FROM INTERACTIVE SMALL GROUP AND CLASSROOM LEARNING TOWARD NETWORKING MINDS IN A TECHNOLOGY-SUPPORTED COLLABORATIVE MATHEMATICS LEARNING ENVIRONMENT

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Abstract

In this presentation two related studies addressing children's mathematics word problem solving are discussed. Taking into account the flaws observed in many primary school pupils' solution processes on word problems, a first intervention study was carried out in which an innovative, constructivist learning environment focusing on the development of a mindful, strategic, and self-regulated approach toward mathematical problem solving was designed and successfully implemented in four fifth-grade classes. The basic design principles of this new classroom environment relate to: 1) the nature of the word problems used, 2) the use of a variety of highly interactive and collaborative instructional methods, 3) the creation of a new classroom climate by introducing alternative social and sociomathematical norms. In a second study this learning environment was technologically enriched by embedding in it "Knowledge Forum", a software tool designed to facilitate and foster a "research team" approach to learning that supports knowledge building, collaboration, and progressive inquiry. Key features in "Knowledge Forum" are a series of cognitive tools for constructing and storing notes, for sharing notes and exchanging comments on them, and for scaffolding students in their acquisition of specific cognitive and metacognitive strategies and particular mathematical concepts. The design of these two collaborative learning environments and the results of their implementation (only preliminary findings of the second study) are presented and discussed.

Introduction

There is nowadays a clear consensus that the acquisition of mathematical problem-solving skills and attitudes and the ability to apply these skills in real-life situations, constitute major objectives of mathematics education at the elementary school level (see e.g., Ministerie van de Vlaamse Gemeenschap, 1997; National Council of Teachers of Mathematics, 1989; Treffers & De Moor, 1990). Unfortunately, recent research findings have revealed that many upper elementary school children do not, or at least insufficiently, master the different aptitudes required to approach mathematical application problems in an efficient and successful way (for more details, see De Corte, Greer, & Verschaffel, 1996; Lester, Garofalo & Kroll; 1989; Schoenfeld, 1992; Verschaffel, in press). According to most scholars, these insufficiencies in pupils' abilities to solve context-based mathematical application problems are induced and shaped by the following characteristics of the current practice and culture of teaching and learning word problem solving: 1) the stereotype nature of the problems used in the lessons in word problem solving; 2) the way in which these problems are dealt with in the mathematics lessons: pupils mainly solve word problems individually by means of fixed standard problem-solving procedures explained and demonstrated by the teacher; 3) the prevailing culture of the mathematics classroom (De Corte et al, 1996; Greer, 1997; Reusser & Stebler, 1997; Schoenfeld, 1992; Verschaffel, 1999)

Over the past decade several scholars have begun to design and evaluate alternative instructional environments aimed at the development of mathematical problem-solving skills in pupils of the upper elementary school or the first grades of secondary school, in so-called 'design experiments' (Brown, 1992; Collins, 1992). The present contribution reports two studies in which a powerful teaching/learning environment for solving mathematical application problems for upper elementary school pupils was designed and implemented. In the first investigation a technology-lean, but innovative learning environment was elaborated, based on general theoretical knowledge about powerful learning environments and on three recent design experiments in which these insights were applied to learn to solve mathematical application problems (Cognition & Technology Group at Vanderbilt, 1997; Lester et al, 1989; Verschaffel & De Corte, 1997). In a second study the theoretical ideas and principles relating to socio-constructive mathematics learning and to teachers' professional development derived from the previous intervention study, were combined with a second strand of theory and research focusing on the (meta-)cognitive aspects of networked collaborative knowledge construction and skill building elicited and supported by "Knowledge Forum", a software tool designed to facilitate and foster a "research team" approach to (mathematics) learning. Key features in "Knowledge Forum" are a series of cognitive tools for constructing and storing notes, for sharing notes and exchanging comments on them, and for scaffolding students in their acquisition of specific cognitive and metacognitive strategies and particular mathematical concepts. For a more detailed report of both studies we refer to Verschaffel, De Corte, Lasure, Van Vaerenbergh, Bogaerts, & Ratinckx (in press) and De Corte, Verschaffel, Lowyck, Dhert, & Vandeput (1999).

Study 1

Design of an interactive powerful learning environment for mathematical problem solving

Aims, major features, and organization of the learning environment

The major aim of the learning environment developed in the first study was the acquisition by fifth graders of a series of heuristic methods embedded in an overall metacognitive strategy for solving mathematical application problems. The overall strategy consists of five stages: 1) representing the problem; 2) building a mathematical model of the problem; 3) operating on that model; 4) interpreting the outcome and formulating an answer: 5) checking and evaluating the solution. In the first and second stage of this strategy eight heuristics are embedded, that are crucial for expert solving of word problems as recent research has clearly documented (De Corte, 1995; De Corte et al, 1996; Lester et al, 1989; Schoenfeld, 1992; Verschaffel, 1999). For instance, in the first step of the strategy the following four heuristics were taught: drawing a picture, making a table, distinguishing relevant from irrelevant data, and using real-world knowledge to complete one's problem representation.

A second important aim of the learning environment was affecting positively the inadequate beliefs and negative attitudes that many pupils hold towards math and solving word problems. Examples are the beliefs that math problems have only one right answer, that there is only one correct way to solve any mathematical problem, that being able to solve a word problem is a mere question of luck, that the mathematics learned in school has little or nothing to do with the real world,... (De Corte, 1995; Schoenfeld, 1992; Verschaffel, 1999).

The main features of the learning environment are the following:

1. A varied set of carefully designed non-traditional complex, realistic and challenging word problems that ask for the application of the intended heuristics and self-regulatory skills that constitute the model of skilled problem solving.
2. A series of lesson plans based on a variety of teacher and learner activities. Each lesson consists of a sequence of small-group problem-solving activities or individual assignments, always followed by a whole-class discussion. During all these activities the teacher's role is to encourage and scaffold pupils to engage in, and to reflect upon the kinds of cognitive and metacognitive activities involved in the model of competent mathematical problem solving. These encouragements and scaffolds are gradually withdrawn as the pupils become more competent in and aware of their problem-solving activity, and thus take more responsibility for their own learning and problem solving.
3. The establishment of new social and socio-mathematical norms about respectively the role of the teacher and the pupils in the (mathematics) classroom, and about what counts as a good mathematical problem, a good solution procedure, or a good response.

The learning environment consists of a series of 20 lessons designed by the research team in consultation with the four regular class teachers, and taught by those teachers. Consequently these teachers were intensively prepared for and supported during the implementation of the learning environment. With two lesson periods each week, the intervention was spread over about three months. The total series involves three parts:

1. Introduction to the content and the organization of the learning environment (1 lesson);
2. Systematic acquisition of the five-step problem-solving model, and the embedded heuristics and cognitive strategies (15 lessons);
3. Learning to use in a flexible and integrated way all aspects of the competent problem-solving model in four "project lessons", each of which was built around only one complex, non-routine problem.

Design of the study

The implementation and the effectiveness of the learning environment were tested using a pretest-posttest- retention test design with four experimental fifth-grade classes (with 27, 19, 21, and 19 pupils respectively) and seven comparable control classes (with 29, 22, 19, 21, 20, 17, and 18 pupils respectively) from eleven different schools in Flanders.

Three pretests were collectively administered in the experimental as well as the control classes: 1) a standard achievement test (SAT) to assess pupils' general mathematical knowledge and skills; 2) a self-made word problem test (WPT) consisting of ten mathematical application problems, none of which can be considered as routine tasks for a typical fifth grader; 3) a self-made Likert-type questionnaire for assessing pupils' beliefs about and attitudes towards (BAQ) (learning and teaching) mathematical word problem solving involving two reliable subscales: a first scale (seven items) dealing with “Pupils’ pleasure and persistence in solving word problems”, and a second subscale (14 items) expressing “A process-oriented view of word problem solving”.

To get a better insight into the qualitative aspects of the pupils' problem-solving processes, three pairs of pupils from each experimental class (one pair of high-ability, one pair of medium-ability, and one pair of low-ability pupils) were asked before the intervention to solve five new non-routine application problems in dyads of equal ability. Their problem-solving processes were videotaped and afterwards analyzed by means of a self-made scoring scheme consisting of three aspects: (1) the final result of the problem-solving process (‘correct answer’, ‘wrong answer’, ‘technical error’ or ‘no answer’); (2) the use of the eight heuristics taught in the learning environment, and (3) the frequency of occurrence of certain valuable metacognitive activities (i.e. orientation, planning, monitoring, and evaluation).

While the intervention took place in the experimental classes, the control classes followed the regular mathematics program.

By the end of the intervention parallel versions of the three collective tests (SAT, WPT, and BAQ) were administered in all experimental and control classes. In order to assess the possible qualitative changes in the problem-solving activities as compared to before the intervention, the dyads of pupils from the experimental classes were again videotaped while solving parallel versions of the non-routine problems used in the pretest phase.

Several months after the implementation of the learning environment a retention test - a parallel version of the WPTs used as pretesst and posttest - was also administered to the experimental and the control classes.

Finally, to assess the fidelity of implementation of the learning environment a sample of four representative lessons was videotaped in each experimental class, and analyzed afterwards in terms of an implementation profile consisting of ten categories of teacher activities that were considered as crucial for the successful implementation of the intervention.

Results

The impact of the learning environment on pupils' results on the three collective instruments (i.e. WPT, BAQ, and SAT) was analyzed by means of univariate analyses of variance with a hierarchical factorial design. Main and interaction effects were further analyzed with a posteriori Tukey HSD tests. Moreover, to get a better idea of the statistical power of the obtained effects, effect sizes Cohen's (1988) were calculated. The most important outcomes of these and several additional analyses can be summarized as follows.

While no significant difference was found between the experimental and control groups on the WPT during the pretest, the former significantly outperformed the latter during the posttest, and this difference in favour of the experimental group continued to exist on the retention test. This effect has a medium effect size of .31. A separate analysis of variance (with the number of problems in the WPT for which at least one of the eight taught heuristics was effectively used, as dependent variable) revealed that the improvement in the WPT scores of the experimental pupils was accompanied by a very substantial increase in the application of the heuristics (effect size = .76).

The experimental group scored significantly higher than the control group on both subscales of the beliefs ans attitudes questionnaire (BAQ) after the intervention, while the scores of both groups did not differ before the intervention. But these effects, though significant, were both small (effect sizes of only .04).

While there was no significant difference between the pretest results on the SAT of the experimental and the control groups, the results on the posttest revealed a significant difference in favour of the former group (effect size = .38). This indicates that the greater attention in the experimental classes at problem solving (at the expense of the more traditional subject-matter topics) had no negative effect, and even a small positive (transfer) effect on pupils' mathematical knowledge and skills as a whole.

Additional analyses of variance on the data of the WPT, the BAQ, and the SAT showed that there was no significant interaction between the factors Group (Exp. vs Con), Test moment (Pretest vs Posttest), and Ability Level (High, Medium, and Low). From these results we can conclude that all three ability levels contributed in a significant way to the increased overall learning results observed in the experimental group. On the other hand, we have to admit that the initial differences between high-ability and low-ability pupils did not decrease.

The results of the qualitative analysis of the videotapes of the problem-solving processes of the three dyads from each experimental class showed that on the posttest pupils made in general nearly twice as much spontaneously use of heuristics as during the pretest. The occurrence of the four metacognitive activities (namely orientation, planning, monitoring, and evaluation) increased as well from pretest to posttest, but this increase was smaller than expected.

The analysis of the videotapes of the experimental lessons in terms of the implementation profile indicated that overall the learning environment was implemented in a satisfactory way in the experimental classes But, an analysis of variance on the implementation scores revealed that there were significant differences in the extent to which these four teachers had implemented the major aspects of the learning environment.

Conclusion and transition

In this intervention study a set of carefully designed application problems, a varied series of highly interactive teaching methods, and an attempt to change the social and socio-mathematical classroom norms were combined in an attempt to create a powerful learning environment that focuses at the development in fifth-graders of a mindful and self-regulated approach toward mathematical modeling and problem solving. The findings indicate that this intervention can have significant positive effects on different aspects of pupils'mathematical modeling ability, on their self-regulation of, and performance in problem-solving, and on their beliefs about (learning and teaching) mathematics. There is no doubt that this investigation has some limitations; for instance, the experimental group consisted of only four classes, and because of the quasi-experimental design of the study due to the complexity of the intervention, it is impossible to draw conclusions about the relative contribution of the different components of the novel learning environment to the observed positive effects. Nevertheless, these results encouraged us to combine in a second study the theoretical ideas and principles of socioconstructivist mathematics learning with a second strand of theory and research focusing on the (meta)-cognitive aspects of computer-supported collaborative knowledge construction and skill building. Taking into account the available empirical evidence showing that computer-supported collaborative learning (CSCL) is a promising lever for the improvement of learning and instruction (Lehtinen, Hakkarainen, Lipponen, Rahikainen, & Muukkonen, 1999), we assumed that the learning environment designed in the previous study could be made more powerful by enriching it with a CSCL component.

Study 2

Networking minds in a technology-supported and problem-oriented learning environment

Background and aims of the study

This study is part of the CL-Net project (Computer-Supported Collaborative Learning Networks in Primary and Secondary Education) supported by the European Union, and involving nine research centers in five countries. The overall aim of the CL-Net project is to examine how knowledge construction and skill building can be fostered in primary and secondary school pupils in different content domains by immersing them under the guidance of a teacher in computer-supported collaborative learning networks (CLNs). CLNs can be characterized as powerful learning environments in which technology-based cognitive tools are embedded as means and resources that can elicit and mediate in a community of networked learners active and progressively more self-regulated processes of collaborative knowledge acquisition, meaning construction, and problem solving (Verschaffel, Lowyck, De Corte, Dhert, & Vandeput, 1998).

Within this broader framework of the CL-Net project the present investigation aims at the design, implementation, and evaluation of a CSCL environment that facilitates the distributed learning of solving and posing complex mathematical application problems in upper primary school children. As in the previous study the learning environment focuses on the acquisition in pupils of the five-step metacognitive strategy and the embedded heuristics for solving problems, as well as on affecting positively their beliefs and attitudes toward mathematical problem solving. In addition the CSCL environment aims at fostering in pupils communication and collaboration skills relating to problem solving and problem posing, on the one hand, and computer skills, on the other, especially proficiency in working, learning, and communicating with CSCL software. The basic hypothesis of the present investigation is that the technological enrichment of the learning environment from the preceding intervention study by embedding in it the cognitive technological tools that constitute a CLN, will lead to a significant improvement in the quality of upper primary school pupils' problem-solving and communication processes and skills, and, by doing so, will result in greater learning effects. In addition the study intends to explore and elaborate an effective strategy to guide and support teachers in the embedded appropriate use of cognitive technological tools in their teaching of mathematical problem solving.

Key features and implementation of the CSCL environment

The same basic design principles as in Study 1 were also used in developing the CSCL environment, namely 1) a varied set of non-traditional, complex, and challenging word problems; 2) the use of different highly interactive instructional techniques, i.e. small-group work followed by whole-class discussion; 3) the creation of a novel classroom culture based on new social and socio-mathematical norms established through negotiation in the community of learners in the class. However, this environment was enriched by embedding in it “Knowledge Forum” (KF), a software tool which - like its predecessor CSILE (Computer-Supported Intentional Learning Environment, Scardamalia & Bereiter, 1992) - is designed to foster a networked “research team” approach to learning that supports knowledge building, collaboration, and progressive inquiry. Key features in “Knowledge” Forum are a series of cognitive tools for constructing and storing notes, for sharing notes and exchanging comments on them, and for scaffolding students in their acquisition of specific cognitive operations and particular concepts (Scardamalia & Bereiter, 1998; see also Verschaffel et al., 1998).

Based on theoretical arguments but also forced by practical circumstances, the use of KF was different from how it has been conceived and mostly applied so far. First, instead of having individual pupils communicate with each other, small groups of pupils were taken as the unit of communication. In other words, there was "shared authorship" of every pupil note created in KF. Second, rather than having the normal class teacher communicate with the pupils through KF, there was a cartoon-like figure - called FIXIT - who introduced problems to pupils, provided them with help and feedback, and communicated with them via KF. However, this does not imply that the teachers' role was marginal. They remained responsible for the classroom management, for the coaching of the group work, and for the organization of the whole-class discussions. Third, whereas in most previous studies the communication through KF was entirely open and unstructured, pupils' use of KF in our CSCL environment was initially quite restricted and teacher-regulated; more intensive and self-regulated involvement with KF increased gradually as pupils became more familiar with the expert five-step model of solving mathematical application problems and with the software.

The implementation of the KF-based learning environment took place in the second and third trimesters of the school year 1998-99 in two fifth-grade and two sixth-grade classes of a primary school in Flanders. Each class was equipped with one computer with a printer and an Internet connection which allowed them to access KF. In addition, pupils and teachers had regular access to a computer classroom (of the adjacent secondary school) with 15 computers all networked to a common file server with an Internet connection and a data projector.

Although the preparation of all teaching materials and the interaction with the pupils via KF was done by the researchers (through FIXIT), the lessons were taught by the regular classroom teachers, who were – as mentioned above - also responsible for the coaching of the pupils during the small-group activities and for the leadership of the whole-class discussion. For the four participating teachers the introduction of the CSCL environment amounted to the adoption and implementation of a fundamentally new role and pedagogy based on a technology-supported, collaborative, and self-regulated perspective on learning. Therefore, substantial attention was paid to prepare and support the teachers in implementing the learning environment, taking as a starting point that the intended fundamental change of the classroom environment and culture should be undertaken in partnership between the researchers and the participating teachers (De Corte, in press). In that perspective a substantial part of the teacher preparation has been realized by simulating the new approach to learning and teaching problem solving supported by cognitive technological tools, in the format of an interaction between the researchers and the teachers, both groups taking turns in acting as teachers and as pupils. In addition a KF database for the teachers was installed consisting of three parts: background information about the learning environment, a discusion forum for the exchange of positive experiences as well as difficulties, and a hotline for making practical arrangements, asking specific questions, and transmitting instructional materials. Also a specific teacher guide for each lesson, and all the necessary teaching and learning materials were provided to the teachers.

Specification of the content and the activities in the CSCL learning environment

The implementation of the learning environment ran from January till the end of May 1999, and consisted of five stages, each composed of several teaching/learning units (TLU). Overall, each class spent about two hours a week in the CSCL environment, resulting in a total of 30 to 35 hours.

Stage 1: two TLUs of one week each in which the problem-solving model and KF were introduced to the pupils. In the first TLU, consisting of two lessons, pupils reflected on the difference between a routine task and a real mathematical problem, and the five-step solution strategy was presented and explored. In TLU 2 (two lessons) pupils were initiated in KF in the computer class; it was the only unit not taught by the regular classroom teacher but by one of the researchers. After a demonstration of the major characteristics and facilities of the system and the distribution of a simple "technical manual", pupils were put in heterogeneous small groups of three children (which would remain the same during the whole intervention), and were invited to read a KF note with a provocative statement ("The TV program 'the Simpsons' should be forbidden"), to react to it by creating a KF note, to read each others' KF notes, and finally to comment on each others' reactions by means of notes that built on the notes of other groups.

Stage 2: three TLUs (TLU 3-5) of one week each during which pupils solved complex mathematical application problems. Each TLU had the same overall structure. In a first one-hour lesson in the beginning of the week pupils worked in their small groups on a problem given to them through KF by FIXIT. As a scaffold they received a pre-structured worksheet (containing the five steps of the problem-solving model) on which they had to write down not only the answer but also their solution steps; they could also ask strategic help by looking at FIXIT's help note available on KF. During the next days the reporters of all groups went simultaneously to the computer class, where they imported the solution but also the solution strategy of their group in KF. At the end of the week, the teacher organized a whole-class discussion and reflection about the problem, the way it had been solved by the different groups, and the role of KF in the solution process. For this discussion the teachers and the pupils could partly rely on a reaction note from FIXIT with some general comments on the correctness of the answers and the quality of the solutions.

Stage 3: three TLUs (TLU 6-8) of two weeks each during which pupils continued to work on complex application problems, but under different conditions. First of all, the scaffold (= the pre-structured worksheet) aimed at having pupils approach the problem in a systematic way was gradually withdrawn. Moreover, the exchange of ideas between pupils through KF was intensified by having them read and comment on each others' notes (each group had to create at least one note reacting to another group's solution), and edit their own response notes based on the comments given by others. This communication via KF was done after the reporters had imported the response note of their own group, and before the whole-class discussion and reflection at the end of the two-week period.

Stage 4: two TLUs (TLU 9-10) of two weeks each during which every group had to pose a problem and put it on KF at the beginning of the unit. Afterwards each group had to act as the expert and coach for its own posed problem during the rest of that unit. As usual, this problem-posing task was introduced by means of a KF note from FIXIT, who also made a help note for those groups who had great difficulty with this task. Because the pupils had little or no prior experience with posing problems, each class was given a folder with copies of photographs and short articles from recent newspapers or other popular publications (such as the well-known Guinness Book of Records) - all dealing with remarkable quantities or measurements. Every group was invited to select an article in this folder as a starting point for the construction of their problem. After the reporters of the groups has imported the self-made problems as problem notes in KF, pupils went to the computer class where they were instructed to read and solve one problem posed by another group. They were asked to put their solution into KF, but also to react to the response note of the group who had solved "their" problem, and, finally, to read the reaction note made by the group who "owned" the problem they had solved. Thus, compared to the previous stages, the interactions and the exchanges of KF-notes were more intensive, more dynamic, and more flexible. The units ended also in this stage with a whole-class discussion, in which the quality of the problem-posing and problem-solving activity in the groups was evaluated, as well as the quality of the groups' reactions to each others' problem solutions.

Stage 5: only one TLU (TLU 11) in which the pupils from all four classes got involved in an international two-week exchange project with several classes of 11-12-year-old pupils from an elementary school in Amsterdam, The Netherlands. Those Dutch classes participated also in the CL-Net project, and had too experimented with using KF for learning and teaching mathematical problem solving during the weeks before this exchange project. Before the Dutch and Flemish pupils actually started to exchange problems and solutions, they were invited by FIXIT to present themselves, their schools, and their cities to each other through KF. To guarantee that every self-made problem would be addressed by at least one group, FIXIT proposed a list of pairs consisting of one group of Dutch and one group of Flemish pupils who had to communicate with each other. As in stage 4, both groups forming a pair had to pose a problem to each other, to solve the problem created by the other group, to read the other group's solution of their own problem and write a reaction note, and to read the reaction note written by the other group.

Research instruments for measuring the effects of the CSCL environment

Before and after the intervention the following instruments were collectively administered in the two fifth-grade and the two sixth-grade classes in which the learning environment was implemented.

A paper-and-pencil word problem test (WPT): two parallel versions of the WPT constructed in Study 1, and consisting of ten non-routine mathematical application problems, were used as pretest and posttest.

A beliefs and attitudes questionnaire (BAQ) about (teaching and learning) mathematical word problem solving: this instrument was also developed in Study 1, and involves two subscales ("Pleasure and persistence in solving word problems" and "A process-oriented view on word problem solving").

A motivation questionnaire: this instrument constructed by the Italian partners in the CL-Net project, consists of 35 Likert-like items dealing with various aspects of pupils' beliefs and attitudes relating to learning in school in general and collaborative learning in particular (BAL).

A short questionnaire about metacognitive and epistemic beliefs (MEB): this instrument was also developed by the Italian partners in the CL-Net project. Three open-ended questions inquire respectively pupils' perception of the source of knowledge ("What do you do if you want to know more about something?"), the criteria pupils use to control the knowledge acquisition process ("How do you know that you really understand something?"), and the role they attribute to exchanging information in knowledge acquisition ("Do you think it is useful for learners to exchange information and ideas with someone else? Why (not)?").

Finally, a questionnaire about pupils' familiarity with, beliefs about and attitudes towards computers (FBAC): the first part of this questionnaire contains ten informative questions about pupils' familiarity with computers in general, and with Internet in particular; the second part involves 15 Likert-scale questions asking for pupils' beliefs about and attitudes towards computers and their role in (school) learning.

The design of the study did not include a matched control group. However, the following reference information is available to evaluate the expected progress of the pupils of the four experimental classes on the above-mentioned tests and questionnaires. First, all pretest and posttest evaluation instruments were also administered in one fifth-grade class of the same school that did not participate in the project. Second, from the results of Study 1 which did involve a control group, we have information about the evolution in the scores of a large and representative group of upper elementary school children on the WPT and the BAQ over a period of four to five months of regular instruction in which no special attention is given to either CSCL or to word problem solving.

Assessing fidelity of implementation of the CSCL environment

Besides the collective tests and questionnaires aimed at evaluating the effects of the learning environment on a broad spectrum of learning outcomes, the following kinds of data are available to assess the fidelity of implementation of the CSCL learning environment in the school, and to reveal the difficulties encountered during the implementation process, and how this process was experienced by the pupils and the teachers.

Pupil notes in the KF-database. At the end of the intervention the KF-database contained a total of 665 notes created by the pupils. The different categories of notes (i.e. responses to the problems generated by FIXIT or by other groups of pupils, reactions to the responses of other groups, self-generated problems, etc.) will be carefully scrutinised from different perspectives (e.g., mathematical correctness, clarity and consistency of the articulation or argumentation,…). Special attention will be given to comparing fifth- and sixth-graders, and to the progression throughout the intervention in the quality of problem solving, problem posing, and communication.

Teacher evaluation forms. At the end of each TLU all teachers completed a four-page Likert-type questionnaire in which they were asked to evaluate the different parts of the TLUs, the role played by KF, and the quality of the support received from the research staff. They were also invited to write some argumentation or additional comments.

Videotaped lessons. A sample of three representative TLUs - one in the beginning, one in the middle, and one at the end of the intervention - was videotaped in the two sixth-grade experimental classes, focusing thereby randomly on one small group of pupils from each class. From these groups we also collected all written notes produced by the group members during the entire intervention.

Pupils' reactions to FIXIT's farewell note. At the end of Stage 5 of the intervention, each experimental class went to the computer class for one hour, and the pupils were asked to react - in their usual groups - to a farewell note from FIXIT which ended with a set of questions asking about their appreciation of the learning environment and what they learned from it. In addition they were invited to read each other's responses and to react through KF-notes.

Closing meeting with teachers and researchers. Shortly after the end of the intervention and prior to receiving feedback about the learning outcomes of their pupils, a final meeting with the four teachers of the experimental classes, the headmaster of the school, and the members of the research team was organised. This meeting which lasted about one and a half hour, was structured around a set of 12 questions given beforehand to the teachers and relating to their appreciation of the different aspects of the learning environment, the difficulties they had experienced in implementing it, and their suggestions for its improvement.

Preliminary results

The data collection of Study 2 was finsihed only a few weeks before this paper had to be submitted. Consequently, the analysis of the data is currently in progress, and it is by now impossible to give a complete and definitive overview of the outcomes of the study. Nevertheless, we can present some preliminary findings based on a first global inspection of the data, and complement them with our own impressions as partners in this design experiment.

First of all, there is no doubt that the vast majority of the pupils enjoyed the learning environment very much. This is evidenced strongly in their positive reactions to FIXIT's farewell note. Indeed, a large number of these reactions contain statements like "We enjoyed very much working with KF", "We would like to continue working with KF next year", "Solving word problems becomes more pleasant with KF" and "Posing word problems to each other was really funny". A recurrent negative aspect reported in pupils' verbal and written evaluative statements is that they had to work continuously in the same small groups. Another negative comment concerns the pressure put on them in the early stages of the intervention to follow the five-step strategy when solving problems, and - especially among the fifth graders - the high level of difficulty of the problems. All these positive and negative elements in the pupils' verbal and written evaluative statements are echoed in the teachers' evaluation forms as well as in their verbal comments during the closing discussion session.

Pupils' enthusiasm about their participation in the CSCL environment does not necessarily guarantee that significant learning effects have occurred. As we do not yet have any idea of pupils' results on the different measures administered after the intervention, we can only rely on the teachers' and our own appreciation of what the children have learned from their immersion in the CSCL environment. Interestingly, there seems to be some discrepancy between the estimation of the effects by the teachers and by the researchers. Indeed, the teachers came up with several illustrations of positive developments they had observed in their pupils during the intervention. More sepcifically, they mentioned the following observations: a number of pupils became more systematic in their approach to word problem solving; their negative feelings about mathematical word problems disappeared; they were more confident when given a non-routine mathematical problem; they demonstrated more perseverance in the absense of immediate success; they became more interested in talking and listening to their peers about different solutions to problems. But, as researchers we have the impression that, while the quality of pupils' mathematical thinking certainly increased, the improvement is not as high as we anticipated, especially in the fifth-grade classes; the same holds true for the quality of the communication and exchange of ideas, both within and between the small groups as well as during the whole-class discussions.

The teachers were also very positive about their participation in the project. While rather skeptic and anxious at the onset, once they were familiar with the new approach to mathematical problem solving and with KF, and when it was clear what kinds of support they would get from the research team, they became enthusiastic and their enthusiasm increased throughout the project. This enthusiasm was unanimously expressed by all four teachers during the evaluative discussion at the end of the intervention. They all declared that they had learned a lot from their participation in the project, wanted to continue to work with KF next school year, intended to explore new possibilities of KF both within the curricular domain of mathematics as well as in other domains (language, history, geography…), and wanted to intensify the collaboration with the other classes and with other schools. However, the teachers also acknowledged unanimously that their growing

enthusiasm had been seriously put to the test by the unreasonably high amount of workload as a consequence of their participation, the many classroom management difficulties experienced when realizing such a radical educational innovation in their rather traditional classroom practice, and the numerous technical problems encountered during the project (e.g., late arrival of the computer equipment, breakdown of the server, …)
As researchers we were really impressed by the teachers' enthusiasm, adaptability and perseverance throughout the project. However, a very first look at the data from the teacher evaluation forms, the videotapes of the lessons, and teachers' comments during the closing evaluation session, suggests that the quality of their guidance and support during the small-group work and the whole-class discussions was not as high as required in a real powerful learning environment. In our opinion, this is not due to the fact that the teachers did not follow the overall sequence of teaching and learning activities as specified in the teacher guides for each TLU; the problem seems rather to be that they did not succeed in fully implementing the demanding general teacher guidelines that we consider as crucial for the successful implementation of those different teaching/learning activities (Verschaffel et al., in press). Apparently, the radically new approach to learning and teaching mathematical word problem solving, combined with the introduction of a totally novel application of computer technology in the classroom, was too innovative for the teachers to be implemented entirely successfully all at once.

Final comment

In Study 2 "Knowledge Forum" was not given the central role it has played in previous design experiments about the educational possibilities of KF and its predecessor CSILE (see e.g., Scardamalia & Bereiter, 1994; Scardamalia, Bereiter, & Lamon, 1994). Nevertheless, in our opinion, the contribution and impact of KF was very substantial. First of all, the enrichment of the learning environment designed in Study 1 discussed above with a technological component helped some pupils to (re)gain their motivation for, and pleasure in learning to solve mathematical word problems. Second, KF allowed a more intensive and dynamic interaction and exchange of ideas between small groups than in the non-KF-supported learning environment of Study 1. Third, knowing that there is a "real" audience for their solutions and their solution processes, as well as the direct feedback they got from that audience, seem to have stimulated pupils to search harder for a solution and for a good articulation and justification for their solution. Fourth, KF is apparently an excellent medium for teaching and learning problem posing - an activity which occurs too rarely within the regular mathematics classroom (English, 1998). And last but not least, the possibilities of KF to exchange problems, solutions and critiques with pupils of other classes of the same school and with pupils from other schools - even from schools located in other countries - offers unique possibilities, not only to make learning mathematical problem solving more attractive and stimulating, but also to take the cultural dimension of mathematics and mathematics education more seriously.

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