LEARNING TO PARTICIPATE - PARTICIPATING TO LEARN IN SCIENCE AND MATHEMATICS CLASSROOMS

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OULU 2003

Abstract in Finnish
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Academic Dissertation to be presented with the assent of
the Faculty of Education, University of Oulu, for public
discussion in Savonsali (Auditorium L4), Linnanmaa, on
August 15th, 2003, at 12 noon.
Abstract

The aim of this thesis is to examine the practices of classroom learning communities whose pedagogy in the learning of science and mathematics draws on the sociocultural perspective. This pedagogical framework views learning as a collective process of meaning making situated in cultural contexts. This research thesis illuminates the ways in which communal learning activity is constructed into being in the social interactions of classroom learning communities. Methodologically, this research is concerned with unravelling the dynamics of collaborative learning processes, and with examining how they give rise to the construction of diverse voices during participation in cultural activities.

The empirical findings discussed in this thesis are derived from three case studies. Case Study 1 examines the nature of participation processes in science classrooms representing three age levels (Kaartinen & Kumpulainen, 2001). Case Study 2 focuses on the construction of explanations in a collaborative science learning project (Kaartinen & Kumpulainen, 2002). Case Study 3, reported in two articles, investigates the processes and conditions for collaborative reasoning in an elementary classroom context with a special interest in mathematics (Kumpulainen & Kaartinen, 2000, 2003).

On the basis of the findings of this thesis, successful collaboration — joint effort towards a joint non-predetermined goal of action — can be said to require the growth of communicative consciousness. This means the ability to approach the problem under question from the point of view of another person and hence conversely, an ability to see one's own position from the point of view of other person.

In this thesis, collaborative negotiation processes consisted of diverse interpretations, varying from informal to formal explanations, and from descriptive reasoning to causal reasoning. It seems evident that the traditional approach to teaching does not give students enough tools to elaborate their conceptions. However, the results of this thesis indicate that the collaborative learning situations here described have the power to provide students with opportunities to elaborate their explanations.

The results of this thesis highlight the potential of the sociocultural approach to engage students in educational interaction, where diverse voices are able to participate and contribute to the ongoing discussion. The involvement of all students in collaborative discourses also poses challenges to sociocultural pedagogy, calling for educators to recognise and support varied opportunities for participation in educational discourse. The examples presented in this thesis are aimed at providing educators and researchers with lenses through which to examine the sociocultural practices of these classrooms and potentially further develop them.

Keywords: collaborative inquiry, discourse analysis, instruction, learning, mathematics, science, social interaction, sociocultural pedagogy
Tiivistelmä

Väitöstutkimukseni tarkoituksena on tutkia sosiokulturaalista pedagogiikkaa soveltavien oppijayhteisöjen käytänteitä matematiikan ja luonnontieteiden luokkahuoneissa. Tämän pedagogisen lähestymistavan mukaan oppiminen nähdään yhteisöllisen, kulttuurisii käytänteisiin liittyvänä osallistumis- ja merkityksenantoprosessina. Tutkimus valottaa yhteisöllisten opiskelutilanteiden rakentumista ja realisoitumista tutkimukseen osallistuneiden luokkahuoneiden sosiaalisessa vuorovaikutuksessa. Tässä tutkimuksessa kehitettyjen tutkimusmenetelmien avulla halutaan selvittää yhteistoiminnallisten opiskeluprosessien luonneta ja sitä, kuinka näiden prosessien avulla voidaan tukea erilaisten lähestymistapojen osallistumista kulttuurisiin toimintoihin.


Tulokset valottavat sosiokulttuurialaisen lähestymistavan mahdollisuutta sellaisen kasvatuställisen vuorovaikutuksen rakentumisessa, joka tukee erilaisten tulkintojen osallistumiseen ja vaikuttamisen mahdollisuutta merkityksenantoprosessiin. Haasteen muodostaa sellaisen kasvatuställisen vuorovaikutuksen rakentaminen, jossa myös hiljaiset oppijat osallistuvat yhteisölliseen merkityksenantoprosessiin. Tutkimuksessa esitettyä empiiriset esimerkit tarjoavat kasvattajille ja tutkijoille välineitä, joiden avulla voidaan tarkastella ja mahdollisesti myös kehittää matematiikan ja luonnontieteiden luokkahuoneiden sosiaalisia käytänteitä.

Asiasanat: diskurssianalyysi, luonnontieteet, matematiikka, opetus, oppiminen, sosiaalinen vuorovaikutus, sosiokulttuurialainen pedagogiikka, yhteistoiminnallisuus
Acknowledgements

I am grateful to many people for their support and guidance during the preparation of this manuscript and the development of the theoretical, methodological and instructional ideas for learner sensitive pedagogy.

I wish to thank Professor Timo Järvilehto for introducing me to the research topic of this thesis as well as for his guidance, criticism and support during the process. Professor Leena Syrjälä’s pedagogical tact in guiding, tutoring and supporting has been a valuable resource for me as a researcher and a teacher during the whole process of my educational studies. I wish to express my deep gratitude to Academy Fellow Kristiina Kumpulainen for her supervision, criticism and collaboration during the process.

Professor Hannu Soini and Senior Lecturer Jouni Peltonen gave me valuable advice, guidance and support during the preparation of this manuscript. I am grateful for their work. I would also like to thank the anonymous referees of the original papers as well as Professor Peter Renshaw and Professor Jos van der Linden for their expertise and criticism during the development of the theoretical, methodological and pedagogical ideas of the participatory approach.

I would like to thank the pre-examiners Professor Jorma Enkenberg and Professor Roger Säljö for their valuable work, comments and suggestions in the final phases of the preparation of the manuscript.

I am grateful to Lecturer Heather Kannasmaa for deep understanding and skill when checking and correcting the language of this manuscript. I would also like to thank Mr. Vesa Komulainen who has given essential support in technical issues related to the preparation of the manuscript.

I wish to thank the University of Oulu, Department of Educational Sciences and Teacher Education for its pedagogical tolerance towards innovative ideas in the course of the development of the teacher education program. I would like to thank all my colleagues, friends and students at the department. I would also like to thank the University of Jyväskylä, Department of Teacher Education for its support and its pedagogical atmosphere.

Thanks are also due to the Academy of Finland, the Colism-project (Project leader Kristiina Kumpulainen, project no: 41969) for making my academic writing possible through its support.
Finally, I would like to thank my parents Aune and Yrjö, as well as my sisters and brothers, for belonging to this family, where support and caring have always been present in every phase of my life. My life-companion Jukka deserves my gratitude for the co-construction of life and the creation of the zone of proximal development. My warmest thanks to my daughter Vera Anita, who gave meaning to all this work.

Oulu, July 2003

Sinikka Kaartinen
List of original papers

This thesis is based on the following papers:


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1 Introduction to the research thesis

1.1 Theoretical foundations of sociocultural pedagogy

Sociocultural views of learning and development have aroused educational interest in the design of instructional settings based on collaboration and distributed expertise, mediated by cultural tools and socially shared practices (Cobb & Bowers 1999, Rogoff 1994, Wells 1999). Recent research has already provided some evidence that the social practices constructed in these learning situations have the potential to support meaningful and student-sensitive learning, in contrast to routinised and mechanistic procedures (Brown & Campione 1994). Despite the potential of the sociocultural approach to create the conditions for meaningful learning, there is still rather little information available on the application of this approach to authentic classroom practices across age levels. Therefore the goal of this research thesis has been to examine the social practices of classroom learning communities whose pedagogy in the learning of science and mathematics draws on the sociocultural perspective.

In recent years cognitively-oriented approaches to science learning have been increasingly challenged by sociocultural theories. The former have approached learning as an acquisition process which takes place as a result of the individual's active reconstruction of scientific knowledge. Since the acquisition approach conceptualizes knowledge as a kind of property that can be possessed, the goal of learning is seen as the individual enrichment of science concepts and principles (cf. Sfard, 1998). The sociocultural learning theories situate learning within the interplay of micro and macro level processes by examining social activity in its cultural and historical context (Cole 1996, Vygotsky 1962, 1978, Wertsch 1991, Wertsch, del Rio & Alvarez 1995). The sociocultural approach holds a conception of the learner as a cultural and historical subject embedded within, and constituted by, a network of social relationships and interactions. It is the changing nature of these relationships and types of participation in cultural activities that explain learning and development (Goos, Galbraith, & Renshaw 1999). Consequently, whereas in the cognitivist views the self can be known and is constructed through a series of developmental stages leading to a greater stability and consistency, the participatory approach holds that the self is constituted by engaging in
cultural activities which are dialogic, changing and contradictory in nature. From this perspective, human learning can be seen as an open-ended process with the possibility of diverse ways of acting, feeling and thinking (Renshaw & Brown 1998). In viewing learning as the process of becoming an active participant in various communities of practice, the participatory approach stresses the role of cultural and semiotic tools as mediators of social interaction and modes of thinking (Vygotsky 1962). Semiotic tools constructed and re-constructed in collective activity create the grounds for meaning-making, transforming the human capacity to act and further develop cultural contexts (Martin, Nelson & Tobach 1995).

Within the framework of the participatory approach, the task of education is to support learners' participation in collective activities between peripheral and central engagement (Lave & Wenger 1991, Wenger 1998). The process of becoming an active member and a legitimate participant in a community involves particular ways of acting and knowing as defined by the culture in question. These include, for example, modes of inquiry, ways of communicating, conventions for presenting ideas, procedures for verifying knowledge and claims, as well as values and beliefs (Goos et al. 1999). The role of the teacher, whose instructional activity is situationally defined, is to scaffold learners' engagement in communal, cultural activities (Rogoff 1990). This involves providing learners with appropriate support and tools to participate and make meaning in collective activity. The teacher's instructional activities can include directing attention, monitoring ongoing performance, and adjusting the degree of assistance depending on the learner's level of engagement. Although the teacher is by his/her profession an expert in a classroom learning community, collective meaning-making requires that there is space for diverse expertise and interpretations that are open to challenge and reconsideration. From this perspective, expertise is seen as a dynamic entity that is distributed over the community (Brown & Campione 1994).

1.2 Methodological basis of the study

The logic-of-inquiry applied in the present research thesis to investigate collaborative learning processes is influenced by the work of Barnes and Todd (1995) as well as by interactional ethnographers (Gee & Green 1998, Kelly & Chen 1999). The methods of analysis have also been influenced by a number of researchers of classroom interaction and learning, namely Barnes & Todd (1995), Mercer (2000) and Kumpulainen & Wray (2002). In addition, domain-specific knowledge about science and mathematics has played an important role in the thematic analyses of classroom interaction and in coding the interaction data (e.g. Lemke 1990).

The methodological grounding of the analysis draws on social semiotics, especially on the work of Halliday (1978, Halliday & Hasan 1989), and on discourse analysis (Edwards & Potter 1992), as well as on the work of interactional ethnographers (Gee & Green 1998). According to Halliday (1978), language is a tool for social action that is centrally involved in the processes by which human beings negotiate, construct and change the nature of their experience. The social semiotic view of language also emphasises the relationship between text (e.g. classroom interaction) and context. Meanings realised in
language are seen as being shaped by the sociocultural context of the situation. This is related to the reflexivity of language, a property whereby language–in–use both creates and reflects the contexts in which it is used. To study language use then, is to concentrate upon exploring how it is interactively and thematically patterned and how these patterns create opportunities for learning (Lemke 1985, Gee & Green 1998).

The analysis methods used in this research thesis are aimed at highlighting collaborative meaning making processes in classrooms across subject-domains and age groups. In this research thesis, the analyses focus in Case Study 3 on dyadic problem solving (Kumpulainen & Kaartinen 2000, 2003), in Case Study 2 on small group problem solving among peers (Kaartinen & Kumpulainen 2002) and in Case Study 1 on classroom interactions between the teacher and students (Kaartinen & Kumpulainen 2001). Although the analytic tools that have been devised for each of the case studies have served specific goals and research questions and, consequently, differ in some ways from each other, the methodological grounding of analytic methods share a common basis.

Acknowledging the simultaneous existence of multiple social functions in language use (Barnes & Todd 1995, Halliday 1978), the analytical tools that have been developed for this research thesis take a synchronic approach to classroom discourse by concentrating on interactional and thematic (i.e. referential) frames of discourse. The interactional frame illuminates the nature of the social relationships that are shaping the interaction, whereas the thematic frame offers an interpretation of the content of the interaction. In this study, the interactional frame analysis has concentrated upon the nature of collaboration between participants as well as on the participatory structures as evidenced in the discourse. The content frame analysis has focused on the nature of reasoning and explanations developed in social interaction, and on the nature of the cognitive processing of the task, as well as on the construction of pedagogical content in the ongoing classroom interactions. The simultaneous analysis of the interactional and content frames in the classroom interaction has made it possible to investigate the dynamics within them (Kaartinen & Kumpulainen 2002).

In order to highlight the evolving nature of meaning making in social interaction, the methods of analysis, and particularly the tools that have been developed to demonstrate interaction data, are influenced by the work of interactional ethnographers (see Green & Wallat 1981). The practice of mapping classroom interactions across time and across the analytical frames has proved to be a potential method of capturing the complexities of the social life in the classroom. Moreover, the construction of analytical maps has provided the study with a way of illuminating the dialogic nature of classroom interaction (Bakhtin 1986), shedding light upon the complex and interconnected relations between the participants and their discourse moves in the process of meaning making in joint activity (Kumpulainen & Wray 2002).

1.3 The empirical cases of the research thesis

The classrooms selected for empirical analysis within the present research thesis, although varying in age, share joint pedagogical principles (cf. Rogoff, Goodman-Turkanis & Bartlett 2001, 7) in science and mathematics learning and instruction. In each
of these classrooms learning is viewed as a collective negotiation process, where collaboration is used as a tool for building on learners’ interests. In these classrooms, learning activities are planned and constructed by the learners as well as by the teachers. These classrooms are places where the teachers are not only nurturing the student’s learning but also themselves learning, through their involvement with the other participants of the learning community. The classrooms are subjected to a qualitative micro-level analysis in order to investigate, evaluate and disseminate the pedagogical ideas behind the classrooms.

1.3.1 Research goals

In this research thesis, the pedagogical practices of the participatory approach to science and mathematics learning and instruction are highlighted with case-based descriptions derived from three case studies, each case with a special interest, titled as follows:

Case Study 1: Negotiating meaning in science classroom communities: Cases across age levels (Kaartinen & Kumpulainen 2001),

Case Study 2: Collaborative inquiry and the construction of explanations in the learning of science (Kaartinen & Kumpulainen 2002),

Case Study 3: Situational mechanisms of peer group interaction in collaborative meaning-making: Processes and conditions for learning (Kumpulainen & Kaartinen 2000), The Interpersonal Dynamics of Collaborative Reasoning in Peer Interactive Dyads (Kumpulainen & Kaartinen 2003).

The specific goals for this research thesis are:
– To develop theoretical, methodological and instructional solutions for learner sensitive pedagogy in science and mathematics classrooms,
– to investigate collaborative reasoning processes in science and mathematics classrooms,
– to develop appropriate analytical tools to investigate explanation-building processes in collaborative science learning,
– to develop appropriate analytical tools to investigate dyadic reasoning processes in mathematics.

1.3.2 The context of the learning situations

The science and mathematics learning situations investigated in this research thesis were all anchored in collaborative problem posing, solving and experimentation. The specific pedagogical premises on which the design of the learning situations rested were:
– Learning is a process of transformation through participation, grounded in social interaction and inquiry based activities in which theories are constructed and reconstructed.
Participation in the learning practices of a classroom community is mediated by cognitive, social and affective elements.

The loosely defined nature of the learning situation, which has connections to everyday life, supports the construction of a personalised relationship with the learning context.

A personalised relationship with the learning situation creates the basis for problem posing and meaning-making.

In the following, each case study is reviewed separately.

### 1.4 Case study 1

Case Study 1 focused on investigating the sociocultural elements of collaborative inquiry in the learning of science across age levels. These include the application of cultural tools in collective activity and the processes of making meaning of a scientific phenomenon.

Specific research questions posed for Case Study 1 were the following:

- How are tools constructed as mediational means in science classroom communities?
- How are meanings negotiated for a scientific phenomenon in the science classrooms of students of various ages?

### 1.4.1 Participants

The empirical data for Case Study 1 are derived from three science classroom contexts representing different age levels. The first classroom comprised eight second-grade pupils aged seven to eight years from a Finnish elementary school, and their science teacher. Four of the pupils were female and four were male. The second classroom represents a seventh-grade classroom learning community in a Finnish secondary school. The class consisted of twelve students, six female and six male, aged between twelve and thirteen years. The third classroom represents second-year student-teachers and their science teacher. The students were participants in a compulsory course in chemistry teaching. The average age of the students – eight females and ten males – was 23.6 years.

### 1.4.2 Description of the learning situation

The learning theme for each science classroom under investigation came from the field of water chemistry, with a focus on acidity. The instructional goal underlying the choice of this learning theme was to engage the students in activities which have the potential to support the student’s personal growth in being able to investigate and understand his or her living environment with the help of cultural tools and knowledge embedded in chemistry. The tools the community used for their scientific investigation were mostly unfamiliar to the students, at least in the school context. Consequently, the educational
goal of the learning activity was to enculture the students in the practices of a scientific community, including specific activity patterns and the application of cultural tools.

The second grade science classroom community investigated the colour change of blueberry juice in two solutions which differed in their pH value. The use of the natural indicator, i.e. blueberry juice, was aimed at supporting the students’ personal engagement with the solution investigated. The seventh grade classroom learning community investigated the pH value of water with the help of an industrial indicator. The water sample was taken from lake Kuivasjärvi nearby the school and most of the students' homes. Consequently, in the secondary science classroom the sample was connected with the students’ experiences of their living environment. Whereas the younger pupils used a natural indicator in their experimentation, the students in the secondary classroom used field equipment for their environmental research. The adult classroom learning community, which consisted of second-year student-teachers, investigated the total hardness of water melted from snow obtained from the university campus area. The experimentation was considered to be meaningful for the students in that the sample was connected to the students’ living environment and the examination of the total hardness of water gave the students opportunities to connect their results with everyday life, e.g. how much washing powder is needed for different types of water. As in the secondary classroom community, the adult students in their experimentation used research methods and tools developed for professional use.

1.4.3 Focus of data analysis

In order to develop a data sensitive analysis method for classroom interaction, the data were analysed in several phases. Firstly, the video material capturing the social activity of the science classrooms was closely examined and reflected upon with the help of the teacher of the classrooms. The analysis of the videotapes was supported by the teacher’s plans and notes from the science courses. Next the discourse occurring in the science classrooms during the courses was transcribed. The final construction of the analytic categories was based on the transcriptions, supported by the video data and teacher reflection. Although the code names of the analytic categories represent context-free codes, the meaning behind the code names has been contextually defined to represent the interaction data of this study. The application of the coding scheme is realised through the microanalysis of evolving classroom interaction by focusing on each conversational turn, using mutually exclusive and exhaustive categories.

1.4.4 Results

Two themes were identified in the cultural activity of the participatory classrooms on the basis of the data analysis, the first theme being the application of cultural tools in collective activity, and the second the processes of making meaning of a scientific phenomenon. The following topics are discussed in the framework of these themes: the
negotiation processes of role and status, cultural tools as mediators, and negotiating meaning for a cultural phenomenon.

The negotiation processes of role and status

In the elementary classroom, the teacher had an active role in initiating and guiding the students into the investigation process. The children acted like novice participants who were guided into the cultural activity by a more knowledgeable member of the community (Rogoff 1990). In the secondary classroom, the communal activity also began with negotiating investigation procedures and the construction of a research plan. Yet, in the secondary classroom the students were active initiators as well as negotiators, who also regulated the thematic focus of the interaction. The university classroom interaction was shaped by the presence of humour, reflecting the negotiation of power relations in the community.

Cultural tools as mediators

The analysis of the application of cultural tools for collaborative inquiry revealed that in the elementary classroom the meaning of the tools to be used in the experimentation was negotiated in teacher-initiated interaction, the teacher guiding the students' perception to the relevant features related to the investigation tools and activity. In this interaction, the students' participatory roles were constructed as peripheral due to their unfamiliarity with the tools. In the secondary classroom, the tool-mediated interaction was more co-constructive. The students were active in clarifying their understanding about the meaning and usage of the tools. In the university classroom, the meaning of the cultural tools was appropriated in the course of the investigation activity. Here, the teacher verbally modelled the usage of the tools, whereas the students performed the modelling into being with the help of the cultural tools. The multidimensional nature of the interaction among the adult students was reflected in the students' initiations and comments that also dealt with the participation rules of the community.

Negotiating meaning for a cultural phenomenon

In the elementary classroom, explanation building was grounded on investigative activity in which the teacher had an active role as a guiding tutor, whereas the students carried out the experiment and paid attention to the relevant features of the phenomenon. What is noteworthy in the situation is that although the students were novices in the activity, the pedagogical situation anchored in experimentation gave the students more room for active participation in their science learning. In the secondary classroom, the classroom community negotiated a conclusion for their investigation activity, constructed a meaning for it and then, finally, related the conclusion to their personal experiences. In the secondary classroom, the students can be characterised as architects of their learning, actively designing, carrying out and reflecting on the nature of their activity. The students’ critical stance towards the information provided by the textbook appears to be a pedagogically remarkable feature, highlighting the students’ authority with respect to their learning. The social interaction and the nature of the students' learning activity in the university science classroom was found to be somewhat similar to that of the secondary
classroom. The meaning-making processes for the scientific phenomenon showed that the adult students were active subjects who were in control of their investigation and reasoning processes. A significant feature in the social interaction of the university classroom seemed to be that the students used their own conceptual knowledge of the total hardness of water when making meaning of their results and conclusions. The equality among the participants in the classroom community was found to be reflected in their social language and comments. The teacher's role in the university classroom was identified to include tutoring, supporting and tactful withdrawing from providing authorised explanations.

1.5 Case study 2

Case Study 2 investigated university students' explanation building processes for the topic of dissolving in collaborative inquiry, and the connection of students’ personal explanations to those negotiated in collaborative inquiry.

Specific research questions posed for Case Study 2 were:
– What is the nature of collaborative explanation processes for dissolving?
– Is there any connection between students' personal explanations and those explanations negotiated in collaborative inquiry?

1.5.1 Participants

Eighteen university students participated in Case Study 2 along with their science teacher at the Department of Teacher Education, Oulu University, Finland. The subjects were second-year students attending a compulsory course in chemistry teaching. The average age of the students, 8 males and 10 females, was 23.6 years. The students' skills in chemistry represented an average level, as assessed by the university lecturer responsible for the course.

1.5.2 Description of the learning situation

The context of the learning situation in which the students worked was derived from kitchen chemistry. The instructional goal of the activity was to develop the students' conceptions of solubility; the activity itself involved collaborative inquiry and experimentation. The concept of solubility is central to the understanding of the chemical properties of solutions and, consequently, it played a central part in the whole chemistry course the students took part in. In the learning situation, the students worked in self-selected small groups. The average size of the mixed-gender groups was four students. The whole class worked simultaneously in the same classroom, carrying out their research designs for identifying the samples. The students' research practices consisted of
making hypotheses, observations and conclusions. In the activity, the students were given five solid samples of different cooking ingredients to be analysed. These five samples were salt, sugar, potato flour, baking soda, and one mixture consisting of wheat flour and baking soda. All were similar in appearance, being white powders. In order to identify the samples it was necessary to apply strategies for scientific investigation. These included developing a reliable method to solve the problem in question. Student-initiated experimental work and discussions arising from it created a platform for the students' negotiation processes about the meaning of solubility. The educational goal of the science course as a whole was to develop the students’ conceptions of learning and instruction in science as well as to elaborate their conceptual understanding.

### 1.5.3 Focus of data analysis

The analysis procedure developed for this case, to investigate the collaborative explanation-building process for dissolving, focuses on four parallel analytic frames, namely discourse moves, logical processes, the nature of explanation, and cognitive strategies. The analysis of **discourse moves** and **logical processes** is aimed at providing insights into the nature of reasoning and explanation-building from the viewpoint of participation in social activity. The analysis of the **nature of explanation** and **cognitive strategies** is aimed at unravelling conceptual and procedural elements in reasoning and explanation-building. Whereas the main analytical frames of the coding scheme are derived from existing literature, the specific analytic categories are based on the interaction data of this study. Consequently, the categories have been contextually defined on a post hoc basis.

In order to develop the analysis procedure to investigate collaborative inquiry and explanation-building in the science-learning situation, the interaction data collected were analysed in several phases. In the first phase, the video material capturing the social activity of the science class was closely examined, first independently and then collaboratively by two researchers. The analysis of the videotapes was supported by the researcher’s field notes from the science course. Next, the discourse occurring in the science class was transcribed. The final construction of the analytic categories was based on the transcriptions, supported by the video and observational data. Although the code names of the analytic categories grounded in the interaction data represent context-free codes, the meaning behind the code names has been contextually defined to represent the interaction data of this study.

### 1.5.4 Results

The analysis of the students' discourse reveals altogether six thematic episodes in the construction of an explanation for dissolving. The conceptual themes concern discussing solute – solvent interaction derived from the experimental work, negotiating the features of physical and chemical phenomena, differentiating between chemical change and
dissolving, investigating properties of solutions, recognising sugar from salt, and negotiating the meaning of dissolving. The identification of these episodes reveal that students used empirical evidence based on experimentation in their reasoning.

The study highlights the reciprocal relationship between the communicative processes and cognitive processes of discourse in collaborative inquiry. From the viewpoint of explanation-building, the case study shows that extending moves, particularly those ones which proposed causes and results, advanced evidence and evaluated collective problem-solving, seemed to be related to formal and causal explaining. The cognitive strategies, often applied in the construction of formal and causal explaining, implied using evidence and applying a principle to a case. These strategies seemed to be connected with the students' logical processes, namely proposing causes and results. The construction of everyday explanations was connected with using everyday knowledge. Although these findings need further investigation due to the small sample size, the synchronic analysis, as demonstrated here, is likely to bring new insights into the complexities of students' reasoning processes in collaborative inquiry.

The data analysis shows that the negotiation processes around the concept of solubility consisted of diverse interpretations, varying from informal explanations to formal explanations, and from descriptive reasoning to causal reasoning. The results of the students' pre- and post-tests indicate that the collaborative science-learning situation provided the students with opportunities to elaborate their explanations for dissolving, reflecting practical, theoretical and applied understanding.

1.6 Case study 3

This part of the research thesis is published in two research articles. The first article (Kumpulainen & Kaartinen 2000) discusses a case study which investigated situational mechanisms of peer group interaction in collaborative activity. The goal of the study was to highlight the processes and conditions for meaning-making in peer-mediated collaborative learning within a context of literacy and geometry. The second article (Kumpulainen & Kaartinen 2003) investigates the micro-level processes of collaborative reasoning in heterogeneous peer dyads working on an open design task in elementary geometry. Special attention was paid to the nature of student social interaction, problem solving strategies and mathematical language and how they shape collaborative problem solving processes.

Specific research questions posed for Case Study 3 are the following:
- What are the processes and conditions for collaborative reasoning in heterogeneous peer dyads?
- What is the nature of dyadic problem solving and mathematical language whilst working in an open design task in elementary geometry?
1.6.1 Participants

Twenty 12-year-old students from one Finnish elementary classroom participated in the study. The students worked in self-selected, same gender dyads during the study. Three dyad cases, one female dyad and two male dyads, were selected from the whole data sample for a close, qualitative micro-level analysis. The selection was based upon the students’ differing outcome scores resulting from their solo and dyadic problem solving sessions.

1.6.2 Description of the learning situation

The learning situation in mathematics consisted of a geometrical design task in which the students were asked to construct three-dimensional objects pictorially represented on a plane with the help of two-dimensional objects. The construction was realised with cards representing different faces of objects. The sketches of the geometrical objects could be visualised in different ways, and hence there were many solutions. From the mathematical point of view the goal of the design activity was to develop the students' understanding of the complex relationship between two-dimensional shapes and three-dimensional objects. In the design tasks, the two-dimensional shapes consisted of polygons, such as pentagons, quadrilaterals and triangles. The three-dimensional objects were sketches of irregular solids representing familiar elements often found in real life settings.

The learning situation in language was built around a story production task in which the students were asked to fill in missing words in a narrative story in order to make it coherent and understandable. The text could be composed in different ways and this promoted the negotiation among the students of a common understanding of the nature of their story and of particular words around which the story was to be constructed. In the dyadic session, the students worked on the same narrative text and, consequently, produced one joint story from several possibilities. The story was from Tove Jansson’s book "Moomin Valley in November". Tove Jansson's publications are considered children's literature classics in the Finnish culture.

1.6.3 Focus of data analysis

The data analysis in Case Study 3 is realised through a microanalysis of evolving peer interactions which focuses on three analytical dimensions, namely the functions of verbal interaction, cognitive processing and social processing. Whereas the functional analysis concentrates on the students’ verbal language, the analyses of the students’ cognitive and social processing focus on interactive dynamics as they occur across the participants. Consequently, a group is taken as a unit of analysis. The three dimensions are treated separately for analytic purposes, although it is recognised that they are closely intertwined. In actuality the dimensions cannot be separated since each element gives
meaning to all the others and simultaneously obtains meaning from them. The analysis of cognitive processing in the article by Kumpulainen & Kaartinen (2003) concentrates on the students’ problem solving strategies and mathematical language in the design process. The categories of each analytic focus are grounded in the interaction data of this study.

1.6.4 Results

The goal of this study was to examine the interpersonal dynamics of collaborative reasoning in heterogeneous dyads working on an open design task. From a mathematical point of view, the study concentrated on investigating the nature of the students' social interaction, problem solving strategies and mathematical language at a micro-analytic level. As a whole, the study aimed at untangling elements in peer collaboration which appeared to support and challenge the construction of a shared understanding during joint reasoning.

In this study, collaborative reasoning was reflected in equal participation in social interaction, including joint reasoning of problem solving strategies and active conceptualisation and visualisation of the situation. Collaboration between peers seemed to be supported by reciprocal attempts to create a joint meaning by making problem solving visible through explanation and demonstration. The students’ appreciation of each other’s contribution to the problem solving and its explicit communication to their partners was also seen to support joint reasoning and to promote the students’ sense of being legitimate participants in their collaborative endeavour.

Collaborative reasoning in heterogeneous dyads was also found to pose challenges for joint meaning-making. Particularly in those dyads which repeatedly faced cognitive or social conflicts, the outcome was often asymmetric interaction and problem solving, with diminished potential for collaborative reasoning. On the other hand, in some cases conflict situations resulted in peer tutoring episodes or argumentative episodes during which one member of the dyad scaffolded his/her partner towards a joint understanding. This mode of peer interaction was found to require a shared focus and explicit attempts to maintain collaboration within the peer group.

The data of this study show that within the context of geometry, the dyads engaged in exploratory activity included reasoning, problem posing and solving in their collaborative reasoning. The strategies used in problem solving included versatile approaches consisting of constructing, measuring, visualising, testing, excluding and evaluating. The students' verbal interactions included reasoning, hypothesising, argumentation, organising, and questioning. From the viewpoint of mathematical reasoning, interactions which supported collaborative problem solving were those which operated on the partners' reasoning and those which co-ordinated perspectives and explanations into a global view in order to apply and test them. This was seen in our analysis of two boys Sami and Teemu, which demonstrated that this dyad could successfully establish, modify, reflect on, and refine their initial task goals and definitions, in order to establish collaboration in dyadic conditions. Much observed evidence points to this particular dyad having constructed a zone of proximal development for one another to facilitate the construction of geometrical reasoning, namely their application of the concepts they had
been studying during their geometry lessons to the present task, their listening to each
other’s explanations and reflecting on their logicality and exactness, and finally their
observation of each other’s experiments and use of these observations to modify their
own task definitions. It should be mentioned here that the collaborative endeavour of
Sami and Teemu seemed to be reciprocal in nature, with Sami appearing willing and
eager to share task responsibilities with Teemu, and expressing his sense of their mutual
goals by using the word “we” when explicating the reasoning to his partner. Throughout
their interaction both Sami and Teemu took turns at listening, argumenting, reasoning,
questioning and organising their joint activities. Their joint reasoning had the qualities of
genuine collaboration: mutuality and equality. The findings of our case of Sami and
Teemu are supported by the research of Forman and McPhail (1993), whose results of
genuine collaboration in dyadic conditions were similar in nature.
2 General discussion and conclusions

2.1 Theoretical reflections on the sociocultural pedagogy

The theoretical background of the articles presented in this thesis share a joint conception of the learner as a cultural and historical subject, embedded within and constituted by a network of social relationships and interaction of the culture in question (Vygotsky 1962, 1978, Wertsch 1991). Within this shared conceptual framework, the task of education is viewed as giving learners opportunities to participate in collective, cultural activities between peripheral and central engagement (Rogoff 1994, Lave & Wenger 1991, Wells 1999). Central to this process is the creation of collective zones of proximal development (Moll & Whitmore 1993). Characteristically, these collective zones conceptualise the learner as a participant engaged in collaborative activity within special discourse environments. These zones are mutually and actively created by teachers and students. Semiotic tools constructed and re-constructed in collective zones create the grounds for meaning making, transforming the human capacity to act and further develop cultural contexts (Martin, Nelson, & Tobach 1995). In this process, the all-important semiotic tool is language, which is not understood as a generalised or abstract semiotic system that mediates activity, interaction and thought, but rather as a multitude of distinct speech genres and semiotic devices that are tightly linked with particular social institutions and with particular social practices (Minick, Stone & Forman 1993). Hence, appropriating the speech or actions of another person, requires a degree of identification with that person and the cultural community that one represents. Central to this appropriation is the concept of prolepsis (Stone 1985, Stone & Wertsch 1984). The concept refers to a communicative move in which the speaker presupposes some as yet unprovided information (Rommetveit 1974, 1979). According to Rommetveit, the usage of such presuppositions creates a challenge for the listener, a challenge that forces a listener to construct a set of assumptions in order to make sense of the utterance. When the communication is successful, this set of assumptions recreates the speaker’s presuppositions. Thus the listener is led to create for himself the speaker’s perspective on the topic at issue. To study the possible traces of learning and development in the sociocultural setting then, is to study discourse and how it is evolved in the flow of social
actions. It is the changing nature of these interactions and types of participation that defines learning and development (Goos et al. 1999). In addition, modes of thinking evolve as an integral system of motives, goals, values and beliefs that are closely tied to concrete forms of social practice (see also Minick et al. 1993).

In this research thesis, the multifaceted nature of sociocultural modes of thinking was seen in Case Study 1 (Kaartinen & Kumpulainen 2001). The study highlights the multidimensional educational interaction of the science learning community, which intertwines social and individual, global and local forms of interpretation when educating a human to participate in cultural activities. Profitable communication was seen in Case Study 2 (Kaartinen & Kumpulainen 2002), where a group of students defined in dialogue the meaning for dissolving. Traces of fruitful communication were also present in the collaborative endeavour of heterogenous dyads whilst working on the mathematics task (Kumpulainen & Kaartinen 2000, 2003).

2.2 Methodological reflections

The task of the sociocultural analysis of science and mathematics learning and instruction in this study is to understand how social activity evolves in ongoing interactions and how it is related to the cultural context of the activity in question (see also Wertsch 1998). This study approached meaning-making in science and mathematics classrooms as a process, which was constituted in social interaction where experimental activity and symbol-using action were intertwined.

The stance of the sociocultural approaches to learning and development is that the development and learning of participants occur as they participate in sociocultural activities (Rogoff 1990, Wertsch 1998). Hence, individual developmental processes are inherently involved with the actual activities in which learners engage with others in cultural practices and institutions, and that variation is inherent to human functioning. Therefore, the units of analysis focus on processes, rather than individuals. Generalities are sought in terms of the nature of the processes as people participate in and constitute activities, rather than simply assuming context-free generality or seeking it in separated characteristics of the person or the task (Rogoff, Radziszewska & Masiello 1995). Cognitively oriented views of learning development often assume that it is possible to design a situation that allows the evaluation of the learner’s competence, independent of the dynamic nature of the activity and of the sociocultural nature of events (cf. Rogoff 1990). However, in a sociocultural perspective, learning and development are regarded as processes of changing participation in cultural activity; no activity is purely individual. Thus pre- and post-tests cannot be interpreted as revealing purely individual performance, instead, they can be interpreted as the sociocultural activity of a particular social and cultural construction (Rogoff et al. 1995). In this research thesis, pre- and post-tests were used to shed light upon the sociocultural practices of mathematics and science learning communities in order to get a deeper picture of the phenomena to be investigated. The goal was not to examine individual performance in its traditional sense, but rather to get information for the design, implementation and evaluation of sociocultural learning practices in science and mathematics.
There is an evident contradiction between the sociocultural framework, as described by Rogoff et al. 1995 and the traditional view of seeking the influence of social interaction on individual development. From the methodological point of view, the sociocultural approach focuses on evaluation of the process and individuals’ participation in and contributions to the ongoing activity. Through the study of the activity then, we can aid teachers and educators as well as learners in widening and deepening their perspectives, since the micro-level analysis of their interaction can provide information on what aspects of problem solving a participant handles with what types of support. According to Brown and French (1979) this kind of approach may be informative for the fostering of cognitive development since it may clarify our understanding of what participants of the learning community are able to do with other people (see also Rogoff et al. 1995).

The challenge for the methodological development of the present research has been to develop analytical tools that are deep and sensitive enough to capture the multifaceted reality. In order to understand the nature of the collaborative reasoning process in science and mathematics classrooms, the specific discourse analytic methods were designed for the present study (Kaartinen & Kumpulainen 2001, 2002, Kumpulainen & Kaartinen 2003). The analytical tools take a synchronic and diachronic perspective on discourse. The synchronic perspective is realised by concentrating on several parallel analytic frames, e.g. discourse moves, logical processes, the nature of explanation and cognitive strategies, whereas the diachronic perspective is reflected in the microanalysis of the students' discourse which evolves on a moment-by-moment basis. The application of the coding schemes is realised through a microanalysis of evolving small group interaction by focusing on each conversational turn, either on an episodic level or on an utterance level. The reliability of the coding of the students’ discourse has been checked by two independent researchers (one science and mathematics educator and one researcher in educational sciences), who have analysed the data and hence developed the analytical tools for the present study. Diverse opinions have been negotiated to establish a joint agreement. The construction of a joint agreement has been guided by domain-specific knowledge of chemistry and mathematics. Due to the interpretative and complex nature of the analysis this procedure was found most appropriate to the rationale of this study.

In this study, the dynamics of social interaction are illustrated with the help of analytical maps which have been created for each case under investigation. The product of the analysis is a series of situation-specific analytical maps that describe a sequential evolution of social interaction as it is constructed by students interacting with and acting upon each other’s messages. A structural map is always a simplification, yet it gives a coherent picture of a complex situation, making comparisons across educational contexts and students. The structural maps also make it easy to return to the original data to check the validity of interpretation. When presenting extracts from the data, one is able to investigate the data context to which the extract belongs. (Kumpulainen & Wray 2002.)

In summary, this research thesis illuminates the micro-level processes of social interaction in science and mathematics classrooms with the goal of providing practice-based examples of socioculturally grounded pedagogy.
2.3 Converting sociocultural theory to pedagogical practice

A major goal for education is to support the development of competent membership in diverse communities of practice. Several theoretical and empirical approaches to learning and development address the above mentioned question, such as the activity theory (Engeström 1987), the situational approach (Greeno 1997) and the sociocultural theory (Rogoff 1994, Lave & Wenger 1991, Wells 1999). Although situational approaches to cognition have enriched our understanding of the situation-bound nature of knowing, these approaches do not capture the whole picture of the theoretical demands for learning and development in the institutionalised context of education, as investigated in this thesis. On the other hand, whilst acknowledging the activity theoretical approach to human learning and development, with a focus on the structure of activities as historically constituted entities (Wertsch 1985, Engeström 1987), this thesis investigates the communally negotiated nature of activities like those reported in the case studies reported here.

This thesis commits itself to the theoretical stance that learning involves transformation of participation in a collaborative endeavour. This is the theoretical foundation of the concept of a “community of learners”, involving both active learners and more skilled partners who provide guidance and are present in the course of the collaborative endeavour (Rogoff, Matusov & White 1996, 388) However, in this thesis, the roles of the participants were not predetermined, but instead, were negotiated in the course of the ongoing activity (see also Linehan & McCarthy 2001).

To foster and support all learners’ active participation in instructional activities of the core subject domains of the curriculum, this thesis applies the concept of a “community of practice” (Lave & Wenger 1991, Wenger 1998) in the design, implementation and evaluation of the instructional conditions of the learning situations in science and mathematics, as reported in the three case studies. In this thesis, instructional activities and pedagogical practices were aimed at modelling culturally established practices of scientists and mathematicians in school contexts. This was done with the help of the professional approach, the language and the procedures of investigation of a culturally authentic phenomenon. In this thesis, the professional approach was especially reflected in relation to knowledge, being defined as a perspective into the problem under investigation instead of a property to be possessed (Sfard 1998).

Methodologically, commitment to the concepts of a “community of learners” and a “community of practice” led to a developmental project lasting several years, where cultural practices of scientists and mathematicians were investigated in detail. After conceiving of what it is to behave like a mathematician and scientist, the developmental path for the design of learner-sensitive instructional conditions (e.g. building on learners interest, values and life experience) was started. For the thesis, the selected contexts under investigation were geometry and water chemistry. The selection of the contexts was based on the extent to which they were the core domains of the subject in question in the curriculum.

In recent years in educational research there has developed a “learning-communities” approach to education. In a learning community approach, the educational goal is to advance collective knowledge in a way that supports the growth of individual knowledge (Bielaczyc & Collins 1999, Scardamalia & Bereiter 1994). In this thesis, the goal of
educational practice was community building among its members and learning was conceptualised as a growing sense of belonging to this community.

Characteristics of social learning that occurs in participatory systems are elements such as action, reflection, communication and negotiation (Illeris 2002). The joint goal in a learning community approach is to foster the emergence and growth of these elements among its members to participate in cultural activities of the community in question. It is important that each member takes responsibility for participation and community building. This sense of responsibility is not a matter of course in traditional classrooms, where students work on standardized tests and they are expected to reach a base level of understanding. Hence, they tend to form their identity through being measured or by measuring themselves against the standards (Bielaczyc & Collins 1999). In a learning community approach, the learner’s identity is formed through participation. The members become who they are by being able to play a part in the relations of engagement that constitute the community (Wenger 1998). The data of this thesis highlights the identity building processes inherent in community building processes. It seems evident from the findings that competent membership of a learning community includes a change in the degree of participation, as well as elaboration of members’ identities as legitimate participants of a learning community. (see also Wenger 1998)

The selected approach of this thesis to human learning and development is also supported by the work of Halliday (1978, Halliday & Hasan 1989) who suggests that intellectual development is a process of meaning-making with others, and hence he argues for the central role of discourse at all levels of education. In this thesis, all of the learning situations were anchored on discourse and cultural activities. However, the nature of the discourse and the activities were not predetermined, rather they were negotiated in the flow of social interaction.

To apply Halliday’s (1978, 2) formulation of “language as a social semiotic” in this thesis is to interpret language within a sociocultural context in which the culture itself is interpreted in semiotic terms. In the analysis part of the thesis, the language took a specific meaning in communal discourse and was further interpreted to construct cultural meanings across contexts. The role of language for collaborative inquiry is also reflected in the writing of Järvi (2000), who stresses the importance of the development of shared language as a tool for collaboration and the importance of the development of consciousness in the evaluation of collaborative action.

On the basis of the findings of this thesis, successful collaboration (joint effort towards a joint non-predetermined goal of action) requires the growth of communicative consciousness. In this thesis, communicative consciousness means the ability to approach the problem under question from the point of view of another person and hence conversely, an ability to see one’s own position from the point of view of other person. The development of communicative consciousness might lead the community of learners participating in communities of practice to a community of learning (Bielaczyc & Collins 1999) where wholeness and order are constructed instead of chaos and disorder.
2.3.1 Discourse analysis as a tool to trace collaborative inquiry in the community of learners

This thesis applies discourse analysis as a method of tracing collaborative inquiry in communities of practices of science and mathematics classrooms. In the present work, the term discourse implies communication that is socially situated and that sustains social positionings, i.e. relations between participants in social interaction or between author and reader in written texts (Hicks 1995, 49).

The methodological foundation of the analysis of this thesis draws on the work of interactional ethnographers (Gee & Green 1998) and on a social semiotics view of language, especially on the work of Halliday (1978, Halliday & Hasan 1989). In addition, some empirical examples of discourse analysis (Barnes & Todd 1995, Kumpulainen 1996) were investigated before the development of the analysis methods presented in this thesis.

According to Gee and Green (1998) one dimension of language as social action and cultural resource is situated meanings. Gee and Green (1998, 122) define a situated meaning as an image or pattern that participants in an interaction assemble simultaneously as they communicate in a certain context, based on how they construe that context and on their past experiences. For example, the data of this thesis neatly highlight how the meaning of the research plan was situationally constructed in learning situations representing different age groups (Kaartinen & Kumpulainen 2001). In this thesis, the meaning for the research plan in diverse classrooms varying in student age carried the following meanings: mutuality of engagement – the ability to engage with other group members and respond in kind to their actions – e.g. Säde and Martti discussing the meaning of a research plan with the teacher, accountability to the enterprise – the ability to understand the community of practice deeply enough to take some responsibility for it – e.g. Kai and Arttu constructing the meaning of the research plan and discussing their results with the teacher and negotiability of the repertoire – e.g. university students negotiated the meaning and the procedures of the research plan (Wenger 1998, 137).

When an ethnographic perspective is applied to guide discourse analysis, the phenomenon under investigation is the dialogue of action and interaction (Spindler & Spindler 1987). In approaching the purpose and goals of ethnography in this way, the focus of the study is dialogue through discourse or dialogue through action. Ethnographically oriented discourse analysis forms a basis for identifying what the members of a social group need to do to participate appropriately (Gee & Green 1998, Heath 1982). In this thesis, the classroom learning communities are investigated in terms of how they are constituted by discourse and the jointly negotiated activity of the domain in question. The reason for such a choice lies in the fact that disciplines such as science and mathematics are partly constituted by culturally negotiated activities and discursive practices, and learning science and mathematics cannot be separated from these activities.
2.3.2 Pedagogical considerations

The participatory approach to science and mathematics learning challenges the traditional pedagogical practices applied in classroom instruction. Whereas the traditional view stresses the individual construction of predetermined explanations obtained via controlled procedures whilst experimenting, the participatory approach puts a particular emphasis on the sociocultural prerequisites for science and mathematics learning. In pedagogical practice these conditions can be realised in learning situations stressing authenticity, tool-mediated activity, social interaction and discourse, joint problem posing and solving, and distributed expertise (Brown & Campione 1994).

In this research thesis, the potential of meaningful, authentic activity was reflected throughout each case study, particularly in Case Study 1 (Kaartinen & Kumpulainen 2001) where second grade children investigated the chemical properties of water with the help of natural indicators. This type of activity is rare in traditional classrooms, which define learning as the enrichment of concepts. In the future, from the sociocultural perspective, it is important that educators give up some of their control over the determination of instructional goals as well as instructional procedures. The case studies of this research thesis show that learners, when given room, are able to take control and responsibility over their learning activities under the indirect and supportive guidance of a sensitive teacher. A challenge for instructional conditions in learner sensitive pedagogy is that they are sensitive to their students’ learning age characteristics, consisting of their learning histories and cultural identities. As the data of this study highlight, the histories and identities of the students can work as a resource for the learning community and, reciprocally, the interaction of the learning community can work as a resource for the individual student to negotiate and renegotiate his or her position and interpretation. Socially shared experiences in the course of communal learning activity appear to create a joint platform for meaning making shaped by the activity, semiotic, material and identity modes of interaction. The cultural tools in the learning situations seem to provide the students with the means to structure their experiences of their living environment and to relate them to the formal culture of scientists. As a pedagogically responsible member of the culture, the teacher's responsibilities and challenges in these science classrooms could be seen as twofold; on the one hand, to support the students’ enculturation towards a full membership of a learning community in the classroom and, on the other hand, to support the students’ personal growth as ethically responsible members of society. The multidimensional interaction which intertwines the social and individual, or the global and local forms of interpretation, may have the potential to educate humans who are able to participate in cultural activities, critically monitor them and to take responsibility for re-creating them.

2.4 Educational significance of this research

The learning situations analysed and described in this thesis provide new information for the design, implementation and evaluation of socioculturally oriented science and mathematics learning situations. The micro-analytical maps of learning situations in this
thesis illuminate the micro-level processes of social interaction in these classrooms with the goal of providing practice-based examples of socioculturally grounded pedagogy. Hence, the maps provide valuable material to be investigated and analysed in the teacher education courses. On the other hand, the analysis methods developed for the case studies of this thesis can be used as tools for authentic evaluation in educational courses.

The requirement of the presence of communicative consciousness in the collaborative activity of participants is demanding. As the case study results of this thesis suggest (Kumpulainen & Kaartinen 2000, 2003) the collaborative interaction of the participants includes argumentative and tutoring episodes during which the participants help one another by explicating their point of view through verbal and non-verbal interaction. Equal participation, jointly negotiated and shared opinions are also features of collaborative activity. It is evident, that participants who are able to collaborate in this manner, gain more in learning situations which are grounded on collaboration than participants whose social interaction lacks these elements. Hence it is possible that the requirement of communicative consciousness for successful participation in educational interaction, brings about inequality among participants in social positioning. Therefore educators who apply sociocultural theory to their pedagogical activities need to take into account adequate measures of support for those participants who so far lack sufficient social and cognitive skills for successful participation.

On the other hand, pedagogical situations which apply discourse as a tool for community building and learning need to recognize and support the growth of diverse paths to academic knowledge. It can be suggested, on the basis of the results of this thesis (Kaartinen & Kumpulainen 2002), that there are multifarious ways of constructing academic discourses and that diversity for one participant or across participants in the community can be respected as a desirable outcome of education in multicultural communities (see also Hicks 1995). This requires that power to judge discourses is equally distributed among the participants and that discourses will be accepted and evaluated from a pluralistic perspective. On the other hand, there is an educational need to make the evaluation of discourses from the perspective of academic knowledge. Interweaving these two perspectives is not an easy task and therefore the evaluator needs to have a high degree of social and domain-specific skills.

From the educational point of view, the involvement of all students in multifarious, collaborative discourses also poses challenges to sociocultural pedagogy. How to support and acknowledge the participation of silent learners? If oral participation takes priority over other participation, should silence then be regarded as a failure to learn? The designers, implementers and evaluators of sociocultural practice need to recognize and support varied opportunities for participating in educational discourses. This includes the identification, involvement and support of silent participants in order that they too have a possibility to gain from sociocultural pedagogy.

Despite the above mentioned critical reflections towards sociocultural educational practice, the approach has also possibilities in educating critical, collaborative and communicative members of a multicultural society, including that of mathematicians and scientists. The descriptive examples presented in this research thesis offer the possibility to provide educators and researchers with lenses through which to examine the social construction of science and mathematics teaching and learning across classrooms. Rather than providing normative guidelines for educators, this study is aimed at making visible
the sociocultural practices of classrooms, including the nature of their participatory and meaning-making processes. Studies of this nature are likely to open up dialogue with their audience and potentially further develop educational practices in science and mathematics.
3 References

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