 310, 313, 360, 361
hip(s), 247, 250
hiring, 387
Hiroshima, 101, 111, 130
HIV, 5, 19
Holland, 53
homeostasis, 225
homework, 39, 124, 269, 295, 296, 297
homosexuality, 5, 26

honesty, 239
Hong Kong, 72
horizon, 92
horse, 77, 264, 265
host, 352
household, 163
human(s), 13, 28, 29, 37, 43, 45, 46, 51, 173, 184, 189, 199, 200, 210, 240, 317, 320, 324
human activity, 46
human development, 51, 240
human interactions, 173
human subjects, 13
human values, 28
humanism, 240
humorous, 299
Hungary, 375
hypermedia, 347
hypothesis, 11, 16, 21, 38, 172, 176, 180, 181, 238, 249, 336
hypothetico-deductive, 6

I

ice, 267
ICT, viii, 32, 354, 358
idealization, 95, 98
identification, 111, 210, 211, 233, 240, 303
identity, x, 47, 50, 54, 133, 153, 161, 258, 259, 260, 263, 265, 268, 270, 271, 272, 273, 275, 276, 277, 281, 378
idiosyncratic, 66
Illinois, 78
illusion, 28
images, 258
imagination, 91, 168
immersion, 76
implementation, ix, xiii, xiv, xvi, 75, 103, 104, 106, 107, 108, 110, 112, 113, 172, 229, 230, 231, 236, 257, 260, 289, 293, 296, 308, 315, 316, 377
implicit knowledge, 259
IMS, 324, 332, 336, 348
in transition, 14, 240
inactive, 312, 368
incentive(s), 116, 128
incidence, 83
inclusion, 56, 77, 81, 94, 213, 215
income, 352
incompatibility, 38
independence, 107, 162
independent variable, 35, 38, 198
India, 194
Indian, xii, 152, 188
Indiana, 1, 54, 245
indication, 47, 61, 222, 252, 385
indicators, ix, xv, 47, 48, 101, 323, 324, 325, 327, 338, 339, 345, 346, 347
individual action, 46, 47, 48
individual characteristics, 33, 47
individual development, 35
individual differences, 246, 365
individual students, 81, 136, 143, 144, 145, 148, 151, 365, 372
individualism, 41, 51
individuality, 378
individualization, 147
Indonesia, 130
induction, 72
industrial, 225, 378
industrialized countries, 102
industry, 165, 216, 378, 379
inequity, 164
inert, 312
inferences, viii, 31, 33
informal groups, 354
information exchange, 45, 47
information system, 347
information technology, 352, 358, 374, 388
informed consent, 77, 172
infrastructure, 103
innovation, 72, 106, 131, 241, 259, 265, 268, 270, 276, 278, 351, 353, 354, 356, 357, 358, 377, 380
insects, 87
insight, 32, 166, 173, 232, 233, 262, 269, 285, 301, 304, 306, 311
inspectors, 107
institutions, xvi, 2, 3, 14, 39, 128, 165, 377, 378, 379, 380, 381, 382, 385, 386, 387
instruction, viii, x, xi, xii, xv, 3, 16, 23, 27, 29, 52, 72, 75, 76, 79, 88, 97, 105, 106, 146, 152, 171, 172, 183, 184, 187, 188, 189, 190, 191, 193, 194, 196, 197, 198, 199, 200, 260, 283, 284, 286, 287, 293, 311, 312, 317, 318, 320, 321, 322, 352, 379
instructional design, 54, 59, 320, 374
instructional materials, x, 101, 112, 120
instructional practice, 147, 284
instructional time, 183
instructors, xi, xii, 5, 25, 76, 159, 171, 172, 188, 196, 197
instruments, 12, 13, 16, 111, 112, 126
insulin, 216
integration, 15, 57, 58, 65, 66, 240, 317, 328, 388
integrity, 28
intellect, 254
intellectual development, vii, 1, 2, 3, 4, 6, 7, 11, 13, 15, 16, 17, 18, 19, 20, 22, 23, 24, 25, 26, 28, 29, 156

intellectual skills, 43
intelligence, viii, 31, 34, 37, 38, 39, 51, 53, 159, 167, 246, 255, 319
intensity, xi, xii, 82, 187, 188, 189, 190, 191, 192, 193, 194, 198, 201, 292
intentions, 332
interaction, ix, x, 24, 34, 35, 42, 43, 45, 46, 50, 54, 101, 105, 107, 110, 111, 112, 113, 118, 120, 125, 126, 127, 128, 152, 159, 198, 199, 213, 225, 258, 272, 273, 274, 321, 347, 360, 361, 371, 372, 373, 374, 375, 380
interaction effect, 198
interaction process, 128, 361
interactions, ix, 8, 14, 45, 46, 47, 49, 51, 53, 96, 101, 104, 105, 111, 118, 127, 128, 133, 238, 260, 272, 324, 334, 341, 361, 373, 380
interdependence, 216, 310, 314
interdisciplinary, xii, 163, 188, 347, 388
interface, 210, 327, 333, 338, 346
interference, 51, 192
internal processes, 378, 381, 382
internal value, 6
internalised, xiv, 257, 268, 270, 276
internalization, 51, 284, 307
international, xi, xii, 98, 102, 187, 188, 190, 194, 204, 205, 321, 352, 353, 357
international teaching assistants (ITAs), xii, 188, 189, 190, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205
internet, 65, 67, 210, 375, 376
internship, 22
interpersonal communication, 233
interpersonal interactions, 134
interpersonal processes, 35
interpersonal relations, 35
interpretation, 7, 15, 17, 27, 41, 42, 43, 98, 185, 284, 313, 329, 331, 333, 335, 348, 363, 387
interrelations, 258
interrelationships, 209, 216, 217, 218, 223, 312, 388
intervention, 19, 25, 107, 230, 233
interview, xiv, 25, 112, 168, 173, 175, 184, 211, 257, 258, 261, 269, 270, 272, 274, 277
interview methodology, 211
interviews, xiv, 65, 112, 173, 175, 181, 196, 197, 242, 257, 258, 261, 263, 303
intrinsic, 246, 247, 278
intrinsic motivation, 246, 247
intuition, 95
invasive, 24
inventiveness, 270
inventors, 146
invertebrates, 9
investment model, 29
irrigation, 165
Islam, 12
island, 24
isolation, 356
isopods, 78
Israel, 283, 287, 319, 322
Italy, 31, 347

J

JAMA, 241
January, 114, 169, 389
Japan, 101, 105, 130, 388
Japanese, 106, 130
JAVA, 335
Jerusalem, 283, 317, 319
Judaism, 4, 12
judge(s), 33, 40, 41, 49, 104, 143, 150
judgment, viii, 27, 31, 32, 33, 34, 35, 36, 38, 39, 40, 41, 42, 49, 53, 111, 355
junior high school, 38
justice, 54
justification, 36, 190

K

K-12, 226
Kentucky, 76
Kenya, 101, 105, 106, 107, 111, 119, 128, 130, 131
Keynes, 168, 321, 349
killing, 334
kindergarten, 44, 287, 302
knowledge acquisition, 46, 286, 291, 325, 389
knowledge construction, xvi, 57, 145, 284, 288, 311, 312, 359, 360, 361, 362, 363, 366, 368, 371, 372, 373, 374, 375, 376
knowledge transfer, 388
Korea, 194, 358
Korean, xii, 188

L

labeling, 36, 84
labor, 163, 379
lack of confidence, 129, 252
lakes, 10
land, 163
language, xi, xii, 32, 60, 119, 127, 129, 144, 151, 152, 153, 187, 188, 193, 194, 195, 196, 198, 200, 202, 203, 204, 214, 271, 300, 311, 312, 352, 363
language skills, 60
Lapland, xiv, 257, 261, 279

large-scale, 90
larval, 78
laughter, 176
law, 96, 214
laws, 91, 92, 97, 217
lawyers, 57
LDL, 336, 348
lead, 5, 36, 43, 57, 76, 79, 105, 109, 128, 129, 143, 151, 158, 163, 166, 177, 180, 217, 218, 254, 267, 293, 295, 302, 343
leadership, xiii, 184, 229, 381
learners, viii, xi, xv, 29, 32, 88, 98, 106, 124, 125, 126, 188, 231, 247, 254, 260, 263, 271, 276, 277, 278, 283, 285, 316, 319, 328, 349, 361, 362
learning activity, 34, 341, 342, 347
learning environment, xv, xvi, 19, 45, 46, 48, 50, 51, 153, 230, 246, 252, 253, 254, 259, 279, 286, 310, 313, 316, 323, 324, 340, 341, 346, 349, 359, 361, 362, 371, 372, 373, 374, 382
learning outcomes, 46, 102, 143, 230, 241, 278
learning process, xiv, xv, 37, 46, 102, 111, 112, 113, 118, 208, 211, 246, 247, 279, 283, 284, 285, 288, 293, 305, 307, 310, 311, 312, 314, 315, 317, 338, 341, 361
learning skills, 58
learning styles, 27, 304
learning task, 14, 25, 78, 316
legislation, 200, 380, 381
legislative, 46, 254
lesson plan, viii, 55, 56, 57, 58, 59, 60, 61, 64, 65, 66, 67, 114, 115, 116, 125, 191, 261, 265, 269, 270, 272, 362
lesson presentation, 106
liberal, 3, 4, 18
licensing, 352
life cycle, 59, 77, 78, 88, 174, 183, 184, 331
life experiences, 267
lifelong learning, 53, 73, 254
lifespan, 20
lifetime, 232, 316
likelihood, 217, 221, 356, 380
Likert scale, 13
limitation, 16
limitations, x, 133, 150, 222
Lincoln, 52, 254
linear, 15
linguistic, 153, 163, 363
linguistics, xii, 188
links, 64, 86, 192, 209, 210, 328, 329, 330, 341, 343, 344, 362, 364
listening, 15, 38, 119, 120, 126, 138, 144, 147, 149, 159, 164, 169, 193
literacy, 184, 355
literature, xii, 14, 18, 34, 36, 52, 57, 72, 76, 103, 104, 148, 156, 174, 188, 189, 192, 193, 199, 225, 230, 234, 238, 267, 273, 274, 277, 286, 287, 293, 300, 303, 306, 308, 312, 313, 315, 317, 351, 360
local authorities, 103
location, 157, 194, 293, 352, 379
locus, 246, 247
London, 51, 52, 53, 54, 72, 73, 88, 130, 131, 153, 184, 185, 225, 226, 278, 280, 281, 319, 321, 322, 388, 389
long period, 103, 301
longevity, 23
longitudinal study, 18, 24, 29, 152, 242, 281
long-term, ix, x, 57, 75, 85, 171, 200, 205, 355
long-term memory, 200
long-term retention, 57, 205
Los Angeles, 133
low-income, 102
low-level, 36, 345
lupus, 237

M

M and A, 153
machines, 330, 334
magnetism, 211, 225
mainstream, 14, 108, 110
maintenance, 63, 236
males, 44
mammal(s), 213, 218
management, 69, 102, 128, 129, 144, 147, 152, 216, 223, 292, 316, 322, 335, 381, 382, 387, 389
manipulation, 129, 221, 325, 326, 333, 360
mapping, 134, 136, 139, 140, 143, 145, 226
market, 379
Mars, 349
Massachusetts, 88, 155, 216, 388
Massachusetts Institute of Technology, 216
mastery, 6, 16, 18, 81, 146, 231, 234, 235
material resources, 37
mathematical, xiv, 24, 50, 78, 81, 119, 135, 183, 214, 223, 257, 259, 260, 261, 262, 263, 268, 269, 270, 274, 275, 276, 277, 280, 281
mathematical knowledge, 262, 274
mathematical thinking, 277, 281
mathematics, x, xiv, 39, 55, 73, 76, 101, 105, 106, 110, 111, 112, 116, 117, 118, 119, 120, 124, 126, 134, 135, 137, 141, 150, 152, 153, 214, 257, 258, 259, 260, 261, 262, 263, 264, 265, 266, 267, 268, 269, 270, 271, 272, 273, 274, 275, 276, 277, 278, 279, 280, 281, 321, 352, 353, 358
mathematics education, 153, 260, 261, 262, 263, 267, 268, 274, 276, 277, 278, 280, 321, 353

matrices, 250
matrix, 47, 48
meanings, 45, 217, 363
measurement, xii, 82, 84, 183, 188, 230, 381
measures, xiii, 6, 15, 16, 19, 47, 49, 190, 197, 200, 229, 230, 320, 381
mechanical, 65, 388
mechanics, 11, 27, 65
media, 111, 191
median, 35
medical school, xiii, xiv, 229, 231, 232, 233, 236, 241
medical student, 18, 29, 231, 232, 233, 241, 242
medications, 237
medicine, 12, 218, 230, 233, 235, 237, 240, 243
melanoma, 29
membership, 146, 213
memory, 38, 157, 189, 192, 260, 271, 319, 337, 360, 372
men, 92, 194
menstrual, 23
mental actions, 278
mental development, 127
mental image, 38
mental load, 52
mental processes, 316
mentor, 233
mentoring, xi, 171, 231
messages, 47, 105, 345, 346, 362, 363, 364, 365, 366
meta-analysis, 35, 73, 190, 352
metacognition, xv, 280, 283, 284, 286, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301, 303, 304, 306, 308, 309, 310, 311, 312, 313, 315, 316, 317, 318, 319, 320, 321, 340
metacognitive, xv, 283, 286, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 313, 314, 315, 316, 317, 322
metacognitive knowledge, 291, 293, 308, 322
metaphor(s), 11, 40, 49, 54, 158, 160, 161, 341
metric, 328
Mexico, 87
microscope, 77, 81, 82, 119, 183
mid-career, x, 155, 156, 158
middle class, 151, 164
migration, 175
militant, 168
Milky Way, 157
millet, 79, 81, 85
mining, 5, 328
Ministry of Education, 105, 107, 117, 128, 129, 130, 131, 379, 389
Minnesota, 27, 168
minorities, 44
minority, 37, 153, 320
misconception(s), 22, 56, 60, 70, 211, 223
misleading, 2
missions, 42
misunderstanding, 211
MIT, 88, 226, 227
mobility, 128
modalities, 38
modality, 338
modeling, 148, 165, 215, 352
models, xii, xiv, 23, 24, 38, 45, 51, 59, 77, 103, 115, 150, 161, 166, 188, 190, 236, 254, 262, 265, 278, 283, 284, 287, 357
modern society, 36
modules, 108, 109, 332
moisture, 77, 176
mold, 175
molecular biology, 12, 225
momentum, 134, 140, 356
money, 357
moral judgment, 41
morning, 302
mother tongue, 264
motion, xv, 4, 217, 221, 222, 283, 310, 311, 312, 313, 314, 315
motivation, xiv, 4, 40, 52, 54, 57, 58, 66, 109, 117, 125, 230, 245, 246, 248, 252, 254, 255, 266, 271, 315, 316, 318, 319, 355
motivation model, 248
motives, 314
movement, xiii, 3, 106, 142, 229, 252
multidisciplinary, xvi, 377, 378, 380, 382, 383, 384, 385, 386, 387, 388
multimedia, 153
multiple-choice questions, 338
multiplicity, vii, 2, 4, 8, 13, 18, 23, 24, 293
mushrooms, 78
musicians, 191
mutant, 175
mutual respect, 239, 306

N

Namibia, 131
naming, 125
narrative inquiry, 279
narratives, 115, 128, 261, 263
nation, 105
national, 5, 76, 88, 106, 107, 109, 113, 128, 153, 184, 252, 254, 354, 356, 357
National Academy of Sciences, 3, 28

National Research Council (NRC), 76, 77, 81, 88, 172, 183, 184
National Science Foundation, 280
national security, 5
NATO, 225
natural, xiii, xiv, 4, 15, 16, 17, 22, 37, 38, 78, 85, 160, 175, 176, 213, 215, 225, 229, 231, 236, 246, 268, 288, 298, 373
natural science, 288
natural sciences, 288
natural selection, 15, 16, 17, 160
Nebraska, 52, 193, 254
negative attitudes, 105, 117
negative consequences, 6, 52
negative emotions, 41
negative experiences, 273, 276
negative relation, 247, 250
neglect, 61, 67
negotiating, 162, 363
negotiation, 33, 45, 313, 324
nervous system, 23
Netherlands, 98, 347, 348, 349
network, 35, 45, 47, 48, 50, 210, 225, 383, 388
networking, 356
neural mechanisms, 52
New Frontier, 349
New Jersey, 255, 279, 281
New Mexico, 193
New Orleans, 254
New York, 26, 27, 28, 29, 50, 51, 52, 53, 54, 73, 87, 88, 98, 152, 153, 168, 169, 184, 225, 226, 227, 254, 278, 318, 319, 320, 321, 347, 374, 388
New Zealand, 73
Newton, xiii, 55, 207
NGOs, 129
Nigeria, 104
non-linear, 337
non-linearity, 337
nonparametric, 15
nonverbal, 240
normal, ix, 10, 15, 21, 89, 93, 94, 96, 200, 239
normal distribution, 21
norms, 33, 36, 39, 40, 42, 51, 259, 260, 279, 281
North America, 153, 165
North Carolina, 88
novelty, 67
nuclear power plant, 5
nucleotide sequence, 17

O

objective criteria, 50
objectivity, ix, 32, 89, 91, 92, 96
obligation, 372, 373
obligations, 239
observations, ix, x, 22, 32, 75, 83, 84, 89, 92, 96, 101, 112, 120, 124, 125, 126, 128, 129, 134, 140, 161, 196, 303, 333, 338, 345
Ohio, 204, 205, 229, 255
oil, 5, 92, 98, 99
Oklahoma, 320
old age, 11
old-fashioned, 268, 271
oncology, 29
online, xvi, 45, 46, 47, 48, 73, 279, 341, 356, 357, 359, 361, 371, 375
online interaction, xvi, 359, 361, 371
online learning, 357, 361
openness, 203, 273
operating system, 332
oral, 33, 42, 79, 81, 123, 129, 142, 234, 238
oral presentations, 81
orbit, 4, 157
orchestration, 136
organ, xii, 34, 207, 213, 237, 303
Organisation for Economic Co-operation and Development, 357, 358
organism, 13, 77, 78, 160, 173, 174, 175, 218
organization(s), xvi, 35, 38, 45, 46, 53, 54, 103, 152, 163, 209, 210, 213, 215, 216, 217, 223, 225, 226, 302, 324, 377, 378, 380, 381, 382, 383, 387, 388, 389
Organisation for European Community Development (OECD), 55, 73, 352
orientation, xiv, 143, 145, 146, 193, 200, 205, 246, 247, 257, 262, 370
originality, 34
overload, 338, 346, 349, 378
overtime, 307
ownership, 142, 146, 148, 149

P

Pacific, 73, 321
paints, 78
paper, xiii, xiv, xv, 23, 27, 29, 54, 77, 115, 119, 120, 131, 134, 150, 151, 176, 183, 189, 229, 231, 235, 254, 255, 257, 269, 279, 280, 289, 290, 298, 299, 301, 320, 323, 346, 347, 358, 375
paper money, 23
paradigm shift, 72, 236
paradox, 357
paramilitary, 164
parents, vii, 11, 39, 51, 107, 108, 129, 247, 352
Paris, 51, 52, 131, 315, 316, 320, 340, 349, 357
participant observation, 173

particles, 98
partnership, 231
passenger, 157
passive, 3, 20, 25, 122, 123, 129, 234, 367
pastoral, 111
pathophysiology, 240
pathways, 192
patient care, 239, 240
patient-centered, 238
patients, 20, 233, 237, 238, 239
pedagogical, vii, x, xiv, xv, xvi, 2, 18, 19, 25, 56, 57, 59, 60, 72, 104, 126, 133, 136, 150, 155, 156, 157, 160, 161, 164, 165, 166, 257, 258, 259, 261, 265, 277, 283, 284, 288, 300, 301, 309, 310, 311, 312, 313, 314, 315, 316, 323, 325, 328, 329, 330, 331, 332, 334, 335, 336, 337, 338, 339, 341, 342, 344, 345, 346, 347, 352, 353, 354, 356, 357, 359, 361, 362, 373, 375
pedagogies, 280
pedagogy, x, xvi, 56, 72, 103, 155, 156, 166, 279, 301, 320, 338, 359, 361
pediatric, 242
peer, ix, 45, 83, 89, 91, 93, 115, 116, 205, 230, 235, 241, 269, 289, 306, 375
peer group, 269, 375
peer review, ix, 89, 91, 93, 235
peers, 36, 85, 143, 144, 146, 183, 231, 236, 246, 247, 253, 260, 277, 317
Pennsylvania, 357
percentile, 352
perception, xi, 34, 53, 54, 66, 188, 284, 286, 294, 298, 315, 316, 344
perceptions, ix, 66, 67, 72, 101, 110, 111, 112, 113, 114, 119, 226, 246, 248, 259, 276, 318
performance, viii, xii, xiii, xiv, 6, 20, 25, 28, 31, 32, 33, 34, 35, 36, 37, 39, 40, 41, 42, 43, 44, 45, 47, 48, 49, 50, 51, 52, 54, 66, 88, 105, 115, 116, 118, 176, 183, 185, 188, 191, 194, 195, 196, 197, 199, 200, 203, 204, 205, 211, 214, 216, 225, 227, 229, 230, 231, 232, 233, 234, 236, 240, 241, 246, 255, 269, 271, 297, 324, 355, 356, 381, 382
peri-urban, 111
perseverance, 156
personal, xv, 3, 5, 7, 13, 14, 15, 16, 19, 27, 28, 35, 57, 59, 64, 84, 124, 128, 129, 134, 146, 148, 156, 158, 166, 167, 225, 239, 240, 242, 246, 254, 279, 283, 284, 285, 286, 288, 289, 290, 291, 294, 296, 300, 301, 302, 303, 307, 308, 309, 310, 311, 312, 313, 314, 315, 316, 317, 341, 343, 362
personal communication, 13
personal learning, 284, 288, 314, 316, 317
personal values, 239
personality, 2, 33, 39, 53, 119, 226, 254
personality traits, 33
persuasion, 35
pH, 175, 180, 183
phenotype, 213
Philadelphia, 254, 357
Philippines, 111, 130
philosophers, 92, 96
philosophical, xiii, 158, 229
philosophy, vii, ix, 2, 14, 89, 90, 91, 92, 93, 94, 95, 97, 98, 99, 161, 172, 225, 381
Phoenix, 319
photographs, 78, 82, 84
phronesis, 317, 318
phylum, 78
physical diagnosis, 237
physical environment, 42, 126
physical sciences, xiii, 90, 207
physicians, 236
physics, xii, 27, 29, 94, 99, 111, 115, 119, 153, 173, 188, 191, 200, 205, 213, 214, 217
physiological, 44
physiological arousal, 44
physiology, 23, 237
Piagetian, 6, 27, 34
pilot studies, 18, 222
pilot study, 7, 14, 17, 18
PISA, 258
pitch, 195
planning, 56, 59, 63, 64, 65, 66, 67, 81, 102, 106, 135, 140, 147, 149, 165, 166, 240, 261, 265, 277, 287, 292, 293, 294, 297, 301, 315, 381, 388
plants, 13, 24, 77, 78, 173, 175, 176, 177, 178, 179, 180, 183, 218, 219, 220, 221
plasmid, 26
plastic, 77, 125
platforms, 46, 324, 328, 335, 336
play, viii, ix, 5, 25, 31, 32, 33, 40, 45, 49, 89, 90, 96, 140, 150, 163, 166, 212, 259, 343, 351, 374
polarization, 26, 28
policymakers, 102, 357
political, 25, 163, 164
politicians, 387
politics, 5, 168
pollutant, 5
pollution, 5
polygons, 269
polytechnics, 379, 388
poor, 37, 39, 105, 107, 114, 117, 128, 129, 164, 183, 262, 266, 271, 274, 345
poor performance, 39, 105
population, 13, 23, 76, 163
population growth, 24, 163
population size, 23, 163

portfolio, xiii, xiv, 229, 230, 231, 232, 233, 234, 235, 236, 241, 242, 243, 267, 270, 271, 272, 274, 277
portfolio assessment, 234, 235, 242
portfolios, xiv, 231, 232, 233, 234, 235, 236, 241, 242, 243, 257, 258, 261, 263
Portugal, 279, 348
positive attitudes, 353
positive correlation, 17, 249
positive feedback, 265
positive relationship, vii, 1, 18, 247, 248, 252, 254
positivist, 94, 176
post-Cold War, 165
power, ix, xv, 5, 11, 89, 91, 127, 160, 162, 163, 166, 167, 247, 252, 283, 308, 315, 317
power generation, 5
practical activity, 61, 107
practical knowledge, 258, 310, 317
pragmatic, 67, 99, 199, 200, 325
preclinical, 233
predators, 24
prediction, 16, 33
predictors, 233
pre-existing, 35, 339
preference, 3, 19, 20, 79
premium, 150
preparation, xii, 7, 13, 67, 95, 106, 124, 129, 183, 188, 190, 191, 194, 200, 232, 304, 314, 355
preservice teachers, x, 88, 171, 173, 185, 258, 279, 281
pressure, xiii, 163, 229, 315, 387
prestige, 36
prevention, 239
primacy, 38
primary school, xiv, 44, 72, 102, 108, 111, 112, 113, 114, 117, 118, 119, 120, 127, 257, 375
printing, 78, 168
prior knowledge, 27, 211, 226, 287, 306, 307, 310, 311, 312, 313, 315, 317, 372
priorities, 239
private, 52, 149, 174, 196, 303, 344, 346, 379
probability, 214
probe, 124, 335, 345
problem-based learning (PBL), 57, 58, 64, 66, 67, 72, 73, 259, 260, 261, 262, 263, 264, 265, 266, 267, 268, 269, 270, 272, 273, 277
problem-solver, 277
problem-solving, xiv, xvi, 2, 35, 45, 57, 99, 111, 126, 140, 257, 262, 280, 286, 315, 316, 319, 359, 372, 373, 374
problem-solving task, 372
procedures, 10, 26, 111, 239, 240
producers, 378
production, viii, 6, 31, 32, 33, 34, 42, 50, 76, 149, 163, 377, 378, 388
profession, 2, 22, 102, 357
professional development, ix, xv, 22, 27, 29, 75, 109, 152, 190, 241, 242, 273, 280, 283, 352, 354, 355, 357, 358
professionalism, 109, 230, 232, 233
professions, 242
profit, 277
prognosis, 20
program, ix, x, xi, xii, xiii, 18, 34, 72, 75, 95, 155, 156, 160, 161, 187, 188, 191, 193, 194, 200, 204, 205, 229, 230, 231, 232, 233, 234, 236, 286, 287, 296, 308, 310, 317, 322, 355, 358, 382, 383, 385
programming, 46
progressive, ix, 11, 62, 65, 89, 91, 92, 96, 98, 231, 232, 233, 235, 343
promote, xvi, 11, 12, 20, 22, 26, 50, 76, 104, 106, 190, 200, 239, 252, 254, 320, 377, 380, 382, 385, 386, 387, 388
promote innovation, 386, 387
pronunciation, xi, xii, 187, 188
propagation, 214, 217, 222
property, 66, 139, 213, 216, 217
proposition, xii, 4, 53, 164, 207, 209, 212, 222
protocol, 173, 307
protocols, 288, 310, 312
prototype, 33, 219, 220
proximal, 145
proxy, 378
psychiatry, 235
psychoanalysis, 37
psychological, xii, 188, 190, 201, 246, 255, 278, 321
psychological processes, 321
psychologist, 291
psychology, viii, xii, 6, 31, 33, 50, 51, 53, 188, 189, 192, 200, 204, 216, 225, 278, 318
psychosocial, 51, 240
public, 3, 5, 11, 76, 96, 107, 111, 141, 148, 173, 357, 360, 372, 376, 385, 386
public education, 357
public policy, 376
public schools, 107
public sector, 385, 386
pulse, 237
pupae, 78
pupil, ix, 32, 35, 39, 41, 43, 50, 53, 101, 104, 105, 107, 111, 112, 115, 116, 118, 120, 123, 124, 126, 127, 259, 261, 262, 264, 266, 267, 268, 270, 272, 274, 276, 278, 352
pupil achievement, 104
pupils, viii, x, xiv, 31, 32, 33, 35, 36, 37, 38, 39, 40, 41, 42, 44, 49, 50, 53, 54, 70, 101, 105, 107, 108,

111, 112, 114, 115, 116, 117, 118, 119, 120, 122, 123, 124, 126, 127, 128, 129, 257, 258, 261, 262, 264, 265, 266, 267, 269, 270, 271, 272, 273, 274, 276, 277, 278, 362

Q

qualitative evaluation, 185
qualitative research, ix, 75, 173, 185, 300, 313, 321
quality assurance, 108
quality control, 378
quality improvement, 240
quantitative research, 316
quantitative technique, 46
quantum, 98
quark(s), 94, 95
questioning, 25, 114, 115, 138, 156, 181, 273, 292, 293
questionnaire(s), xiv, 35, 38, 41, 42, 98, 245, 249, 250, 288, 303, 313
quizzes, 13

R

race, 135, 352
radical, 158, 168, 252
rain, 175
random, 24, 64, 125, 127
range, viii, 9, 12, 17, 18, 23, 45, 55, 58, 62, 102, 107, 113, 126, 134, 136, 137, 141, 142, 143, 145, 147, 148, 163, 165, 216, 230, 238, 240, 309, 314, 316
ratings, 13, 22, 195, 198, 199
rational reconstruction, 98
raw materials, 4
reading, 13, 113, 157, 216, 261, 269, 273, 291, 292, 293, 362
real time, 333
reality, 22, 36, 51, 115, 128, 176, 189, 252, 375
reasoning, 5, 6, 9, 17, 19, 26, 27, 58, 72, 78, 95, 118, 139, 147, 148, 149, 152, 156, 158, 214, 264, 360, 363, 364, 365, 366, 367, 368, 370
recall, x, 59, 61, 97, 101, 123, 125, 126, 129, 148, 190, 211, 226
reciprocity, 48
recognition, 17, 92, 95, 117, 124, 128, 191, 233, 236
reconstruction, 95, 168, 258, 300
recreation, 341
recycling, 195, 203
Red Cross, 35
reduction, 108
refining, 161
reflection, 20, 67, 105, 115, 135, 136, 143, 233, 234, 242, 252, 260, 270, 272, 298, 300, 304, 306, 308, 314, 315, 316, 320, 360, 372
reflective practice, x, 155, 156, 166, 231, 232, 233
reflexivity, 340
reforms, 153
refractory, 93
regional, 165, 249, 377, 378, 379, 380, 381, 382, 383, 386, 388
regression, 20
regular, 65, 97, 114, 115, 117, 189, 192, 193
regulation, xv, 23, 225, 291, 292, 293, 308, 316, 323, 324, 325, 335, 338, 339, 340, 344, 345, 346, 347
rehearsing, 156, 157
reinforcement, 125, 127, 230
rejection, xiv, 13, 20, 127, 245, 247, 249, 253
relationship, xii, 4, 6, 8, 16, 19, 20, 23, 32, 37, 97, 205, 207, 212, 213, 214, 215, 222, 247, 258, 260, 276, 285, 310, 355, 378
relationships, vii, xii, xiii, 1, 44, 50, 86, 153, 162, 163, 166, 167, 207, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223, 247, 248, 249, 250, 251, 252, 255, 280, 313, 354, 388
relevance, 59, 64, 65, 69, 70, 108
reliability, 197, 211, 235, 241, 249
reliability values, 249
religion, 3, 26, 30, 135
religious, 3, 11, 12, 13, 25
religious beliefs, 4
religious groups, 11
remediation, 232, 236
remodeling, 158
repair, 195, 202
repetitions, xi, xii, 187, 188, 190
replication, 179
reproduction, 23, 24
reputation, 36
research and development (R&D), xvi, 204, 205, 321, 377, 378, 379, 380, 382, 383, 384, 385, 386, 387
research design, 111, 113, 175
researchers, 5, 22, 41, 97, 102, 104, 111, 112, 120, 136, 166, 167, 173, 174, 211, 216, 253, 287, 291, 293, 304, 314, 315, 318, 352, 353, 378
reservoir, 316
resistance, 150, 172
resource availability, 24
resources, xvi, 8, 24, 42, 43, 46, 50, 57, 58, 60, 61, 67, 106, 108, 111, 114, 115, 116, 163, 239, 240, 292, 336, 339, 340, 343, 345, 346, 357, 359, 363, 364, 365, 366, 367, 368, 369, 370, 371, 372, 373, 382
respiration, 211, 227

responsibilities, 26, 40, 73, 125, 204, 205, 232, 239, 355, 382
responsibility for learning, 161, 236
restaurant, 194
restructuring, 271
retention, 108, 192, 204, 205, 230
retired, 23
returns, 183
reusability, 54
revenue, 382, 386, 387
rhetoric, 90, 103, 274, 278, 279
rigidity, 92
risk, viii, 12, 55, 58, 156, 158, 166, 167
risks, 4, 12, 159, 161, 316, 374
room temperature, 216
rotations, xiii, 229, 232, 233
rote learning, 126, 127, 128, 129, 208, 270
routines, 123
rubrics, 78, 88
rural, 111, 157
Rutherford, 95
rye, 173

S

safety, 5, 70, 240, 278
salaries, 352
salt, 165, 175, 178
sample, xi, 38, 41, 111, 112, 113, 159, 175, 176, 179, 187, 231, 249, 354, 357
sampling, 111
sanctions, 36
SAT scores, 22
satisfaction, 57, 63, 258, 273, 316
scaffold, 140, 142, 147, 361
scaffolding, 9, 145, 147
scaffolds, 360
scheduling, 58
scholarship, 76, 318
school activities, 33, 40, 50
school culture, 247, 252, 259
school failure, 37, 39, 40, 41, 53
school learning, 355
school management, 57
school performance, 32, 36, 39, 43, 52
schooling, 105, 147, 152, 153
science department, 23
science education, ix, 3, 56, 75, 76, 78, 85, 87, 88, 89, 90, 93, 94, 97, 98, 106, 150, 171, 172, 175, 184
science educators, xi, 99, 171
science literacy, 87, 183
science teaching, x, 59, 61, 63, 99, 106, 171
scientific, ix, x, 3, 4, 7, 10, 11, 13, 15, 17, 22, 38, 51, 52, 56, 75, 76, 77, 78, 81, 85, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 99, 118, 119, 163, 165, 171, 172, 174, 176, 181, 183, 185, 211, 238, 284, 288, 291, 378, 379, 388
scientific community, 3, 93, 95, 96, 172
scientific knowledge, 7, 17, 56, 95, 118, 284, 388
scientific method, ix, 81, 89, 91, 92, 94, 96, 176, 181, 183, 238
scientific progress, 96
scientists, ix, 3, 11, 22, 79, 82, 89, 90, 93, 95, 163, 172, 176, 183
scores, xi, 7, 8, 9, 13, 16, 17, 18, 33, 35, 58, 64, 187, 199, 219, 220, 233, 352
scripts, 361, 373, 374, 375, 376
search, 28, 50, 94, 99, 208, 234, 254, 264, 272, 291, 307, 311, 318, 324
searches, 324
searching, 270, 284, 296, 297, 299, 303, 305, 327, 336
second language, xi, xii, 123, 129, 187, 188, 192, 200
secondary education, 114
secondary school students, 118, 258, 319
secondary schools, 111, 113, 114, 119, 120
secondary students, 29
secondary teachers, xiv, 245, 249
secret, 138
sediments, 10
seeding, 140
seedlings, 175
seeds, 78, 79, 81, 175
selecting, 59, 60, 197
self, 234, 235, 242, 246, 254, 283, 287, 315, 316, 318, 319
self-assessment, 230, 232, 234, 242, 246, 261, 265
self-awareness, 159, 231, 285
self-care, 240
self-concept, 278
self-confidence, 260, 269
self-discrepancy, 279, 281
self-efficacy, 246, 247, 254, 255, 302
self-esteem, 246, 318
self-reflection, 109, 233, 236
self-regulation, 246, 318
self-report, 22, 242
self-study, xv, 56, 58, 107, 208, 283, 287, 317, 320, 354
self-worth, 247, 248, 254
semantic, 331, 333
Senegal, 102, 131
sensitivity, 239
sentences, 84, 124, 127, 195, 201, 202, 203, 265, 296

separation, 129
sequencing, 60, 336, 337, 342
series, 11, 12, 24, 41, 45, 57, 66, 96, 124, 125, 138, 163, 192, 193, 223, 246
service provider, 130
services, 114, 333, 382
sex, 44
sexual reproduction, 81
shame, 41
shape, 51, 60, 102, 137, 165, 213, 269, 294, 295, 296, 298
shaping, 165, 166
shares, 36, 384
sharing, xvi, 3, 46, 113, 134, 138, 141, 142, 144, 145, 146, 359, 366, 367, 368, 369, 371, 372, 389
shocks, 36
short run, 386
short term memory, 192
short-term, ix, 7, 75, 205
shoulder, 181
sign(s), 232, 237
signals, 147, 183, 338
significance level, 208
silver, 318
similarity, 213
simulation, xi, 23, 187, 195
simulations, 195
Singapore, 73
sites, 10, 235
skeleton, 268
skill acquisition, 235
skills, viii, x, xi, xv, 20, 22, 39, 44, 55, 56, 57, 58, 59, 60, 64, 65, 66, 67, 76, 78, 81, 86, 103, 108, 109, 111, 124, 126, 128, 129, 156, 165, 171, 172, 183, 187, 191, 192, 193, 195, 196, 200, 203, 230, 232, 233, 234, 235, 237, 238, 242, 265, 271, 283, 286, 289, 290, 296, 308, 317, 320, 322, 353, 375, 380
sociability, 375
social, viii, ix, 2, 10, 28, 31, 33, 34, 35, 36, 37, 38, 39, 40, 42, 43, 44, 45, 46, 48, 50, 51, 52, 53, 54, 78, 83, 88, 89, 91, 127, 144, 155, 160, 164, 165, 168, 215, 216, 226, 237, 240, 246, 250, 252, 254, 260, 278, 281, 285, 313, 341, 356, 363, 366, 368, 370, 372, 375, 376, 378, 380, 381, 386, 387
social behavior, 33
social capital, 380, 381
social categorization, 34
social change, 53, 285
social cognition, 34, 51
social cohesion, 356
social comparison, viii, 31, 36, 39, 43, 52, 53
social comparison theory, 43
social construct, 36, 51, 88
social context, viii, 10, 31, 155, 160, 260, 281, 378
social environment, 34
social group, 43
social identity, 44
social network, 380, 381, 386
social norms, viii, 31, 33, 42, 50, 51, 52, 53
social order, 36
social organization, 144
social presence, 375
social psychology, 34, 42, 50, 52, 53, 216, 226
social regulation, 53
social relationships, 246, 252
social roles, 48
social rules, 42
Social Services, 380
social standing, 144
social status, 45
social structure, 52
social support, 45, 366
social systems, 215
socialization, 36, 42, 54, 258, 279
socially, 144, 152, 368, 370, 376, 378, 386
society, vii, x, 6, 36, 39, 41, 50, 94, 155, 156, 163, 232, 321
sociocultural, 45, 153
socioeconomic, 40, 239
socioeconomic status, 40
sociological, 35, 164
sociologists, 163
sodium, 175
software, 210, 211, 329, 332, 334, 335
soil, 163, 176, 217
soil erosion, 163
solar, 156, 157
solar system, 156, 157
solutions, 14, 24, 58, 63, 64, 65, 115, 134, 137, 138, 139, 140, 141, 143, 144, 146, 148, 164, 175, 183, 265, 267, 272, 273, 307, 324, 334, 351
sounds, 191
South Africa, 103, 130
South Korea, 358
Soviet Union, 278
space shuttle, 157
space-time, 158
Spain, 225, 226, 227
spatial, 163, 268, 333
special education, 108
specialists, 164, 190
specialization, 287
specialized cells, 216
species, 11, 24, 77, 78
specific knowledge, 208

specificity, 319
speculation, 91, 95, 96
speech, 195, 202, 203, 374
speed, 150, 157, 214, 216, 292, 341
spore, 78, 174
sports, 11
SPSS, 73
SQL, 327
SQUID, 325, 327
staff development, 103
stages, vii, xv, 2, 6, 20, 58, 106, 246, 284, 287, 288, 295, 296, 297, 298, 299, 300, 304, 308, 311, 312, 314, 315
stakeholders, 107, 108, 109, 113, 381
standard deviation, 219, 220, 250
standardization, 252
standardized testing, 230
standards, ix, 7, 42, 75, 76, 77, 78, 79, 85, 86, 88, 98, 111, 156, 159, 162, 166, 167, 172, 184, 195, 230, 231, 232, 233, 234, 236, 238, 252, 279, 357
Staphylococcus, 26
stars, 4, 10
statistics, 6, 27, 197, 198, 199, 200, 327
steady state, 216
stereotype, 44, 51, 54
stereotypes, 44, 54
stigmatized, 44
stimulant, 295
stimulus, 39, 85
storage, 210, 327, 333
strains, 77
strategic, xiv, xvi, 53, 147, 257, 311, 377, 380, 381, 384, 388
strategic management, 381
strategic planning, 380, 381
strategies, ix, x, xiii, 13, 19, 22, 23, 24, 25, 28, 29, 79, 89, 90, 91, 95, 98, 103, 104, 108, 129, 133, 134, 138, 139, 141, 142, 144, 147, 148, 150, 195, 196, 202, 203, 208, 215, 216, 219, 221, 222, 223, 239, 246, 291, 292, 293, 303, 311, 312, 315, 316, 319, 351, 352, 353, 354, 355, 388
strength, 7, 14, 16, 18, 19, 44, 157, 231, 236, 284, 293, 298
Strengthening of Mathematics and Sciences in Secondary Education (SMASSE), ix, 101, 105, 106, 107, 110, 111, 112, 113, 114, 115, 117, 118, 119, 120, 121, 122, 123, 126, 128, 129
stress, ix, xi, xii, 20, 75, 187, 188, 195, 196, 197, 198, 199, 201, 266
stretching, 61
strokes, 151
structural characteristics, 47
structuring, xvi, 22, 331, 334, 359, 361, 373, 375
student achievement, xiii, xv, 189, 229, 246, 250, 255, 351, 352, 353, 354, 355, 356, 357
student behavior, 252
student development, 24, 134
student group, xvi, 192, 359, 361, 371
student motivation, 245, 246, 247, 252, 255
student teacher, xiv, 56, 57, 59, 66, 225, 257, 258, 260, 261, 263, 270, 275, 277, 278, 280, 285
subgroups, 47
subjective, 32, 38, 259
submarines, 6
Sub-Saharan Africa, 102, 131
subtraction, 152, 268, 294
success rate, 345
suffering, 36
sugar, 216
suicidal, 129
sulfuric acid, 175
summaries, 23, 174
summer, xi, xii, 22, 187, 188, 189, 197, 203
sunflower, 173
superiority, 157
supervision, 261, 274, 382, 384
supervisor, 261
supervisors, 72, 115, 287
supplemental, 20
suppliers, 77
supply, 24, 45, 102, 108, 163, 325
support staff, 254
suppression, 28
surgery, 235, 242
surgical, 237
surprise, 129, 297, 304
survival, 129
susceptibility, 50, 54, 158
sustainability, 357
switching, 328
symbols, 262, 281, 299
synchronous, 360, 371, 372, 375
syntactic, 288, 333
synthesis, 4, 158, 159, 189, 240
synthetic, 338
systematic, 37, 73, 104, 113, 160, 184, 231, 237
systematic review, 73
systems, 5, 23, 24, 33, 34, 36, 39, 45, 102, 108, 215, 216, 217, 225, 227, 234, 236, 237, 246, 333, 334, 348, 361

T

Taiwan, 348
talent, 191
tangible, 381

targets, 43, 102, 195
task difficulty, 39
task force, 246
taste, 181
taxonomy, 54, 58, 72, 168
teacher performance, 103, 104
teacher preparation, 73
teacher relationships, 247, 248
teacher support, 148, 354
teacher thinking, 279
teacher training, viii, 55, 56, 57, 66, 72, 102, 193, 266
teaching experience, xiv, 245, 248, 249, 260, 261, 262, 264, 265, 273, 274, 277, 353, 362, 372
teaching process, 317
teaching strategies, 95
teaching/learning activities, 122
teaching/learning process, 126
team leaders, 388
technological, 360, 361, 378
technology, xvi, 46, 95, 208, 225, 226, 227, 264, 351, 352, 353, 354, 355, 356, 357, 359, 360, 361, 373, 378, 379, 389
telephone, 328
temperature, 216
temporal, 163, 333, 343
tenants, 40
Tennessee, 75, 76, 88, 171, 184, 352, 358
tension, 38, 161, 162, 163, 164, 166, 167, 268
territory, 8
test data, 27
test scores, 235
Texas, 26, 187, 201, 205, 352
textbooks, ix, 59, 89, 90, 92, 94, 96, 98, 99, 107, 108, 114, 119, 120, 124, 137, 211
Thailand, 104
theoretical, viii, xii, xiii, xvi, 3, 14, 31, 33, 34, 35, 36, 37, 39, 40, 41, 45, 51, 53, 90, 103, 104, 151, 152, 157, 185, 188, 197, 199, 208, 227, 249, 258, 259, 262, 269, 277, 278, 284, 286, 288, 289, 291, 297, 298, 304, 306, 310, 312, 313, 317, 359, 362, 364, 365, 366, 370, 371, 372, 373
theory, vii, ix, 2, 19, 23, 30, 34, 37, 38, 41, 42, 43, 48, 50, 52, 53, 54, 56, 57, 60, 72, 89, 90, 91, 92, 124, 153, 156, 204, 208, 259, 274, 277, 278, 279, 280, 281, 284, 286, 287, 318, 319, 320, 321, 347, 378
third party, 234
Third World, 104, 105, 130
threat, 43, 44, 51, 52, 54
threatening, 43, 52
three-dimensional, 115
threshold, 230
Ti, 195, 196
time constraints, 179
time frame, xii, 188, 194
time use, 113, 121
timing, 65
title, 299, 314
tolerance, 175, 178
topographic, 147
topology, 342
torture, 36
tracking, xiii, xiv, xv, 46, 47, 48, 50, 211, 229, 231, 283
trade, 5, 77
tradition, 34
trainees, 103, 234, 260, 262, 263, 272
training, viii, xiii, xiv, 45, 46, 55, 56, 57, 58, 61, 66, 102, 103, 104, 106, 107, 108, 109, 115, 116, 117, 125, 126, 128, 129, 165, 166, 195, 196, 200, 204, 205, 229, 230, 231, 232, 233, 234, 236, 241, 242, 261, 324, 382
training programs, 205
traits, 20, 160, 291
trajectory, 147
transcript(s), 61, 173, 236
transfer, 14, 126, 215, 278, 286, 334, 340
transformation(s), 83, 85, 88, 297, 325, 327, 331, 332, 333
transition, xiii, xiv, 44, 92, 195, 202, 229, 231, 232, 236, 237, 284
transitions, ix, 89, 96, 98
translation, 291
transmission, 45, 47, 57, 126, 128, 150
transparency, 269
transport, 379
travel, 157, 214
travel time, 214
trees, 209, 216, 217
trend, 107
trial, 3, 38, 379
triangulation, 173, 288, 376
tribes, 378
triggers, 221
truism, 5
trust, 39, 239, 313, 356
tuition, 115
turbulent, 378
Turkey, 194
Turku University, xvi, 377, 378, 389
tutoring, 109
two-dimensional, 209

U

uncertainty, 7, 161, 265, 316, 378
undergraduate, x, xii, xiii, 3, 22, 23, 27, 73, 155, 156, 181, 188, 189, 195, 200, 204, 229, 230, 231, 232, 235, 242, 243, 252
undergraduate education, 22
undergraduates, 3, 6, 29, 160, 242
unemployment, 165
UNESCO, 102, 131, 349
unfolded, 270
uniform, 164, 327
United Kingdom (UK), 53, 55, 56, 97, 184, 185, 319, 349
United States, 3, 5, 12, 76, 173
universality, 378
universe, 38, 156
universities, 378, 379, 380, 381, 388
university students, 30, 48, 248
upward comparisons, 52
urban, 6, 114, 249
urban areas, 6
urea, 175
users, xv, 66, 210, 323, 325, 327, 328, 329, 330, 333, 343, 344
Utah, 5, 204
UV light, 176

V

validation, ix, 89, 91, 248, 255, 329
validity, 3, 27, 151, 173, 211, 226, 235, 242, 250, 303
values, 15, 20, 33, 36, 39, 40, 41, 42, 128, 147, 150, 153, 214, 219, 220, 259
vancomycin, 23, 26
variability, 217
variable, viii, 11, 31, 38, 179, 189, 198, 199, 280, 293
variables, viii, 15, 24, 31, 33, 35, 36, 189, 197, 198, 214, 249, 291
variance, 6, 198, 352
variation, 23, 33, 35, 124, 172, 183, 190, 191, 192, 217
variety of domains, 211
vascular, 88, 238
vein, 14, 35, 328
Venezuela, 89
venue, 163
vessels, 128
veteran teachers, 248
victimization, 36
video, 196, 338, 343
videotape, 79
Virginia, 76, 184
virtual world, 341
visible, 77, 143, 360
vision, 90
visual, 195, 196, 203
visualization, 347, 375
vocabulary, 158, 189, 204, 300
vocational, 33, 46, 48, 379
vocational education, 379
vocational schools, 379
vocational training, 48
voice, 26, 156, 159, 203

W

Washington, 8, 26, 28, 88, 152, 184, 205, 255, 321, 358, 376
waste, 5, 268
watches, 173
water, 114, 165, 179
weakness, 107, 231, 232, 233, 235, 236, 293
wear, 290, 307
web, viii, xvi, 32, 45, 46, 47, 48, 50, 78, 157, 325, 328, 343, 347, 349, 359, 361, 362, 363, 364, 365, 371, 372, 373, 374, 376
web pages, 46
web sites, 328, 347
web-based, xvi, 157, 349, 359, 361, 362, 363, 364, 365, 371, 372, 373, 374
welfare, 386
Western culture, 40, 41
Western societies, 41
wheat, 173
wholesale, 271
wind, 150
windows, 113, 344
wine, 225
winter, 268
Wisconsin, 28
wisdom, 97, 311
witness, 157
women, 44, 51, 52, 54, 194
work ethic, 40
workers, 35, 239, 349
working conditions, 117
working memory, 44, 51, 54
workload, 373
workplace, 57
workspace, 347
workstation, 334
World Bank, 131

World War, 23
World Wide Web, 347
worldview, 4, 25
worry, 265
writing, 2, 26, 114, 124, 129, 157, 158, 161, 166, 183, 196, 231, 289, 302, 304, 370, 371, 372
writing process, 304
Wyoming, 193

Y

yield, 85, 156, 158, 167, 176, 190

Z

Zimbabwe, 131
zoology, 173