



How students interact when working with mathematics in an ICT context

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Abstract

There is a common assumption that computers will change the conditions for teaching mathematics. This paper discusses expectations regarding changes in working methods and, specifically, adolescents' interaction in the computer-aided teaching of mathematics in middle school. The empirical material was collected through interviews with eighteen teachers in grades 7-9. The author also participated in all of the computer-aided lessons given by two teachers during one year, which means access to 700 lessons where teachers and students could use computers. During this year they used computers in only 18 lessons. This particular study reports from a closer analysis of seven observed lessons and 18 teacher interviews.

In sum, using the computer when solving mathematical problems with peers is not always a successful learning method. The empirical data indicate that the linguistic interaction consists mostly of one student posing a question and another giving an answer. There was a lot of communication in the classroom but very little could be signified as dialogic. The different forms of interaction observed also tell us that students are not involved in communication about scientific concepts. Their communicative ability is therefore not developing to any large extent. When students collaborate in order to solve math problems they oscillate between disjunctive and complementary tasks. It means that different students practice different skills, some that are important for their mathematical ability and some that are not.

Keywords: Interaction, Computers, Adolescents, Middle school, mathematics.

Introduction

Changes in society are reflected in school, albeit with some delay. Few specific contemporary events have had such a powerful influence on society as the introduction and development of information technology (IT). A review of literature in the field shows the importance of the communicative function of IT; therefore the term ICT, Information Communication Technology, is frequently used (Edström, 2002).

In several Swedish governmental documents (e.g. Utbildningsdepartementet, 1994; Utbildningsdepartementet, 1997) it is argued that the computer is an agent of change which can contribute to finding new teaching methods and giving the students possibilities for developing new knowledge. The new technology can reshape pre-requisites or conditions for learning. Within the research community, there are those who argue that computer programs can make fundamental changes in the conditions for students' learning in mathematics (Blomhøj, 2001; Niss, 2001). Other researchers argue that students' mathematical skills will be affected negatively (cf. Young, 1968; Galbraith & Haines, 1998).

A common teaching method in the Swedish classroom is characterized by teachers instructing or imparting knowledge and students then practicing their skills (Lindqvist, Emanuelsson, Lindström & Rönnerberg, 2003, NU, 2003). This teaching method encourages a dependence on a teacher's confirmation, a book that drills, and a key that gives the right answers. Wyndhamn (2002) draws attention to another teaching method where students are organized in smaller groups in order to discuss and investigate mathematical phenomena. With this new method, one aim is that the computers will challenge common teaching practices and help teachers to organize their teaching in a more interactive way, as stressed by Wyndhamn (2002). This paper discusses expectations regarding changes in working methods and specifically the possibilities of interaction in the computer-aided teaching of mathematics in middle school.

The everyday teaching of mathematics

It appears that very few articles about the use of computers in the everyday teaching of mathematics have been published. This could be because computers are not used very much in teaching (Rosen & Weil, 1995; Becker, Ravitz, & Wong, 1999; Nissen, 2002; Samuelsson, 2003). Many studies can be regarded as field experiments using different types of computer programs as conditions that influence the ways in which the work is carried out as well as the results the teachers are focusing on (Ruthven & Hennessy, 2001). Usually the researcher first decides what classroom arrangement he or she will investigate. Then he or she discusses results that come out of the work.

Some articles discuss how computers can be used in an experimental activity (Marrades & Gutiérrez, 2000; Holahan, Jurkat & Friedman, 2000; Hammond & Mumtaz; 2001). When students use tool programs for experimental activities, the learning changes from mastering of procedures to conceptual understanding, and the ability to interpret, analyze and assess data in diagrams and other statistical materials is emphasized (Marrades & Gutiérrez, 2000; Ruthven & Hennessy, 2002).

There are studies that highlight a change in the way computers are used, from drill programs focusing on procedural knowledge to activities with more simulation and problem solving (Dahland, 1998; Pemberton, 1995; Forster, 1997; Galbraith & Haines, 1998). Samuelsson (2003) argues that drill programs are the most common programs used in math teaching in elementary and middle school. Other studies tell us that computer-aided teaching can influence students' feelings towards mathematics (Galbraith & Haines, 1998).

One conclusion from the research done in the area is that few researchers have been interested in what happens in everyday teaching. Studies of everyday use of computers in teaching math were already in demand at the end of the 1980's (Fey, 1989). Studies of how the computer can be used and what contributions it can make do exist, but there are no descriptions or analyses of

how computer-aided instruction is carried out in everyday teaching. Ruthven & Hennessy (2002) point out that:

There is a pressing need for naturalistic studies more directly grounded in the actuality and contingency of teaching, (p. 51).

In order to help teachers to take advantage of computers in the teaching process it is important to describe and analyze the use of computers in everyday teaching (Samuelsson, 2003).

Theoretical concepts important to the study

Interaction in this study is defined as when two or more actors are involved in what happens on the computer screen (Svensson, 2001). The review of literature related to fields of interaction focuses on technology's importance in forms of collaborative learning (Koschman, 1996; Lee, 1993; Silverman, 1995). Computers support collaborative work, reduce distances and create a shared focus (Edström, 2002). Crook (1996) stresses that computers will help a teacher to organize a collaborative learning environment. There are several studies showing that computers get people together *to interact and communicate* (Svensson, 2001; Klerfelt, 2002). Some studies (Alexandersson et al, 2000; Alexandersson, 2002) describe students who interact as more focused on the goals of the activity than students working individually. Svensson (2001) argues that it is an effective and constructive working method where children help each other (Clements, 1993; Liang, 1998).

There are several factors affecting the outcome of collaborative work. There are many studies indicating that the way the task is presented and the combination of how children work together strongly affect the outcome (Helleve, 2003). One researcher who tried to understand interaction in small groups is Steiner. Steiner (1972) constructed a typology where he described different types of collaborative work. He stresses that a group's performance is decided by three factors: a) the demands of the task, b) the resources in the group, and c) the processes in the group. A starting point for the typology is the task. Steiner (1966, 1974, 1976) suggests five different types of tasks: a task may be additive, disjunctive, conjunctive, compensative or complementary. When students work with an additive task, their contribution is valued as equal. One person's contribution is just as important as another's. The result is the product of all group members' contributions. In a disjunctive task only the answer is important. One answer represents a group's performance. Also, one answer must be accepted in the group and any other rejected. In a collaborative work situation, this type of task helps capable students to learn while less capable students stand back (Samuelsson, 2003). Significant for a conjunctive task is that all students have to manage the task. A complementary task is performed when all group members' understandings are collected and the average understanding is the group's result. Lastly, Steiner discusses the complementary task. When students are told to solve a complementary task, they split the task up and different students then solve different parts of the task. The result is the sum of all students' contributions. The key element of effective collaborative work is the active exchange of ideas through verbal communication (e.g. King, 1999; Samaha & Lisi, 2000; Webb & Favier, 1999). When students communicate they interact with each other. One aspect of communication is the dialog (Dysthe, 2001) where students discuss and try to understand a problem together. Another aspect of communication is a question-answer practice (Sahlström, 1999). One big difference between these types of communication is the possibility to learn scientific concepts (Säljö, 2000) which is important in mathematics education. In a community signified by dialog, students have a greater opportunity to develop their concepts (Säljö, 2000)

Looking at math specifically, there are few studies that draw attention to students' interaction when working with computers. Considering *mathematics as a language* where students are supposed to develop their adaptive reasoning, it is interesting to notice two studies by Ivarsson, 2002 and Wyndhamn, 2002. They indicate that students cannot on their own, without the teacher's support, create a meeting between their everyday concepts and the scientific discourse (Vygotsky, 1986) when they work together in front of a computer screen.

Another aspect of importance for the interaction is the program. Drill programs seem to recall students' past competitive experiences (Liang, 1998; Samuelsson, 2003). The competition can affect students in a negative way (Samuelsson, 2005), and they can form a basic assumption group, a term introduced by Bion (1961). A group in working position is mature and task-oriented. A basic assumption group is marked by immature and less task-oriented work. The basic assumption phenomenon is a group's reaction to anxiety which competition can cause. These states are ways of dealing with impulses to satisfy the defensive needs of members. A basic assumption group may be supportive, or it may be an obstacle. If the group needs a break in order to continue with the task, the basic assumption group helps students to achieve their goals. Bion identifies three basic assumption groups: a) pairing, b) fight/ flight, and c) dependency.

The aim of the study

The purpose of this study is to investigate the interaction between adolescents working with mathematics problems in an ICT context. The purpose is specified in two questions:

1. What type of tasks do students work with when they interact in order to solve math problems in an ICT context?
2. How do students communicate when they interact in order to solve math problems in an ICT context?

Method

Design

As my intention is to capture students' everyday activities and processes in the classroom, I prefer to use the ethnographic approach. According to Hammersley and Atkinson (1995), ethnography is a method, or a set of methods, suitable for exploring this kind of phenomenon:

In its most characteristic form, it involves the ethnographer participating, overtly or covertly, in people's daily lives for an extended period of time, watching what happens, listening to what is said, asking questions - in fact, collecting whatever data are available to shed light on issues that are the focus of the research. (Hammersley & Atkinson, 1995, p. 1)

The approach is based on the assumption that the understanding of an action is reached by gaining insight into those ideas or understandings that make the action meaningful. The researcher can observe the behavior of the actors and interview them about their thoughts concerning the activities (Nardi, 1996; Larsson, 2000). I was inspired by ethnography in my effort to understand the interaction in front of a computer screen.

Selection of participants

The criterion for selecting classrooms for the study was that the responsible teachers had demonstrated some interest in using computers in their teaching. During one year, I followed two teachers in their computer-aided teaching of math. This means I had access to 700 math lessons where computers could be used. During this year the teachers chose to use computers in 18 lessons. Every computer-aided lesson was documented in field notes. Eighteen teachers in six municipalities were interviewed. The interviews were tape-recorded.

Analysis

Interviews and observations notes have been analyzed and interpreted in several steps. First, the notes were read from the first to the last letter. During the reading of interviews and field notes, I took notes about my observations in the margins. These notes helped me to construct categories related to learning math using computers. Then I tried to write detailed descriptions (Geertz, 1991) about what was seen in the material. From these descriptions, it is possible to classify several different types of computer-aided lessons. One type of lesson is therefore constructed from several observed lessons. A detailed description, rather than a fragmental description, gives the reader better insight into the everyday interaction between adolescent solving math problems in front of a computer screen. To strengthen an observed phenomenon, quotations from the teacher interviews are used. I also use transcription of dialogs in order to exemplify different phenomena in the classroom. These transcriptions were made during the lesson. They are very short and were easily transcribed.

The following type of lesson is a result of seven observed lessons and 18 teacher interviews. In these 7 lessons most students worked in pairs. They worked together with different math tasks and therefore had to interact and communicate with at least their peer. The description of the lesson type focuses on students' interaction and communication while solving math problems in the classroom.

Results

Tasks and communication

This mini-story describes my observations of students' interaction while solving math problems in an ICT context. The lesson started in an ordinary classroom with one computer. The teacher described the program they would be working with and why students should practice using this program. The program contained different tasks and it was important for students working together to agree on procedure and results. After the information, the students ran down to the computer lab. When I asked a student why she was running, she said that she wanted a computer of her own. There were 25 students competing for 15 computers. When the students arrived in the classroom, they tried to find a computer of their own. Students who came too late sat down next to a friend who heaved a deep sigh because he or she had to collaborate with a classmate. After a while, the students were all sitting either alone in front of the screen or with one friend. They logged in and opened the program they were going to work in.

I was surprised how calmly the lesson began. The students who were collaborating whispered to each other and tried to solve the math problems that popped up on the screen. Students who were working alone focused on their own screen. Interaction with their classmates on other computers did not exist. After approximately ten minutes something happened: the students started to talk to each other in a noisy way. It wasn't just the pairs who were

chatting with each other; the communication took place all over the room. The figures illustrate some of the observed interactions. The letters symbolise both students and computers.

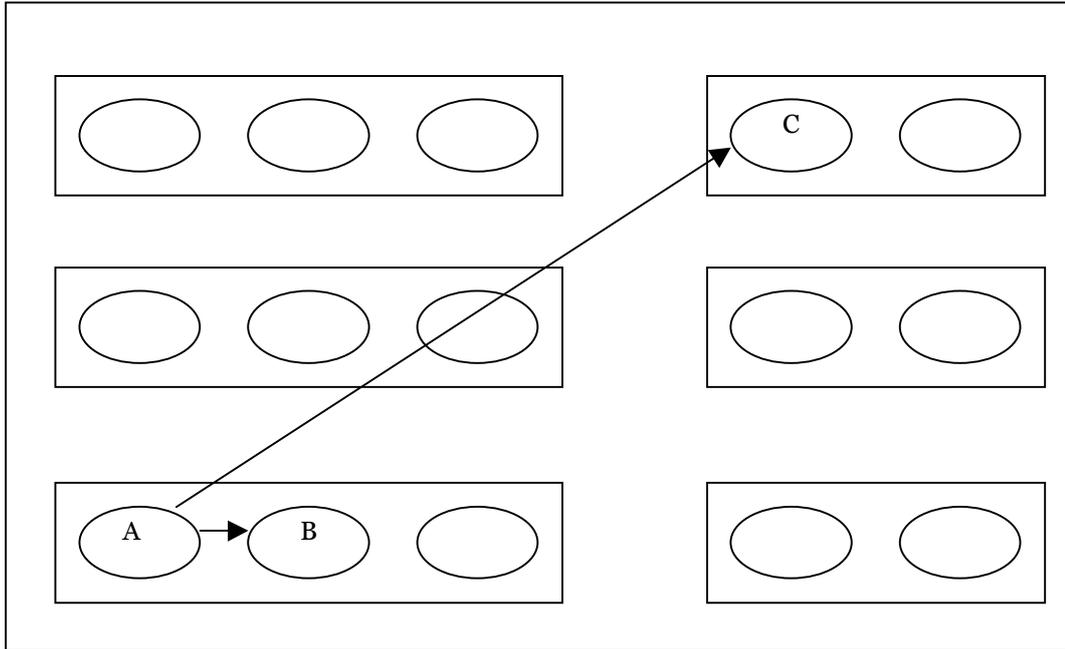


Figure 1. Student A trying to interact with classmates B and C across the room

Student A tried to communicate with classmates in order to get help with the math task he or she couldn't solve. The most common interaction was the one between A and B. If B didn't have the answer to the task, A looked for help from a friend further away in the room (in this case C). Sometimes students shouted out their questions in the room hoping that someone would help them. In most cases, the question remained unanswered. Frequently, the teacher went down to the shouting student and tried to answer his or her question in a less noisy way. The teacher did not correct the student's behavior. To shout out a question in a computer-aided lesson seemed to be acceptable. The ordinary behavior of raising a hand if you need help was not emphasized. If a student was understood to be a good mathematician by classmates, he or she would get many questions during a computer-aided math lesson.

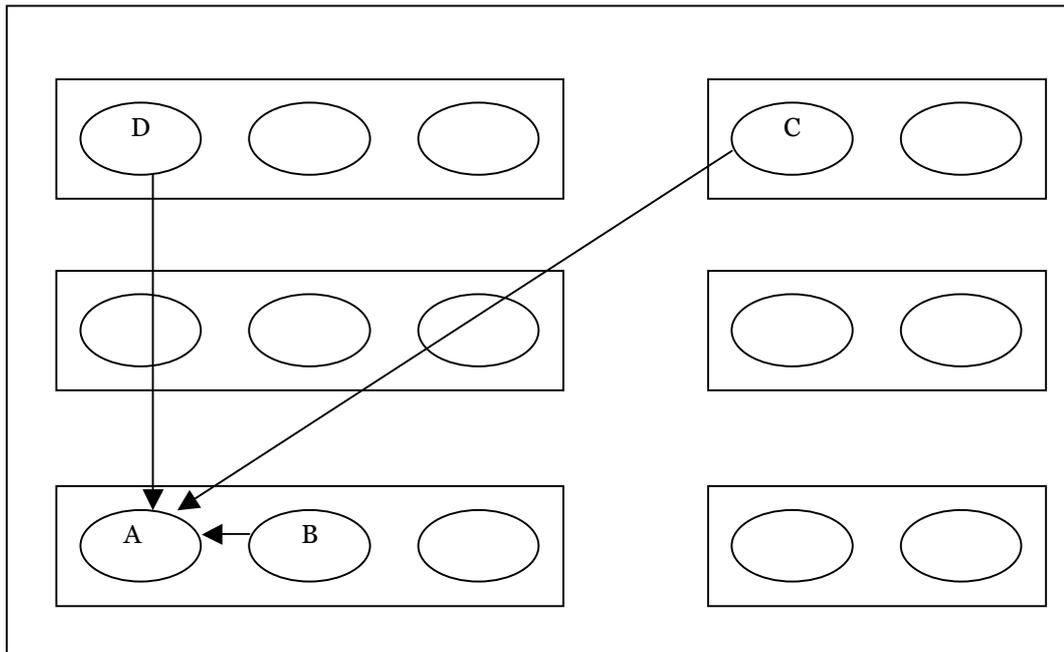


Figure 2. Student B, C and D trying to interact with student A

When the screen and the tasks were visible to people around, it was acceptable to read someone else's screen and help a classmate having difficulty with a task. The tasks in this type of program varied, but in most cases they involved simple arithmetic and were clearly defined. When students looked for help, it was only specific answers they were looking for. I did not notice any deeper discussion about concepts or mathematical relationships in the interactions.

After fifteen minutes, the communication in the classroom increased to a level where the teacher needed to calm the students down. Sometimes a student who asked a classmate for help didn't get any help. All students worked with timed tasks, so to help another student means that you would lose time on your own task. Some of the interviewed teachers described similar experiences.

There's always a lot of communication in the room. They always try to help each other. The problem is when someone is very focused on his or her task, the person doesn't have time to help a classmate (Teacher).

Even though students sometimes chose not to help each other, I still see collaborative activities as a common process in computer-aided math learning.

Looking at the collaborative work where pairs tried to solve tasks presented on the screen, I observed the following interactions:

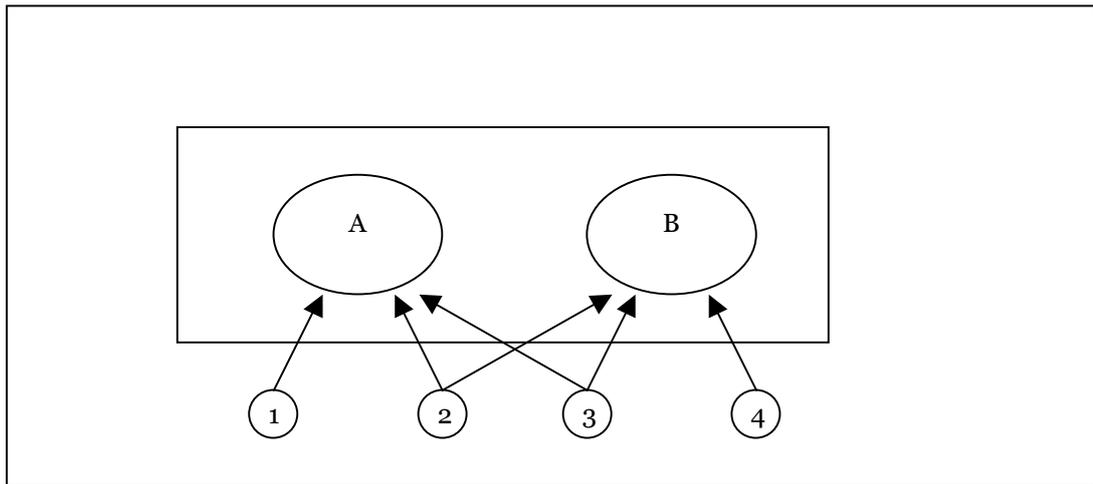


Figure 3. Four students collaborating in front of two computer screens

One student at each computer acted as a navigator (students 1 and 4). Student 2 and 3 controlled both screens and tried to solve problems on both computers (A and B). The four students communicated about what answers they would enter during the whole lesson. Answers were accepted or not accepted by the navigator, whose responsibility it was to enter the response into the computer. Once again, I notice that it was just a short answer that was communicated in the interaction. One teacher described the communication in the following way:

When they work in pairs, they communicate a lot all over the room. If they have questions, they ask everyone they think can help them, regardless of their location (Teacher).

This emphasizes my observations in Figures 1-3 about the communication in the computer-aided math classroom. In order to see how the collaborative work was processed, I walked around in the classroom and observed three different ways in which students collaborated:

- One student navigated the computer and calculated. The other student sat beside him/her and helped to calculate with paper and pencil or a calculator.
- One student navigated the computer and the other delivered answers. The student who delivered answers didn't use any aids to solve the math tasks.
- One student worked and one watched.

One teacher expressed his anxiety about the collaborations described above:

Weak students will not grow when they work in pairs. They just follow the one who is a stronger mathematician. I don't think the collaborative work functions when two students try to solve math problems with a computer (Teacher 4).

When I walked around in the classroom, it was obvious that some students weren't working on the tasks. They just sat and talked to someone or just watched what was happening on the screens. Two students who were working alone turned off the computer when 20 minutes of the lesson had passed:

- *Why did you turn off the computer?*, asked the teacher.
- *I am too tired to work anymore*, replied one of the students.
- *Ok*, said the teacher, *sit down with a friend and try to help him*.

The students who started to work alone with a computer then sat down with a classmate. I doubt that such behavior would be accepted in any regular math lesson. In other words, a student who is tired of working in the textbook would probably not be allowed to sit down with a classmate and help him or her with the math tasks in his book. Further, a student who couldn't manage a task would never be allowed to change books with one of his or her friends in order to get help solving the problems. Several times I observed students using each other in such a way: students who weren't able to move on in the program changed computers with a friend who could manage the problem. When the friend solved the problem, they exchanged computer again.

At the end of the lesson none of the students were working alone. The ones who got tired sat together with one or more classmates. Something very interesting seemed to be on going by one computer. Four students eagerly discussed how to solve a problem presented on the computer screen. When the teacher tried to finish the lesson, these students continued their work, and three more students joined the group. The teacher didn't interfere.

- *We have to solve this before we go*, said the students.
- *I can wait*, said the teacher.
- *But help us then!*
- No, there are so many of you that you can help each other.

After the students had been working for five minutes, they decided to give up.

What a pity, said the teacher, you were so close to solving it.

I have never seen so many students stay and try to help a classmate who was trying to solve a math problem after a regular math lesson.

Analysis and discussion

The purpose of this study was to investigate how students interact when solving math problems in an ICT context. When 25 students run from their regular classroom to a classroom with computers, they all have the intention of working alone with a computer. Almost every middle school, in Sweden, has one or two classrooms with 15 computers each. Teachers and students who go to the classrooms with computers are aware that some of the students will have to collaborate and therefore be obliged to interact. Therefore, collaborative work is an integral part of everyday computer-aided math learning.

Tasks and interaction

Collaboration has been the basis for the development of communities that foster children's learning. The idea is that children and adults are responsible for helping each other to learn (Rogoff, Turkans & Bartlett, 2001). In this study, it is obvious that students sometimes work together, but if they are able to choose, they will work alone on the math problems. Students' motivation to interact could have implications for how they communicate with each other. If a student doesn't want to work together with someone, and he or she has control over the computer, it is possible that this student won't let the classmate participate. If a student does not participate in solving the task, he

or she will not practice any math or computer skills that lesson. The active student practices both his math skills as well as his computer skills.

There is a risk of losing weak students when students collaborate with drill programs in everyday computer-aided math lessons (e.g. Samuelsson, 2003). There are several times in the described lesson where students are not task-oriented. Alexandersson, et. al, 2000 and Alexandersson, 2002 observed that a necessary component of collaborative work is that it is focused on goals. I stress that when students collaborate in order to solve math problems, they do not always focus on the goals of the activity. Groups of students or individuals find excuses for what Bion (1961) would call flight: they run away from the task. Sometimes they try to help a classmate and sometimes they just sit down beside a classmate and talk about something unrelated. For those students, collaborative work (Gabriele & Meegan, 2001) and computers (Dahland, 1993; Galbraith & Haines, 1998; Thomas & Thomas, 1999) do not function as motivational tools.

When students interact, they just focus on getting the right answer. Steiner (1966, 1974, 1976) describes these tasks as disjunctive. One answer must be accepted in the group, and any alternative must be rejected.

When students try to solve problems together, the task could be described as a complementary task (Steiner, 1966, 1974, 1976). To solve such a task, students do different activities. Some students navigate the computer; others calculate with calculators, pen and paper. Different activities affect what students can learn. Students who only navigate computers learn to navigate the computer. If they don't participate in the math activity, they will not practice their math skills. A student who calculates with a calculator or an algorithm is practicing his or her math skills. When students interact in order to solve math problems in an ICT context they oscillate between disjunctive and complementary tasks.

Communication

According to my classroom observations, there was a lot of communication in the classroom. The students communicated all over the room and this was accepted by the teacher. But was it an effective form of communication that will help students to develop higher-order cognitive skills? The teachers in the study have a tendency to focus on language. By providing elaborate explanations, asking appropriate questions, providing sufficient time for a partner to think, and using supporting communication skills with one another, the students can construct a specific world of representations whereby they can detect and conquer the concepts, words and expressions of mathematics. Vygotsky (1986) makes a distinction between scientific concepts and everyday concepts. Scientific concepts are cultivated, whereas everyday concepts are unsystematic and concretely derived. The teachers' intentions to make the students communicate could (theoretically) mean that the students develop their arsenal of scientific mathematical concepts. My empirical data indicate, however, that the linguistic interaction, above all, consisted of one student posing a question and another giving an answer. The different forms of communicative interaction observed also tell us that it is not communication about scientific concepts that the students are involved in. Their communicative ability is therefore not developing to any large extent. Wyndham (2002) suggests that students cannot create a meeting between their everyday concepts and the scientific discourse on their own. This connection may require the teacher's support, which I think is often lacking in computer-aided instruction. Several studies of students' conversations while working at the computer have pointed out this problem (e.g., Ivarsson, 2002; Wyndham, 2002).

Concluding remarks

In my introduction I wrote about the computer as part of information technology (IT). Today the term ICT is often used, where the letter C stands for communication. My results indicate that the computer enhances communication between the learner and him/herself (intra-subjectivity). There are also examples of communication between learners (inter-subjectivity). However, the results do not demonstrate how students, by means of the computer, create virtual classrooms where they communicate with other classes, exchange mathematical problems, or discuss different solutions. ICT, for the most part, remains IT only. The traditional methods of teaching mathematics seem to have such a strong hold that the computer's position as an agent of change is relatively weak. Instead, it seems that the computer is assimilated into existing math teaching traditions as regards both content and form.

Visions in curriculum and governmental documents still remain visions. Idealistic experiments about the computer's possibilities in the teaching process have not reached the classrooms. There are possibilities for change, but very little happens in everyday teaching.

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