Collaborative learning of mathematics:

Problem-solving and problem-posing supported by 'Knowledge Forum'

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Abstract: The aim of the present study was the design and evaluation of a computer-supported collaborative learning environment in which upper primary school children are guided and supported in becoming more strategic, motivated, communicative, mindful, and self-regulated mathematical problem solvers and problem posers. Major characteristics of the learning environment were: use of a varied set of challenging word problems; application of highly interactive instructional techniques supported by 'Knowledge Forum' (a cognitive, technological tool for knowledge construction and exchange); creation of a fundamentally new classroom culture and climate. Major results of the study are: the participating teachers implemented the learning environment appropriately; the learning environment was received enthusiastically by the pupils; the intervention had a significant positive effect on sixth graders' problem-solving competency.

Key words: ICT-supported learning, collaborative learning, powerful learning environments, problem-solving, mathematics

1. INTRODUCTION

The research presented in this paper is part of the comprehensive CL-Net project (Computer-Supported Collaborative Learning Networks in Primary and Secondary Education) funded by the European Union. The overall aim of

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the CL-Net project was to examine how knowledge construction and skill building can be fostered in primary and secondary school pupils by immersing them under the guidance of a teacher in computer-supported collaborative learning networks (CLNs). CLNs can be characterised as powerful learning environments in which technology-based cognitive tools are embedded as a 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. The project combined the relevant expertise available in eight research centres spread over five European countries. The shared expertise related to such aspects as software development, teacher preparation for the implementation of CLNs, design principles for technology-supported powerful learning environments, and the construction of assessment instruments. In the context of the CL-Net project these eight centres were working at different levels of education in a variety of content areas, and with different software tools that can support collaborative learning.

2. THEORETICAL AND EMPIRICAL BACKGROUND, AND HYPOTHESIS OF THE STUDY

The part of the CL-Net project reported in this paper aimed at the design and evaluation of a computer-supported learning environment that facilitates the distributed learning of problem-solving and problem-posing skills in upper primary school children. From that perspective two strands of theory and research were combined and integrated.

A first line of enquiry relates to the (meta-)cognitive aspects of collaborative learning supported by 'Knowledge Forum' (KF) and its predecessor CSILE (Computer-Supported Intentional Learning Environment) (Scardamalia and Bereiter, 1992). KF was designed to foster a networked "research team" approach to learning that supports knowledge building, collaboration, and progressive enquiry. Key features in KF 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.

A second theoretical underpinning derived from a series of recent intervention studies focusing on the development in pupils of a disposition towards genuine mathematical problem-solving. The present investigation drew especially upon a design experiment in which a technology-lean, but innovative, constructivist learning environment aiming at the development of a mindful, strategic, and self-regulated approach towards mathematical problem-solving, was created and successfully implemented in a number of fifth-grade classes (Verschaffel, De Corte, Lasure, Van Vaerenbergh, Bogaerts and Ratinckx, 1999).

Combining these two strands of theory and research has resulted in a learning environment in which pupils, under the guidance of their teacher and using KF, learned collaboratively to solve and pose mathematical application problems, and to communicate about and reflect on their problem-solving processes starting from the shared descriptions of, and on mutual commenting about notes on their solution strategies. The basic hypothesis of the study was that the technological enrichment of the earlier learning environment (Verschaffel et al., 1999) by embedding in it the cognitive technological tools that constitute a CLN, especially KF, would lead to a significant improvement in the quality of upper primary school pupils' problem-solving and communication skills, and, by doing so, would result in greater learning effects than in Verschaffel et al.'s (1999) study. In addition the study intended 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.

3. AIMS AND BASIC FEATURES OF THE NETWORKED COLLABORATIVE LEARNING ENVIRONMENT

The overall aim of the learning environment was to guide and support upper primary school children in becoming more motivated, strategic, communicative, mindful, and self-regulated solvers and posers of mathematical application problems. This general aim can be specified in terms of three sub-goals:

1. Acquisition by pupils, guided by the teacher and supported by the cognitive technological tools, of a five-step meta-cognitive strategy for solving and posing mathematical problems in which heuristic methods are embedded;
2. Developing in pupils appropriate, positive beliefs and attitudes toward (learning) mathematical problem-solving;
3. Acquisition by children of skills for collaboration and communication in mathematical problem-solving, using thereby the technological tools involved in 'Knowledge Forum'.

Key features of the learning environment were the following:

1. Use of a varied set of (non-traditional) complex, realistic, and challenging word problems that elicit and enhance the application of heuristic and meta-cognitive strategies;
2. Application of highly interactive and collaborative instructional techniques (especially small-group activities and whole-class discussions) supported by KF;
3. Creation of a fundamentally changed classroom culture and climate based on new social and socio-mathematical norms;
4. Gradual removal (taking into account children's increasing mastery of the problem-solving strategy as well as their skills in using KF) of the external regulation by the teacher in the learning environment in favour of self-regulation by the pupils.

For the teachers the introduction of the CLN-approach 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. Taking this into account, substantial attention was paid to the preparation of the teachers, 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, 2000). From that perspective, a substantial part of the teacher preparation was realised by simulating the new computer-supported approach to learning and teaching problem-solving in the format of an interaction between the researchers and the teachers, both groups taking turns in acting as teachers and as pupils.

4. SPECIFICATION OF THE LEARNING ENVIRONMENT IN A SERIES OF LESSONS

Starting from the aims and the basic features of the learning environment a series of lessons was elaborated and implemented from January to May 1999. Each of the participating classes spent about two hours a week in the learning environment over a period of 11 weeks. The series of lessons can be divided into five phases.

<u>Phase 1</u> (2 weeks): Introduction by the teacher and exploration by the pupils of the five-step problem-solving strategy and the software tool 'Knowledge Forum'.

<u>Phase 2</u> (3 weeks): In the beginning of each week the children solved in groups of three a problem presented in KF by a comic-strip character called FIXIT. Initially they could use scaffolds provided by FIXIT in the form of KF-notes with strategic help for solving the problem in a mindful way. Taking turns they imported their solution but also their solution strategy in

KF, on which the teacher (through FIXIT) made comments in KF before the second lesson at the end of the week. During that lesson a whole-class discussion was organised about the solution and solution strategies of the different groups taking into account the teacher's comments (presented by FIXIT), and about the role and use of KF in problem-solving.

Phase 3 (6 weeks): Pupils continued to work on complex application problems (two weeks per problem) presented by FIXIT through KF. However, in this phase the scaffolds were gradually withdrawn as the pupils made progress, and they were encouraged to read the work of the other groups and to comment on it in KF before the whole-class discussion at the end of the second week.

Phase 4 (4 weeks): In the beginning of each of two two-week periods the groups had to pose an interesting mathematics application problem themselves which they imported into KF; also they had to solve at least one problem posed by another group. Each group acted as 'coach' for the other groups with respect to their own problem. The products of that work (problems posed, solutions given by the groups, and possible comments, all imported in KF) were again the object of whole-class discussion and reflection at the end of the two-week period.

Phase 5 (2 weeks): All four participating classes got involved in an international two-week exchange project with pupils from an elementary school in Amsterdam, The Netherlands, during which pairs of Flemish and Dutch groups of pupils exchanged problems and problem solutions in a similar way as in Phase 4.

5. IMPLEMENTATION AND EVALUATION OF THE COLLABORATIVE LEARNING ENVIRONMENT

The designed learning environment was implemented in two fifth-grade and two sixth-grade classes of a Flemish primary school. A computer was available in each classroom; in addition, teachers and pupils had access to a classroom with a large number of computers all networked to a common server.

The preparation of the teaching materials and the interactions with the pupils via KF (through FIXIT) was done by the researchers in consultation with the teachers. However, the lessons were taught by the regular classroom teachers, who were also responsible for the coaching of the pupils during the small-group activities and for the leadership of the whole-class discussion.

A large variety of instruments – a word problem test, several questionnaires, logfiles analysis, classroom observations using videoregistration, and interviews with pupils and teachers - was used to collect quantitative data before and after the intervention about the cognitive, meta-cognitive, and affective effects of the learning environment on the participating pupils, as well as qualitative data about its implemention and about the changes in the pupils' and the teachers' mathematical thinking and communication processes in reaction to the CLN-based environment.

6. RESULTS

The cognitive, meta-cognitive, and affective effects of the CLN-environment on the pupils were mixed. According to the results of the word problem pre-test and post-test, the learning environment had a significant positive effect on the problem-solving competency of the sixth graders, but not of the fifth graders. Contrary to what was observed in the previous technology-lean study (Verschaffel et al., 1999), questionnaire data revealed no significant positive impact of the intervention on children's pleasure and persistence in solving mathematical application problems, nor on their beliefs about and attitudes towards learning and teaching mathematical problem-solving. However, the CLN-environment yielded a significant positive influence on pupils' beliefs about and attitudes toward (collaborative) learning in general. Finally, a significant effect of the i in general and computer-supported learning in particular.

The study has shown that it is possible to create an innovative computer-supported collaborative environment for teaching and learning mathematical problem-solving in the upper primary school. From the data of the teacher evaluation forms administered throughout the intervention and the answers during the final interviews, we can derive that the teachers were very enthusiastic about their participation and involvement in the investigation. Their positive appreciation of the learning environment related to both the approach to the teaching of problem-solving as well as to the use of KF as a supporting tool for learning; for instance, they reported several positive developments observed in their pupils such as a more mindful and reflective approach to word problems. Furthermore the implementation profiles, based on the analyses of videotaped lessons of the two sixth-grade teachers, indicated a high degree of fidelity of implementation of the learning environment.

Finally, the CLN-environment was also enthusiastically received by most of the pupils. Throughout the lessons and in reaction to FIXIT's farewell note at the end of the intervention, they expressed that they liked this way of doing word problems much more than the traditional approach. Many of the children also reported to have learned something new, both about information technology and about mathematical problem-solving.

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BIOGRAPHY

Erik De Corte is professor of educational psychology and director of the Centre for Instructional Psychology and Technology at the University of Leuven, Belgium. His major research interest is to contribute to the development of theories of learning from instruction, focusing thereby on learning, teaching, and assessment of thinking and problem-solving, especially in mathematics and in computational environments. He is currently president of the International Academy of Education (1998-2004). In March 2000 he was conferred the doctorate honoris causa of the Rand Afrikaans University, Johannesburg, South Africa.