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Journal for educational research online 3 (2011) 1, S. 29-55

urn:nbn:de:0111-opus-46810

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Journal for Educational Research Online
Journal für Bildungsforschung Online
Volume 3 (2011), No. 1, 29–55
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Verbal communication at a stand-alone computer

Abstract

The study this article refers to investigates pupils' face-to-face verbal communication at a computer in a mathematics lesson. The pupils (14 years) work in single-gender pairs and each pair shares one computer. The study applies a design-based research approach and consists of two phases. The first phase is a descriptive-analytic phase and the second is an intervention phase. The data material is analyzed using several analytic loops and extensive pupil-teacher-researcher collaboration.

This article reports on the first phase of the study. The pupils use spreadsheet software and work with the mathematical concepts of circumference and area. Six communication patterns are identified and discussed: 1) the level of verbal activity, 2) progressive utterances, 3) to address, 4) to speak in chorus, 5) mutual language, and 6) humor. The patterns are discussed and exemplified through the use of excerpts from the transcriptions. The study contributes to the field of micro-analytic research which describes verbal communication at stand-alone computers in education.

Keywords

Education; Communication patterns; Computer; Mathematics

Verbale Kommunikation an einem Stand-alone-Computer

Zusammenfassung

Dieser Artikel bezieht sich auf eine Studie zur Untersuchung von verbaler Kommunikation (Face-to-Face) zwischen Schülerinnen und Schülern an einem Computer im Mathematikunterricht. Die 14-jährigen Schülerinnen und Schüler arbeiten in gleichgeschlechtlichen Zweiergruppen jeweils an einem gemeinsamen Computer. Der Untersuchungsansatz der Studie ist „design-based" und setzt sich aus zwei Phasen zusammen, einer deskriptiv-analytischen Phase und einer Interventionsphase. Die Daten wurden unter Berücksichtigung mehrerer analytischer Schleifen sowie extensiver Zusammenarbeit von Schülern, Lehrern und Forschern analysiert.

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In diesem Artikel wird über die erste Studienphase berichtet. Die Schülerinnen und Schüler verwenden Programme zur Tabellenkalkulation und arbeiten mit mathematischen Konzepten für Umfänge und Flächen. Es werden sechs verschiedene Kommunikationsmuster identifiziert und diskutiert: 1) der Grad verbaler Aktivität, 2) progressive Äußerungen, 3) die Ansprache, 4) im Chor sprechen, 5) wechselseitiges Sprechen und 6) Humor. Die Muster werden auf Grundlage von Auszügen der Transskriptionen diskutiert und veranschaulicht. Die Studie trägt zur mikro-analytischen Forschung bei, welche die verbale Kommunikation an Stand-alone-Computern in Bildungskontexten beschreibt.

Schlagworte
Bildung; Kommunikationsmuster; Computer; Mathematik

1. Introduction

Over the last ten years, Norway has become a leading country as regards the accessibility of technology in schools and the wider community (Hægeland, Kirkebøen, & Raaum, 2009; The Norwegian Directorate for Education and Training, 2008; Vaage, 2009). There is a need for more knowledge and awareness about how this is influencing our education system, especially regarding the national curriculum (Ministry of Knowledge, 2006). This national curriculum considerably increases the status of ICT as an important basic competence (digital competence), which is obligatory for teachers and pupils in all subjects at all levels (1–13). Norway is the first nation to emphasize digital literacy so clearly in the national curriculum (Krumsvik & Almås, 2009), and this is a significant event in the history of Norwegian education. This, together with high technology density in Norwegian schools (1:1 in upper secondary school) and homes, provides favorable conditions for the implementation of ICT in schools. Nevertheless, a recent study by Hatlevik, Ottestad, Skaug, Kløvstad, and Berge (2009) reveals that despite these new opportunities and policies, the use of ICT in school subjects varies between schools, subjects and teachers. Thus, more knowledge is needed about what kind of ICT use contributes to pupils' learning in order to achieve the National Curriculum's intentions. More knowledge is also needed for the development of a didactic framework for teachers using educational technology.

From a communicative perspective, the concepts of dialogue and reflection have attracted increasing attention in research into mathematics education. However, an extensive amount of research shows that pupils have little time allocated for intellectual enquiry through talk in mathematics and science education (Alseth, Breiteig, & Brekke, 2003; Galton, Hargreaves, Comber, Wall, & Pell, 1999; Newton, Driver, & Osborne, 1999; Wegerif, 1996b). As a consequence of this, and the increased status of ICT in subjects, in syllabi and in exams, there is an urgent need to initiate studies at a micro level, highlighting pupils' interactions when using computers and educational technology in specific subjects. Furthermore, there is a need to conduct research into computer support for discussions *in* the classroom as it is

the context in which pupils most often participate, and it is a context that has not been prioritized by researchers (Overdijk & Diggelen, 2009).

This article refers to the first phase of a one year, small scale, *design-based research* study. The study consists of two phases, and the overarching emphasis is on gaining knowledge about the relationships between communication quality and learning quality in a non-networked computer context. The first phase was conducted during the 2009 spring semester and aimed to investigate how 14-year-old pupils communicate when working in pairs at a stand-alone computer. This first phase is non-interventional and provides the groundwork for phase two, the intervention part of the study. The focus of the first phase is on communication and learning processes, not learning outcomes. Gaining knowledge of communicative processes is important in order to enhance pupils' learning. Consequently, the research question addressed in this article is: What characterizes pupils' verbal communication at a stand-alone computer in a mathematics lesson? Identifying and illuminating communication patterns is of special interest.

In research into computers and learning, different terms are sometimes used for the same phenomenon and different phenomena are sometimes given the same term. In order to achieve a more uniform terminology, Crook (1994) outlines four different social configurations whereby computers enter into learning activities: collaborative interaction *with* computers (a computer-based tutor), collaborative interaction *around* and *through* computers (interaction can be asynchronous and participants not co-present), collaborative interaction *in relation to* computers (collaborators able to refer to previous computer experience), and collaborative interaction *at* computers. The latter expression is used in this article and it is also incorporated in the research question. Communication at computers is face-to-face communication when pupils, usually in pairs, "[...] work on the same computer-based problem at the same time" (Crook, 1994, p. 148).

2. Theoretical framework

2.1 Relevant research

Much of the research literature on communication and learning at computers relates to the work of Barnes and Todd (1978) and Sinclair and Coulthard (1975). Barnes and Todd identified three different types of talk in small groups: disputational, cumulative and explorative talk. Disputational talk is characterized by disagreement and individualism. In cumulative talk, pupils build on each other's utterances, but in an uncritical manner. Within explorative talk there is no immediate acceptance of views, as in uncritical acceptance. Nor is there an immediate rejection as a quick defense of one's own knowledge or viewpoints. On the contrary, in explorative talk there are challenges and disagreement within a collaborative environment. Sinclair and Coulthard identified the Initiative-Response-Feedback (IRF) communication structure in secondary school classrooms. This structure is teacher

dominated – the teacher makes an initiative, the pupil gives a response, the teacher evaluates – which leaves little room for more investigative and flexible communication patterns. Neither Barnes and Todd's nor Sinclair and Coulthard's research dealt with computer settings. The emphasis on communication at computers started in the 1990s when Fisher (1993) identified IRF communication structures and Mercer (1994) identified Barnes and Todd's three types of talk in pupils' communication at computers.

In an overview of the research literature within face-to-face communication and learning at computers, Herheim (2010) extracts four areas that are focused on in the literature. Two of them are particularly relevant for this article. The first is the *common ground* aspect. A common ground is a shared frame of reference, and as Teasley and Roschelle (1993) argue, a body of shared knowledge. Solving a task is not only about solving the actual task, but also about developing a common ground. Effective communication requires a shared understanding of the task, and a minimum of shared language and knowledge (Stahl, 2005). Two of the communication patterns identified and discussed in this article, addressing and mutual language, are closely related to the common ground discussion.

The second focus area identified by Herheim (2010) that is of relevance for this article concerns *communication characteristics*. Typical communicative aspects that are highlighted as being important for pupils' learning are thinking aloud (Kieran, 2001; Monaghan, 2005) and shared decision making (Healy, Pozzi, & Hoyles, 1995). Many researchers, e.g. Alrø and Skovsmose (2002), emphasize verbalization: to share information, to pay attention to each other's perspectives, and justify, challenge and evaluate these perspectives. Researchers like Teasley and Roschelle (1993) and Healy et al. (1995) were among the first to accentuate the importance of verbalization and building and maintaining channels of communication in computer settings. Wegerif (1996b) investigates how keywords can be indicators of exploratory talk. This article discusses the importance of the word *wait*. Wegerif (e.g. 1996a) integrates the aspect of discussion in IRF communication structures. His research context is pupil dyads or triads and their communication at computers, and the D in his IDRF-structure is the part where pupils discuss a matter rather than giving an immediate response to the computer's initiative. The six communication patterns identified and discussed in this article are all situated within this discussion aspect introduced by Wegerif.

According to a review by Prinsen, Volman, and Terwel (2007) on gender-related differences in Computer-Supported Collaborative Learning (CSCL) there are, particularly for mixed-gender pairs (e.g. Underwood, Underwood, & Wood, 2000), gender differences. The differences found are "... in line with gender differences in conversational styles that are found more generally" (Prinsen et al., 2007, p. 406). Boys try to dominate discussions and to control the keyboard or mouse (Baker & Andriessen, 2009). This "transfer" of gender differences is also documented by Ding, Bosker, and Harskamp (2011). In single-gender pairs the gender differences are less pronounced. However, Underwood and Underwood (1998) also identi-

fy differences between girl-girl and boy-boy pairs: girl-girl pairs are more willing to collaborate, they compare and evaluate ideas, they ask more questions and are generally more verbally active than boy-boy pairs. Girls joke and laugh and are more relaxed about working together. In boy-boy pairs each boy takes his turn to write and the other member is then "off-task". Underwood and Underwood also found that girl-girl pairs collaborate whatever instructions they are given, while boy-boy pairs collaborate if they are encouraged and instructed to do so.

2.2 Theoretical perspective

This study focuses on learning that takes place within a social context. Language, communication, and collaboration are key theoretical concepts, and they are vital in order to understand what characterizes pairs' communication at computers. Vygotsky's (1996) theory on how individuals' productive interaction with others is mediated through the use of tools, and language being the most important tool, serves as an important theoretical foundation. Vygotsky accentuates that pupils' learning takes place in *the zone of proximal development*. This zone constitutes the potential for what pupils can learn through communication with a co-pupil and/or the teacher. Furthermore, the knowledge achieved in collaborative learning "... may not be attributable as originating from any particular individual" (Stahl, 2005, p. 81). Knowledge is distributed among the participants. The focus in this article on communication patterns stems from this theoretical viewpoint of language, communication, collaborative learning and knowledge.

Language and communication is regarded as the connecting link between individual construction and social interaction. Skjervheim (1996) stresses that man has language, and human interaction and development takes place mainly by means *of* language and *in* the language. Learning is a process in which language, communicative abilities and knowledge about a field's existing norms and rules are developed. Language is viewed as the cornerstone for the acquiring of understanding: "[L]anguage is the universal medium in which understanding occurs" (Gadamer, 2004, p. 390). One of the keys for collaborative learning is the ability to ask questions – to see what is questionable (Gadamer & Linge, 1977). If pupils that work in pairs are able to enquire about the same subject matter, if they respond to each other's ideas and intuitive conceptions, then they are genuine participants (Skjervheim, 1996). This is related to Lave and Wenger's (1991) view of learning as becoming a competent participant in a community of practice.

Several theoretical contributions that are relevant to this study have been made within the CSCL paradigm, see Stahl, Koschmann, and Suthers (2006). CSCL is a research field which investigates how to support collaborative learning when using computers. Research in CSCL mainly deals with online, written communication. This study is situated in a small segment of CSCL which deals with face-to-face, verbal communication at stand-alone computers. CSCL is strongly influenced

by Vygotsky and his emphasis on the inter-psychological dimension of learning and the focus on the role of language in intellectual development (Koschmann, 1996). Research in CSCL focuses on collaborative small group settings and some of this research has a pronounced focus on relationships between communication and learning, e.g. Wegerif, Mercer, and Dawes (1998). Collaborative learning and understanding is a key issue within CSCL. The common ground theory developed by Clark and Brennan (1991) is an important basis as collaborative learning requires mutual understanding among the participants, a minimum of shared language and knowledge (Stahl, 2005). This study follows Koschmann (1996) and his definition of collaborative learning as becoming a member of knowledge communities and as a mutual effort to solve a task together.

The connections between learning and talking are discussed by both Sfard and Kieran (2001) and Alrø and Skovsmose (2002). They underline collaboration and talking as important parts of pupils' learning. Cuban (2001) underlines that a computer does not improve pupils learning in itself. Equivalently, learning by talking cannot be taken for granted and there are certain communicative qualities that must be effectuated. This study's emphasis on communicative patterns adds to this discussion.

3. Method

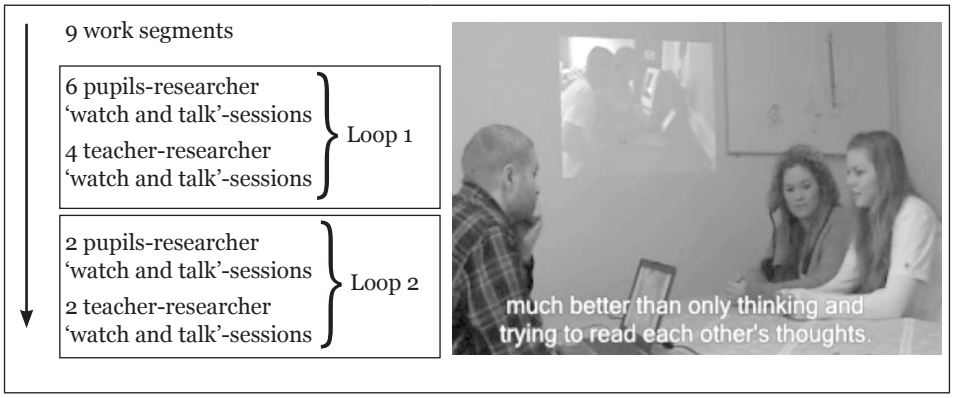
Hitchcock and Hughes (1995) argue that methods and data collection techniques are influenced by the methodological foundation. The methodological underpinning of this study is design-based research, which has its roots in the work of Brown (1992) and Collins (1992). The approach involves a special focus on context sensitiveness and collaborative research (Wang & Hannafin, 2005). It is a methodology for educational interventions and aims to encourage a better understanding of the interplay between theory and practice. It generates knowledge that is informative for other teachers and researchers. The focus of this article is to understand and map the current situation, which is the first step of design-based research. The Design-Based Research Collective (2003) highlights iterative cycles of development and collaborative research as key aspects. This study's emphasis on involving pupils and teachers in the research process and the extensive use of analytic loops reflects those aspects.

3.1 Participants, video recording and analysis loops

The data collection period of phase 1 of the study lasted four months, but the most important and intensive part was conducted during February 2009. One school, two grade nine classes, three teachers, and nine single-gender (five boy-boy and four girl-girl) pairs of pupils participated. One work segment of each of the nine pairs was observed and video recorded. A work segment lasted between 20 to 30 minutes and entailed two pupils working in a computer setting. A stand-alone video camera with an external microphone recorded the pairs perpendicularly from one side, capturing both verbal and non-verbal communication. A screen recorder was used to capture the pupils' activities on the computer. In the recording period the researcher made field notes and was an *observer as participant* (Merriam, 1998).

Six of the nine work segments were subsequently discussed and analyzed collaboratively through a pupils-teachers-researcher collaboration. These six recordings were analyzed because the recordings were of good quality and the pupils wanted to take part in the subsequent analytic process. The six pairs watched and discussed their work along with the researcher. Four of these six segments were also watched and discussed by the involved teacher and the researcher. These ten 'watch and talk' sessions constitute loop 1 of the analytic process, see Figure 1. The recordings were seen in their entirety during loop 1, and these 'watch and talk' sessions were also video recorded, see still shot in Figure 1.

Figure 1: To the left: Overview of the research process, the work segments and the two loops of analysis
To the right: A still shot from a loop 1 session. The pupils' work segment is played on the wall



Note. The use of pictures is approved by the parents or guardians and the Norwegian Social Science Data Services.

In order to generate more in-depth discussions and strengthen the trustworthiness of the study, one more 'watch and talk' session was arranged. Based on the dis-

cussions in loop 1, the work segments from two of the pairs emerged as particularly interesting, for two reasons: First, these pupils were interested in participating in a follow-up discussion of their work segment. Second, and most importantly, it became apparent during loop 1 that these two pairs' communication entailed many distinct and interesting communicative aspects. The two pairs' work segments seemed to be two very different examples of communication at computers. Hence, these two work segments were scrutinized in a follow-up loop 2, see Figure 1. The same collaborative analytic approach was applied as in loop 1. However, in loop 2 some key moments from the pupils' work segments were singled out in order to narrow the discussion and to generate more in-depth reflections. These key moments were elected based on the joint analysis of loop 1. Working with contrasting examples evolved as an effective way to identify communication patterns and to gain insight into what characterizes the communication in this computer context.

The four pupils were Laura and Mary in pair 1 and Eric and Rick in pair 2. The teacher was asked to describe the four pupils with regard to their level of achievement, their technological competency and their communicative skills. The teacher regarded Eric and Rick as above average achievers and highly technological competent. Eric was regarded as more competent than Rick as regards communicative skills. Laura was regarded as an above average achiever and Mary as a below average achiever, while both of them were regarded as having a medium level of technological competence and good communicative skills. These four pupils were used to working in pairs. However, Laura and Mary have worked together more often than Eric and Rick. Neither the research question nor the research design entailed a gender perspective. Yet, gender issues are reflected upon of two reasons: (1) the communicative patterns identified in this study confirm some of the results from research on gender differences, and (2) gender cannot be neglected when dealing with group work and computers (Ding, 2009).

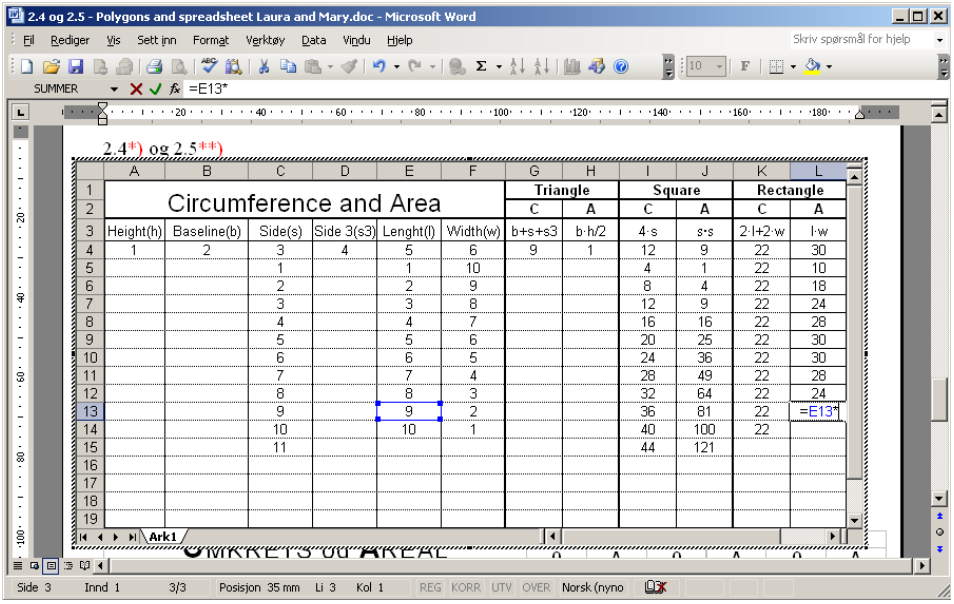
The video recordings of the work segments are transcribed in their entirety. The parts of the 'watch and talk' sessions which included relevant discussions according to the research question are also transcribed. Through these research processes, six communication patterns and three communication triangles have been developed. The patterns originate from the pupils' work segments and they are developed through the collaborative analytic process described above.

3.2 The task

All of the nine pairs worked on the same task. The learning aim of the task was twofold. The task was mathematical and concerned circumference and area, how these two concepts are related, and how one of them varies when the other is kept constant. The other aspect was how to become a competent user of the spreadsheet in general and of the dragging function in particular. The pupils faced both geometrical and spreadsheet challenges. However, large parts of the geometry were

merely repetition for most of the pupils. A major part of the pupils' communication deals with how they should utilize different functions of the spreadsheet.

Figure 2: A screen shot of the screen recording of pair 1's work on the computer



Note. This screen shot is a reproduction by the authors in order to anonymize the pupils and to translate the work into English.

The spreadsheet, which was pasted into a word document, included different aspects of geometry. When the pupils worked with the rectangle, the length and width values were decided by the teacher. When the pupils had filled out most of the cells in the two right columns, the teacher could ask the pupils why the circumference does not change and about when and why there is a maximum area. The task was a well-structured problem (Jonassen, 2000).

3.3 Data coding and analysis

When Bergmann (2004) describes conversation analysis he describes it as a "breaking-down" process, splitting transcriptions into small(er) units of meaning by a systematic process of comparing. Further analysis of these categories makes it possible to better discover connections and to find answers to the research questions. This is in line with the unadapted hermeneutic circle, to better understand the whole by looking at the parts. However, as Flick (2006) points out, the process of splitting into smaller and smaller units may lead to decontextualized and isolated pieces of utterances. In addition, it only illuminates the whole by examination of the parts and not vice versa. It is only one half of a hermeneutical circle. Thus,

in this study an additional complementary analytic approach is applied. In order to understand and single out important communication patters one also analyses larger components of communication or a work segment in its entirety. Rather than trying to deconstruct the communication, patterns are identified using a holistic approach. The parts are illuminated by examining larger parts or the whole. The analysis focuses on communication sequences and pays attention to the context of the statements (Flick, 2006). This combination of the two analytic approaches illuminates a pair's communication by reflecting it within a complete hermeneutic circle.

The pupils and the teacher were not familiar with theoretical data analysis. Still, they were able to identify and describe communicative patterns and make important comments, corrections and individual contributions to the generation of patterns. The researcher did the majority of the work on the data material, e.g. the transcriptions and the technical work with the video recordings, but the pupils and the teacher were genuine participants (Skjervheim, 1996) throughout the research process.

During the 'watch and talk' sessions the focus of attention was on communication patterns. The unit of analysis was the communication between pupils, teacher (when present) and the computer. In the CSCL paradigm, the unit of analysis is the group and not the individual mind as in previous versions of instructional technology research (Koschmann, 1996). It was a search for patterns by locating interesting episodes. The process of applying analytic loops was inspired by Kvale's (1996) three contexts of interpretation: self-understanding (the interviewee), critical understanding based on common sense, and theoretical understanding. The analysis relates to Merriam's (1998) *constant comparative method* and Kvale's (1996) *meaning categorization*. These analytic approaches emphasize a 'code and retrieve' process, a search for stable, meaningful units and finding expressions to label these units. This type of categorization makes it possible to single out important communication patterns. Much of the terminology presented in Table 2 is a phrasing or a rephrasing of pupils' and teacher's utterances.

3.4 Validity

To enhance internal validity, the study uses multiple investigators, multiple sources, and multiple data collection techniques and methods to establish emerging findings. This kind of triangulation decreases well known validity threats such as researcher "bias" and reactivity (Maxwell, 2005). This is of special importance in the study, since a design-based research approach is applied and the pupils-teachers-researcher collaboration is a cornerstone of the research's design. The findings of the six communication patterns presented in this article underwent multiple steps of inquiry before they became patterns. In loop 1, a potential pattern may just be indicated in the discussion with the pupils or/and the teacher. During loop 2 a more distinct pattern emerged through more focused discussions. Member checks

(respondent validation) and collaborative modes of research (Maxwell, 2005) are conducted to enhance the study's credibility and trustworthiness. Colleagues' comments on findings are an additional source in this respect. In this way, Kvale's (1996) three validation communities have been used to enhance the internal validity.

Additional data material is collected by the researcher's field notes, screen recording and the documents with pupils' finished work. The two latter sources were important in order to make the transcriptions useful according to the research focus (Kvale, 1996). Whenever it was difficult to grasp the content of the pupils' communication, the screen recording served as a very helpful clarifying tool. Video recordings with high sound and picture quality contribute to the research's reliability. Likewise, the focus on the audit trail of the research process makes the findings more consistent and dependable. The audit trail, together with the descriptions and the information on typicality, should also give the readers a basis for comparison.

4. Findings and discussion

What characterizes communication when pairs of pupils use a computer in a mathematics lesson? To answer this question the study emphasizes identifying communication patterns. Analysis of the data material highlights several communicative patterns which may prove valuable for the understanding of this educational context.

Observation and video recording provide both visual and auditory data material. Oral communication was analyzed in-depth and arose from questions like: what is said and not said, how is it said, when is it said, why is it said, and who says what. There are, however, some immediate visual signs from the video recordings, no sound required, that can be investigated. These signs concern issues such as how do the pupils sit, where do they look, and who uses the keyboard and the mouse. A closer look at pair 1, on the left picture in Figure 3, shows two pupils who sit closely together. Their focus of attention jumps back and forth between the laptop and their partner. At one second one of them uses the keyboard, the other the mouse. At the next second the roles are reversed. Sometimes there are four hands simultaneously on the keyboard. The computer is situated in the middle; it is shared by the pupils. They are sitting on the edge of their chairs, leaning a bit against the computer and a bit on their partner. The two pupils and the computer are, as one of the teachers describes it, as in a bubble. Nothing seems to disturb them.

Figure 3: Still shots from the work segments of pair 1 and pair 2

Pair 2, on the right picture in Figure 3, shows a quite different type of co-work. Two pupils sit as far apart as possible within the limits of still calling it pair work. One pupil controls the keyboard and the mouse and, when the computer is portable, quite often moves the computer closer to himself. The other stares into space and twists his fingers. Every now and then the pupil who controls the computer turns it over to his partner. This is an exchange of roles which often occurs when a task is finished or a problem has proven to be too difficult to be solved alone. The computer is moved back and forth. It looks like individual work in a pair. These observations of pair 1 and 2 are in line with the findings of Underwood and Underwood (1998) and Sanders (2006): The girls collaborate; they work together on all parts of the problem. The boys cooperate; they divide the work between themselves.

An interesting aspect of the communication in this context is the degree to which the pupils are verbally active. Table 1 shows a simple quantification of the number of utterances in pair 1 and pair 2.

Table 1: Number of utterances

Pair 1, 23 minutes		Pair 2, 24 minutes	
Laura:	275	Rick:	42
Mary:	244	Eric:	108
Both:	25	Both:	0
Teacher:	34	Teacher:	116
Total:	578	Total:	266

The two pairs' work segments are of approximately the same duration but with huge differences with respect to the number of utterances. Pair 1 makes almost four times as many utterances as pair 2. And, furthermore, the teacher makes almost four times as many utterances with pair 2 than she does with pair 1. Most of the utterances by both pairs have to be reckoned as short ones. Pair 2's low number of utterances is then not compensated by entailing lengthier utterances.

The silent periods, the periods where it seems like it is only one of the pupils who is active, are more frequent and long lasting with pair 2. This indicates that the probability that pair 2 has achieved something together and taken advantage of each other's knowledge and reasoning abilities is lower than for pair 1. The teacher's more active role with pair 2 contributes to more verbal activity when the teacher is present. One can assume that the teacher also tried to establish a communicative foundation, a common ground (Stahl, 2005), for pair 2 so that they would also discuss the sub-seeding questions when they are on their own, to some degree. However, during the periods when the pupils pair 2 work on their own, the level of communicative activity is much lower than when the teacher is present and also when compared to pair 1. These different levels of verbal activity between the girls in pair 1 and the boys in pair 2 is in accordance with Underwood and Underwood's (1998) research. The level of verbal activity is further explored in the discussion of pattern number 1 below.

A quantitative discussion does not reflect much about the content or the characteristics of the pupils' utterances. Both of the pairs' talk is task oriented, but as pointed out in section 3.2, more focused towards spreadsheet challenges than mathematics. In the following, a qualitative description of six communication patterns gives a more in-depth inquiry into what characterizes the verbal part of communication at computers. The patterns in table 2 will be reflected upon chronologically and exemplified by dialogue excerpts from the transcriptions. The discussion about pattern number 1 includes excerpts from the pupils' work segments and from both analytic loops. These extracts and the discussion are illustrative of the research process. The succeeding five patterns are generated through the same analytic process.

Table 2: Six communication patterns

	Pair 1	Pair 2
1	Verbal style, think aloud, 'talk and write' Many (short) utterances, in rapid succession	Write directly on computer Long periods of silence
2	Drive (mutual), progression: "Let's go on!"	Individual progression Teacher as driving force
3	Teacher often addresses both of the pupils Pupils use *we* and *us*	Teacher often addresses *one* pupil Pupils rarely use *we* or *us*
4	Speak 'in chorus' 'Huey, Dewey and Louie' talk	Two individual/parallel conversations
5	Repeat what the other says Uses the same linguistic turns	Little amount of mutual language
6	Laughter/humor, speak positively about their work. Supportive	No/little amount of laughter and support

4.1 Pattern no. 1: Level of verbal activity

The pupils in pair 1 have a verbal style. Laura and Mary verbalize almost every move they make on the computer. Their communication is compounded by many short utterances in rapid succession. As mentioned in the description of the task, parts of the communication are more technical than mathematical:

Excerpt 1: Pair 1's work segment

[14:31.23]	Laura:	No, no, no. What did I do now?
[14:34.13]	Mary:	No, multiplication, it *is* correct.
[14:35.28]	Laura:	But we have to ... forgot plus.
[14:37.07]	Mary:	No, we *have* plus.
[14:39.14]	Laura:	But it is not just that, because it is 18 ... One more time. One more time.
[14:43.05]	Mary:	What?
[14:44.12]	Laura:	Ok, check this out. We just do ...
[14:45.12]	Both:	2 times ... (in chorus)
[14:48.04]	Mary:	... the first.
[14:49.03]	Laura:	Aha! No, I was wrong.
[14:50.20]	Mary:	Yes.
[14:50.29]	Laura:	Sorry.
[14:51.21]	Mary:	Exactly.

In this excerpt, the pupils are doing the first cells on the circumference of the rectangle so that they are able to use the spreadsheet's dragging function. Excerpt 1 lasts only 20 seconds. Still, they manage 13 on-task utterances. This excerpt is representative of their verbal activity. Every move on the keyboard is part of a mutual activity and an utterance takes into consideration the previous utterance. In this excerpt the pupils face a problem when they get a calculation wrong because of a technical error. Characteristically, they express their suggestions back and forth throughout the excerpt to solve the matter. Their communication does not follow an IRF (initiative-response-feedback) communication structure, as identified by Sinclair and Coulthard (1975) and then also by Fisher (1993), in educational settings with computers. The pupils are critical but constructive with each other's ideas, for instance when Laura says "But it is not just that, because it is 18 ...". This are features that Mercer (1995) ascribes to the concept of exploratory talk.

Sinclair (2005) highlighted the aspect of *inviting* as important in stimulating communication. The pupils in pair 1 invite each other due to the way they express themselves, by their tone of voice and their choice of words. There are also examples which more specifically invite the other to generate mutual reasoning, e.g. when, in the excerpt above, Laura says "check this out".

Both of the pupils and the teacher took part in the analysis of this work segment. Laura and Mary accentuate the importance of their verbal style in loop 1 of the analytic process:

Excerpt 2: Loop 1, 'watch and talk' with pair 1

[25:40.28] Laura: Can't read each other's thoughts ... Then it's easier to think aloud so that the other understands the way we think, maybe.
[25:49.12] Mary: Yes, understands (unclear)

[26:12.06] Laura: We are maybe three pupils speaking in chorus and writing, and then ... I don't know. It has just become a habit.
[26:19.12] Mary: Yes
[26:20.16] Rune: Yes, ok. Mhm.
[26:21.19] Mary: But I think that it works much better than just thinking ... and then trying to read each other's thoughts. It's not possible.
[26:27.13] Laura: To try to understand what the other does while he is writing ... ooh, can't you just think aloud instead?

The pupils point out the importance of *thinking aloud*. They say that if you have to read each other's thoughts it is not possible to communicate. Research by Alrø and Skovsmose (2002), Monaghan (2005), and Kieran (2001), for example, shows that thinking aloud is a vital aspect of pupils' communication. Understanding what the other thinks is a necessary prerequisite for communication.

The teacher focuses on Laura and Mary's roles when, in the following excerpt, she comments on the pupils' mutual engagement:

Excerpt 3: Loop 1, 'watch and talk' with teacher about pair 1's work segment

[16:21.22] Teacher: They both participate.
[16:25.00] Rune: Yes, they do. Not only on the keyboard, but ...
[16:30.00] Teacher: No, in the dialogue as well

[18:46.12] Teacher: They both engage in the same thought process
[18:49.08] Rune: Yes
[18:50.25] Teacher: That is very good

[19:25.14] Rune: They speak ... speak in chorus?
[19:27.17] Teacher: (Laughs). To articulate is important.

The teacher points out that both Laura and Mary are participants and that both of them engage in the same thought process. Skjervheim's (1996) disjunction *participant-spectator* serves as a relevant theoretical perspective in this respect. The pupils focus their attention on the same subject matter, they engage in the same thought process. They are both participants and engaged in the same subject matter. This way of interacting, which involves two people and one subject matter, is termed *a triangular relationship* by Skjervheim.

In opposition to this, there is the much less verbal style of pair 2, Eric and Rick. They have long periods without any talk. The pupil who controls the keyboard makes his adjustments and additions directly onto the computer without consulting his partner. In Skjervheim's terminology, the other pupil is just a spectator. There is neither a joint focus nor a joint thought process. When they do speak

there are often only short exchanges. During these periods without talk, one pupil works on the computer and the other is sporadically involved. The next excerpt is a descriptive example of how the pupils in pair 1 write directly on the computer and the concurrent period of silence. The pupils are challenged by the teacher to explain why there is a maximum value for the area of the rectangle. Eric and Rick have trouble coming up with an explanation. Their progression is faltering until Rick speaks up:

Excerpt 4: Pair 2's work segment

[22:17.15] Rick: Hey, I got it.
(Rick moves the computer closer to himself and starts writing an explanation. Eric stares into space, and the next utterance does not occur until 54 seconds later)

Rick says he got it, but he does not say anything about what he has figured out. He simply takes charge over the computer and starts writing without talking. This makes it difficult to initiate a discussion. By writing his idea directly onto the computer without any verbal accompaniment, Rick does not invite Eric to join him in his reasoning. Kieran (2001) has an identical finding, in which one of the pupils states he has figured out something but this something is never quite discussed. The screen recording shows that Rick is not quite able to write an explanation. Despite the fact that Rick finds it difficult to articulate his thoughts in writing, Eric does not get involved. The pupils' communication shows signs of being two individual conversations which co-exist as parallel lines.

Baker and Andriessen (2009) claim that boys often try to dominate discussions and to control the keyboard. Ding (2009) and Prinsen, Volman, Terwel, and van den Eeden's (2009) results within online communication show that while girls ask more questions and provide more intuitive conceptions, boys tend to make more authoritative answers. The authoritative utterance made by Rick and the lack of questions and suggestions by the boys in Excerpt 4 largely confirms these results. As Gadamer and Linge (1977) emphasize, the girls seem to gain an advantage by being able to see what is questionable. They develop a mutual engagement and can both be regarded as participants, while the boys develop an alternating engagement and they alternately play the part of the spectator (Skjervheim, 1996).

Naturally, one possibility could be that Eric reads what Rick has written and thereby establishes a mutual point of departure for discussing the matter. However, writing something straight into the computer could give the impression of something that is almost finalized. Instead of being inviting and stimulating, it could effectively bring a discussion to an end. This is reinforced by the fact that Rick, by saying "I got it", presents his idea as the final answer. When Eric and Rick see their work segment for the second time and a clip of Laura and Mary's segment to get a basis for comparison, their comments are:

Excerpt 5: Loop 2, 'watch and talk' with pair 2

[16:14.25] Rick: It was not very much talking. It was more like we divided the work between us.
[16:18.29] Rune: Mhm.
[16:19.22] Eric: Yes.

Damon and Phelps (1989), just like Underwood and Underwood (1998), distinguish between cooperative and collaborative interaction. Damon and Phelps emphasize that cooperation is low in mutuality, while collaboration is high in mutuality. Based on pair 2's own opinion they worked individually on separate parts of the task. This confirms the visual observations discussed at the beginning of chapter four that Eric and Rick cooperate while Laura and Mary collaborate. This aspect of mutuality is also central to the discussions of the following patterns.

4.2 Pattern no. 2: The drive

Progression, the drive, whether the pairs cooperate or collaborate, is an important aspect. It is two sided: There is the drive and the urge to go on – a forward thrust, and there is the will to get to the bottom of the matter. There are several situations during a work segment when pupils reach a kind of intermediate split, for instance when something unclear is clarified or a task is finished. In pair 1, at these intermediate points the pupils have a strong drive to go on working. Typical driving utterances are:

Excerpt 6

[09:57.22] Laura: Ok, let's go on.
[10:31.26] Mary: Ok, let's drag.
[25:15.13] Laura: Two, I believe we did, we chose one there. Anyhow, let's continue.

The three utterances above are all utterances which are quite distinctly intended to enhance progression. The language used by Laura and Mary in these utterances also reveals an underlying collaborative attitude. Both of the pupils use *let's* to promote the progression. This choice of words illustrates that the work and the progression concerns both of the pupils, and is a part of the process of maintaining and nurturing what Stahl (2005) terms a common ground for the girls.

For pair 2, there is a different situation. The progression is faltering and when there is progression it is an individual one. In pair 1 the pupils themselves are the driving forces. For pair 2, the teacher is the one that mostly serves the task of progression:

Excerpt 7: Five of the teacher's driving utterances from pair 2's work segment

[04:55.04]	Teacher:	Then you can do that and see what happens.
[05:31.09]	Teacher:	Do a new side length ...
[07:08.01]	Teacher:	... then you can try to find the area.
[08:40.00]	Teacher:	Now you shall do the rectangle.
[11:20.26]	Teacher:	And then the next.

All five utterances in the excerpt above show the teacher as a driving force. The pupils make few contributions to enhance mutual progression. The absence of expressions like "Let's do this!" or "Let's try that!" strengthen the impression that Eric and Rick only alternately take responsibility for their progression.

4.3 Pattern no. 3: Addressing

The driving utterances in Excerpts 6 and 7 illuminate another communication pattern, namely addressing. Laura and Mary use pronouns as *us* and *we* when they describe what they have done and when they plan what to do next. The social dimension of their learning is clear, their common ground is strengthened. They ask each other questions, and utterances are addressed to the other or to the both of them. They act as a unit. The girls generate knowledge together, they become more and more competent participants in this learning context (Lave & Wenger, 1991). The teacher also mostly addresses both Laura and Mary.[1] The matter of addressing is an important factor to stimulate pupils' communication. Alrø and Skovsmose (2002) also relate to this when they talk about *tuning into each other* in order to establish the contact that is essential for the ability to collaborate.

For pair 2, the teacher does address both pupils to a certain extent, but these parts are succeeded by periods where she gets more involved with only one of the pupils. In the first and the third utterances in Excerpt 7 the teacher addresses only one of the pupils, while in the fourth she addresses both of them. It seems as if the pupils are partially considered to be one unit and partially two individual pupils.

One additional aspect of addressing appears in the following excerpt from pair 2's work segment:

Excerpt 8

[11:31.16]	Teacher:	Yes, try that one.
		(Eric works and the teacher leaves without Eric noticing.)
[11:42.01]	Eric:	Plus, plus ... like that. Oops, is that correct? (Addresses the teacher)
		(10 seconds silence)

1 In English the pronoun *you* is used when addressing both one and more. In Norwegian there is a pronoun, *du*, to address one person and another, *dere*, to address more than one. This analysis on addressing can therefore be based on the verbal activity alone. Unfortunately, these linguistic differences are lost in translation.

When the teacher is present the pupils tend to address only the teacher, not their partner. Eric speaks a bit too loudly to be addressing Rick and he also turns in the direction of where the teacher was standing a few seconds earlier. Rick did not answer the question, which may illustrate how clearly Eric addresses his question to the teacher. These seconds with Eric's question: "... is that correct?", his search for the teacher, and Rick's silence, form a strong example of how the presence of a teacher can influence pupils' communication.

4.4 Pattern no. 4: 'Huey, Dewey and Louie' talk

When the pupils were left on their own there were pronounced differences in how they communicated. In pair 1, on several occasions the pupils appear to be a verbal version of synchronized swimmers. They speak in chorus, either completely or at least completing sentences together. It is very much like Donald Duck's three nephews, Huey, Dewey and Louie. They are noted for sometimes finishing each other's sentences or composing sentences where each of them alternately makes a short contribution. This is also the case for pair 1 and one example goes like this:

Excerpt 9

[25:46.06]	Mary:	Baseline
[25:47.12]	Laura:	Baseline
[25:48.06]	Mary:	multiplied by
[25:48.24]	Laura:	altitude
[25:50.02]	Mary:	divided by
[25:50.20]	Laura:	2
[25:51.07]	Both:	equals (in chorus)

In the last utterance the pupils speak in chorus and complete the sentence together, as identified by Sinclair (2005), Kieran (2001), and Teasley and Roschelle (1993). The six utterances prior to that form a good example of how the pupils alternately participated in mutual talk. There is not only mutual talk at a general level; even at the sentence level Laura and Mary drive communication forward through a mutual effort and they construct sentences together. This mode of speaking and thinking also applies to lengthier reasoning, in which the pupils take part and alternately make small contributions to develop a larger, joint reasoning. It is a mutual conversation. These collaborative communicative patterns are not found in pair 2. Many utterances are never followed up and many utterances do not invite a follow up either. One of the most illustrative examples of this is when Rick, in Excerpt 1, says "I got it" and then immediately starts writing on the computer. Such statements do not encourage discussion; they quite effectively close the door on any mutual communication.

4.5 Pattern no. 5: Mutual language

When one looks at the words and the linguistic turns used by the pupils, there are some patterns that can be seen in the communication of pair 1. Quite often one of the pupils repeats what the other pupil says. One example is the two first utterances in Excerpt 9, above, when Mary starts by saying baseline and one second later this is followed up by Laura, who repeats what Mary said. One more example:

Excerpt 10

[09:07.04] Laura: Yes. Yep.
[09:09.10] Mary: Yep.

Such repetitions are most common in the following utterance, but there could also be a repeat of something the other pupil said earlier on in the discussion. A related characteristic appears when a pupil uses the same choice of words as her partner. This is most obvious when a pupil has a somewhat odd phrase that is adopted in the language of the other pupil. Such linguistic turns can then occur repeatedly throughout the pupils' communication and contribute to the pupils' common linguistic ground. The girls develop a mutual vocabulary; they develop the medium where knowledge can be generated (Gadamer, 2004).

Wegerif (1996b) and Monaghan (2005) deal with how focusing on pupils' usage of *keywords* can serve as an indicator of exploratory talk, and Wagner and Herbel-Eisenmann (2008) examine how the word *just* can be used to suppress or invite dialogue. The excerpt below exemplifies how the word *wait* was used by Laura and Mary:

Excerpt 11: Six wait-utterances

[11:55.24] Laura: Yes. Multiply, wait. Plus
[14:05.07] Mary: Wait, wait, wait, multiply, where's the plus?
[16:57.27] Laura: It, oops ... equals, yes. No, wait, wait, wait.
[17:41.13] Laura: No, wait a moment. Baseline plus s plus s3?
[20:51.08] Mary: Ah ... wait, wait a minute, need the length as well.
[26:09.16] Laura: Ok wait then, just have to, I feel I'm losing control.

The word wait is used multiple times by Laura and Mary, and it is used with a particular function. It seems as if, for instance in the second and the fourth utterance, that they see something they do not understand. They ask for a break to clarify things. They do not build uncritically on each other's utterances, so it is not what Mercer and Wegerif (e.g. 1998) would term cumulative talk. The uninhibited urge to ask the other to 'wait a minute' indicates that Laura and Mary have established an environment in which a space is created that invites discussion.

These characteristics are mainly absent for pair 2. It is hard to identify any mutual language or keywords that could indicate the creation of any collabora-

tive space. The pupils seem to keep their own language, to stick to their own arguments, and to stay with their own idea of how to solve a task.

4.6 Pattern no. 6: Humor

One of the characteristics of pair 1's work is the amount of humor and laughter. Short but frequent laughs are mingled with their on-task work:

Excerpt 12

[07:53.20] Laura: (laughter). This one is probably wrong.
[07:58.15] Mary: No, no, go a bit further.
[08:00.03] Laura: No, it is not that. Oh! (Rough laughter)
[08:02.06] Mary: (Laughter).

It seems as Laura and Mary are having a good time and enjoy being part of this context. They laugh together, and the humor unites them. This corresponds well with Underwood and Underwood's (1998) result that girls joke and laugh and are more relaxed about working together. In pair 2's work segment there is rarely any laughter. The pupils' body language and limited verbal activity indicate that they are a bit bored. Their work is colored by the fact that this is something they *have* to do and in a context that they do not necessarily think is their favorite one.

In association with humor and laughter, it is appropriate to bring up a related communicative aspect from the work of pair 1, namely that of speaking positively about their work. This includes acknowledging your partner's and your own contributions, and giving credit for *how* the contributions are conducted:

Excerpt 13: Supportive, talking positively about their work

[11:40.15] Mary: There.
[11:41.26] Laura: Great!

[12:08.02] Mary: Can you do that one?
[12:09.59] Laura: Yes.
[12:11.00] Mary: (gives Laura a thumbs-up)

[21:20.21] Both: (High fives and laughter)

Utterances like "Great!" and gestures like thumbs-up are supportive and keep up good spirits. In some sense, they can also be regarded as meta-knowledge. The pupils are showing and developing consciousness about their own work processes when they recognize a good argument or a good decision.

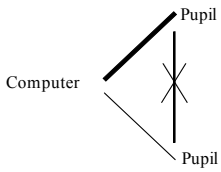
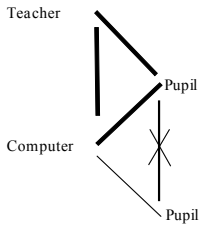
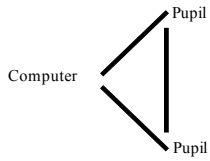
5. Concluding comments

Six communication patterns are illuminated through the analysis and discussion of communication at computers. This analysis gives insight into general communicative patterns through looking at details, as well as insight into details in the light of a holistic perspective. For instance, the analysis of how Laura and Mary use the word wait generates knowledge about their collaborative environment, and is an example of how examination of parts can illuminate the whole. In Excerpt 5 Rick sums up his and Eric's work by saying "There was not very much talking". This holistic comment provides a basis for better understanding Rick's utterance, "I got it". The cyclical analysis of hermeneutics is compatible with the iterative style of design-based research.

The six patterns which are identified, exemplified and discussed in this article are: 1) the level of verbal activity, 2) progressive utterances, 3) to address, 4) to speak in chorus, 5) mutual language, and 6) humor. The focus on communication patterns and linguistic details adds to a growing body of micro-analytic research which describes the communication in computer contexts in education.

These six patterns can be related to communicative roles. Three communication triangles have been developed in this study to visualize three different role patterns:

Table 3: Communication pattern triangles

Communication triangle I	Communication triangle II	Communication triangle III
		
One of the pupils communicates with the computer, but not with his partner.	The teacher, one pupil and the computer communicate, while the other pupil is more like a spectator.	Pupils communicate with each other, with the teacher and with the computer.

Two communication triangles have been developed on the basis of the interaction for pair 2. In a context with two pupils and one computer there are three "players". This gives the pupil two 'points of reference' – the pupil with whom he is working and the computer. For a pair such as pair 2, the pupils have frequent, long-lasting periods where they do not talk to each other. One dominant communication pattern is that only one pupil works and this pupil communicates only with the computer. This is illustrated with a bold line between the computer and one of the

pupils in communication triangle I in Table 3. The bold line represents Eric and Rick's individual use of the computer, their individual progression, and their low amount of mutual language. The characteristics of all Eric and Rick's six patterns fit this communication triangle.

The presence of the teacher adds one more player. Analysis of pair 2's communication when the teacher is involved shows increased verbal activity. However, it is largely a conversation between only one of the pupils and the teacher. This is also highlighted in the discussion in section 4.3, where the teacher tends to address only one of the pupils. Furthermore, the pupils tend to address the teacher and the computer and not their partner. This is illustrated by communication triangle II.

The pairs have the opportunity to take a break from the computer screen, sit back and discuss the task and their next move. This discussion part is the D of Wegerif's (1996a) IDRF structure, a revision of Sinclair and Coulthard's (1975) IRF structure. Pair 1 uses this possibility. Sometimes it is only for a few seconds, to discuss an input from the computer, but also for longer periods if they need to summarize, get organized and find out what to do next. Looking at pair 1's communication, one finds that the pupils communicate with each other and with the computer. This is illustrated by three bold lines in communication triangle III. This triangle illustrates Laura and Mary's mutual use of the computer, their mutual progression and the large amount of mutual language. All of Laura and Mary's six communication patterns fit this triangle.

A great deal of research (e.g. Kruger, 1993) shows the importance of pupils' ability to participate in a community, to express themselves, to communicate, and to develop their language. This is also emphasized as a basic competence in the national curriculum in Norway. Laura and Mary develop their communicative abilities to a much greater extent than Eric and Rick. This can prove important in their future learning. However, Laura and Mary's lack of mathematical in-depth communication, and Eric and Rick's general lack of communication, confirms the results of many researchers (e.g. Monaghan, 2005; Nussbaum et al., 2009; Sfard & Kieran, 2001): collaboration does not yield learning in itself.

There are several potential limitations to this study. It is a small-scale study with only one researcher, three teachers and eighteen pupils. Larger projects with several researchers can manage more extensive data material and have the possibility to conduct processes like intercoder reliability. There are also clear limitations as regards how one can generalize from a small-scale study like this. The reflections on how this study confirms gender differences may seem somewhat strong if all of the nine pairs' work segments are taken into consideration. The two pairs discussed in this article can be seen as two extremes, but the rest of the pairs were distributed across the scale with no clear gender differences. It is also worth noticing that the review by Prinsen et al. (2007) reveals that a great deal of research on gender in CSCL still has to be done. Furthermore, the small amount of research conducted on gender differences provides more tendencies, and to some extent diverging tendencies, than convincing results.

This study has several interesting methodical aspects that can be further refined in future research. The inclusion of pupils as co-researchers throughout several analytical loops is an exciting and fruitful approach. The extensive use of video recording has proved to be important as it captures so much of the action, and it provides an arena in which pupils, teachers and the researcher can watch and discuss the previous day's work together. This approach makes a joint analytical process possible. The study has added more knowledge about what characterizes pupils' communication at stand-alone computers by describing and analyzing six communication patterns. However, a natural focus for further research would be to analyze and develop a communicative approach, which to a larger extent entails in-depth subject matter discussions. There is also a need for more micro-studies in classrooms in future research, where pupils use research-based (e.g. Mayer, 2009), transparent ICT tools in mathematics as a new gateway to subject matter discussions and knowledge construction.

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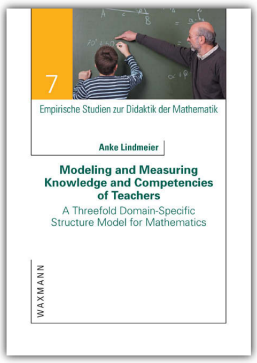
WAXMANN

Recent studies used content knowledge and pedagogical content knowledge as predicting variables for expertise in order to explain success in student learning for example. In this book, potential disadvantages of these approaches are analyzed: Acting competent in classroom situations demands more dispose of content and pedagogical content knowledge. Central topic is the analysis and description of these domain-specific competencies. Therefore, the study proposes a model compatible with existing approaches. It consists of 3 components of domain-specific competencies: First, a basic component of mathematical and mathematical pedagogical knowledge, second, reflective competencies, and third, action-related competencies.



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Modeling and Measuring Knowledge and Competencies of Teachers
A Threefold Domain-Specific Structure Model for Mathematics

Empirische Studien zur Didaktik der Mathematik Band 7
2010, 232 pages, pb, 29,90 €,
ISBN 978-3-8309-2453-1

Waxmann Verlag GmbH
Steinfurter Straße 555
48159 Münster
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