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ABSTRACT

The goals of this study were to investigate problem-solving in a context that requires a rich interaction among social, motivational, and cognitive processes and to compare the effects of the mediated and discovery models of learning on students' problem-solving processes in the complex technology-based learning environment. Subjects were 88 Finnish fifth-grade students. Two research groups underwent different instructional procedures: the mediated group received Logo-programming teaching according to the mediated model; and the discovery group was taught according to the discovery model. The essential difference between the groups was that the goal was set by the teacher in the mediated group, whereas in the discovery group, students set the goal. After the teaching period, students participated in the experimental phase, which consisted of an open authentic Logo problem-solving task. Students' problem-solving processes were videotaped and analyzed according to the following factors: (1) cognitive conflict solving, including attempt to resolve cognitive conflict, failure/success in resolving of cognitive conflicts, persistence, performance components, and monitoring solution processes; (2) cooperation with teacher, including cooperation with the teacher, cooperation with another child, assistance seeking, and selecting performance components; and (3) explicit planning, including rule determination, self-directed work, expressing pleasure, deciding on the nature of the problem, and combining performance components. (Contains 16 references.) (MES)

Students' Problem-solving in a Complex Technology-Based Learning Environment

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Objectives

Traditional problem-solving research is concerned with individuals' cognitive processes derived from well-defined and relative lean experiments (Bereiter & Scardamalia 1993). Most studies of problem-solving attempt to minimize - at every stage of the discovery process - the mutual influence of cognition and context for the sake of experimental rigor (Klahr & Dunbar 1988; Salomon 1993). The first goal of the work described in this study is to extend earlier studies by investigating problem-solving in a context that requires a rich interaction among the processes of the social, motivational and cognitive parts of problem-solving. While previous studies have shown the beneficial effects of computer to the students' problem-solving skills upon a structural problem-solving situation (Nastasi & Clements 1994), little is known at present of the effect of different types of teaching/learning method in the complex problem-solving situation. The second goal of the present study is therefore to compare the effects of the mediated model of learning and the discovery model of learning on students' problem-solving processes in the complex technology-based learning environment. The basic presuppositon of this study is that the LEGO/Logo learning environment exemplifies the complex technology-based learning environment, in which students can learn, first, to encounter cognitive conflicts and, second, to solve those cognitive conflicts in adequate ways.

Theoretical Framework

Problem solving has been regarded as the skill of finding a suitable way around difficulties when striving toward a goal which is not immediately attainable (Holyoak 1991; Mayer 1992). The ability to solve problems is one of the most essential features of the cognitive skills of humans (Holyoak 1991). Previously emphasis has been placed on context-independent general skills based on symbols structured of individuals in the problem solving (Newell & Simon 1972). Currently, the movements of situated and distributed cognition emphasize, that the performance of an individual problem solver is based on the social and the cultural determinant, not only on cognitive processes (Clancey 1993; Hatsch & Gardner 1993).Although this idea has been allowed in general there are few studies of this interaction (Littlefield & al. 1989; L.B.Resnick 1989). This study tries to solve this methodological problem by applying Clements and Nastasi's (1988) model of problem solving.

According to Clements and Nastasi (1988), problem solving includes areas concerning social problem solving, effectance motivation and information processing. Social problem solving means the capability of effectively applying problem solving skills to real-life social situations. Effectance motivation means the ability to control or effect change in the environment (Clement & Nastasi 1985). Information processing includes metacomponents and performance components. Metacomponents are executive processes utilized in planning and evaluating one's information processing (Clements & Nastasi 1988; Kolligian & Sternberg, 1987; Sternberg 1985). Performance components are used in the actual execution of tasks. For this study the observational technique based on Clements and Nastasi's model was developed and data was analyzed according to this model.

Method

The subjects of this study are 88 eleven to twelve-year-old Finnish fifth-grade students at two primary schools in rural communities in central Finland. Although the schools are a sample of convenience, there are no indications that they are in any way different from other primary schools in Finland. International comparisons (Linnakylä 1993, 1995) suggests that the between-school variance in Finland is small. There were no statistical differences between the groups in the Piagetian pretest. The mean test score on the Piagetian test was 15.37 in the mediated group and 16.92 in the discovery LEGO/Logo group, [$t(100) = 1.90, p = 0.061$]. Thus, it is reasonable to assume that all groups represent typical students in this age group.

Two research group underwent different instructional procedures. The mediated group (n=42) received Logo-programming teaching according to the mediated model, whereas the discovery group (n=46) was taught according to the discovery model. The essential difference between the mediated and the discovery group was that the goal was set by the teacher in the mediated group, whereas in the discovery group, students themselves set the goal.

The size of the group taught at a time was 10-12 students and most of the students worked in pairs with PC computers. Every computer include LEGO/Logo set with Lego building blocks and controllable motors with the Logo programming language. Nine groups were composed, four of which were mediated groups and five discovery groups. The 20-hour-long teaching programme consisted of the merry-go-round - and the robot projects.

After the teaching period students participated in the experimental phase, which consisted of an open authentic Logo problem-solving task. The task involved programming Lego robot to follow a certain route. The students' problem-solving processes were videotaped and the subsequent analysis was based on observational measures developed by Clements and Nastasi (1988) (See Suomala 1996, 1999). The whole problem solving process of each pair was videotaped using on-line techniques. A VGA/PAL-video-transfer-card was used to record students' programming code from the computer screen on to the other videotape during the programming process. Subsequently students' problem solving processes were analyzed from this real-time video material. To assess social problem solving and effectance motivation, observations for each pair of students were conducted from the videotape. The occurrence of behavioral features was assessed at intervals of 10 seconds. The frequencies of each variable in the areas of social problem solving and effectance motivation were counted.

Students' conversations during the problem-solving process were categorized according to the scheme for information-processing components (See Clements & Nastasi 1988; Suomala 1996). Every sentence was categorized into one information processing category. The frequencies of each variable in the area of information-processing were counted and changed into percentages of occurrence.

In addition, the last Logo program constructed by a student pair during the experiment phase was analyzed. In this study operational measures of high quality software have been developed on the basis of such observable program characteristics as the *program length* and the *versatility of the program.*

Based on observational data, factor analysis was conducted based on variables presented previously (Clements & Nastasi 1988; Suomala 1996). Three interpretable and reliable factors were composed. Factor I was named as *Cognitive Conflict Solving*, factor II was named as *Cooperation with Teacher* and Factor III *Explicit Planning.*

Factor I, (*Cognitive Conflict Solving*) included *Attempt to resolve cognitive conflict*, *Cognitive conflict*, *Failure to resolve cognitive conflict*, *Success in resolving of cognitive conflicts*, *Persistence*, *Performance components* and *Monitoring solution processes*. All previously enumerated variables had a clear loading for the first factor. The highest loadings on the factor were *Attempt to resolve cognitive conflict* (loading 0.84), *Cognitive conflict* (loading 0.83) and *Failure in resolving of cognitive conflict* (loading 0.77). The variables *Persistence* (loading 0.66), *Success in resolving of cognitive conflicts* (loading 0.47) and *Monitoring solution processes* (loading 0.47) also had a substantial loading. Only *Performance components* had a negative loading (-0.49) on this factor. To sum up the high score of the cognitive conflict solving factor (Factor I) means that students have many cognitive conflicts and that they make many attempts to solve those conflicts during the problem solving processes. This process may lead to either failure or success. Cognitive monitoring is also related to this process.

Factor II (*Cooperation with teacher*) included *Cooperation with the teacher*, *Cooperation with another child*, *Assistance seeking* and *Selecting performance components*. All previously enumerated variables had a clear loading for the second factor. The highest loadings on the factor were *Cooperation with the teacher* (loading 0.94) and *Cooperation with another child* (loading -0.94). In addition, the variable *Assistance seeking* (loading 0.50) also had a substantial loading. Although the variable *Selecting performance components* (loading -0.34) did not have such a substantial loading for factor II, it clearly belongs to this factor because the loadings for factor I (loading 0.16) and for factor III (loading -0.13) were much lower. The variables *Cooperation with another child* and *Selecting performance components* has a negative loading on this factor. A high score on *Cooperation with teacher* factor means that students prefer to work with the teacher during problem solving. In contrast, a low score on this factor means that students prefer to cooperate with another student.

Factor III (*Explicit planning*) included *Rule determination*, *Self directed work*, *Expressing pleasure*, *Deciding on the nature of the problem* and *Combining performance components*. The highest loadings on the factor were *Rule determination* (Loading 0.79), *Self directed work* (loading 0.57) and *Deciding on the nature of the problem* (loading 0.57). Also the variable *Combining performance components* (loading 0.42) had a substantial loading and the variable *Expressing pleasure* (loading 0.25) had a relatively low loading. All variables with the highest loadings for factor III had positive loadings on this factor. The high score of *Explicit planning* means that students plan in an explicit way about the final goal of the task and about how this goal could be achieved during the problem solving process. Also much self directiveness occurs if students have a high score on this factor. Explicit planning describes a planning strategy in which a high score on this factor describes a formal programming style like behavior, whereas a low degree of occurrence describes concrete programming style like behavior.

The connections between the different problem solving processes and students school achievement and gender were studied. To determine whether there were overall differences between the groups in the problem-solving process, described by the variables *Cognitive conflict solving*, *Cooperation with teacher* and *Explicit planning*, two three-way analyses of variance (ANOVA) were used.

Results

How does problem-solving processes differ in the mediated and discovery group?
The analysis revealed significant main effect of the learning model for cognitive conflict solving, $F(1, 87) = 26.94, p<0.001$. This indicates that the mediated group (x = 0.52) have more cognitive conflict solving than the discovery group (x = -0.47) in the open problem solving situation. When the variable of cooperation with teacher is used as a dependent variable one significant main effect concerning the learning model found, $F(1, 87) = 4.97, p < 0.05$. This indicates that the mediated group (x = -0.26) has less cooperation with the teacher than the discovery group (x = 0.24) during

the problem solving processes. In addition, when the variable of explicit planning is used as a dependent variable the analysis revealed two significant main effects concerning the learning model, $F(1, 87) = 4.68$, $p<0.05$, and school achievement, $F(1,87) = 4.39$, $p<0.05$. This indicates that the mediated group (x = -0.19) shows less explicit planning during the problem solving than the discovery group (x = 0.18). In addition, low achievers in the school (x = -0.19) show less explicit planning than high achievers (x = 0.18) . There were no significant interaction effects.

How does girls and boys differ?

The analyses revealed a significant main effect of gender for cognitive conflict solving, $F(1, 87) = 10.63$, $p < 0.001$. This indicates that boys (x = -0.28) have less cognitive conflict solving than girls (x = 0.30) during the problem solving process. When the variable cooperation with teacher was as the dependent variable, analysis revealed the significant main effect of gender, $F(1, 87) = 4.14$, $p < 0.05$. This indicates that boys (x = -0.20) have less cooperation with the teacher than girls (x = 0.24) during the problem solving process. And finally, when the variable explicit planning was as the dependent variable, the analysis revealed significant main effects of gender, $F(1, 87) = 8.96$, $p < 0.01$. This indicates that boys (x = -0.28) perform less explicit planning than girls do (x = 0.33) during the problem solving process.

Does the quality of the final Logo program differ between the mediated and the discovery group? In the experimental phase, all pairs created a Logo program that worked. Thus, every pair used at least moving commands (Forward, Back, Right and Left) in their final Logo program. The mean number of all Logo commands was 21.77 commands (range 7 to 88). The three commonest types of command were moving commands (mean 10.87), music commands (mean 4.2) and light commands (mean 2.66). Only 2 pairs used repeat commands, and only 4 pairs used subprocedures. In addition, 11 pairs used waituntil commands. The complexity of the final program was as follows. Only 3 pairs used a program that included only moving commands and 10 pairs had two components (moving commands and one of the following: light or music or repeat or subprocedures or waituntil); 18 pairs had three components; 12 pairs had four components; and, finally, only one pair had five components. However, there was no statistically significant difference between the mediated and discovery group - nor between any other groups - with regard to the degree of complexity of the program. For this reason, the number of music commands was chosen in this analysis because it was the only area of commands which differentiated groups in a statistically significant way. Thus, the use of music is an indication of the versatility of the final Logo program in this study.

The length of program[1] in the mediated and discovery groups respectively was 18.90 and 24.39 respectively [$t(69.64) = 1.99$, $p< .05$]. The mediated group had an average of 3.71 and the discovery group 7.15 music commands in their final Logo program. This difference was statistically significant [$t(82.38) = 2.43$, $p<.05$].

Discussion

The results of the study indicated that learning model, gender, and school achievement accounted for group differences in the complex problem solving among students. Overall the results were interpreted as supporting the validity of the discovery learning model, when students are solving

[1] The variable *length of program* describes the number of all the commands that the final Logo program included.

problems in a complex technology-based learning environment (LEGO/Logo). The student's role as an active learner during progressive problem solving should be respected by the teacher but, at the same time, the teacher should provide appropriate support in those situations where students encounter insuperable problems during problem solving. Consistent with the common view in the current literature, this study shows that student's role as an active learner during progressive problem solving should be respected by the teacher (Järvelä 1996). Especially in situations where learners encounter cognitive conflicts or when they show that they have novel ideas, the teacher's role as a sensitive "coach" is important. In the whole class context, the essential questions will be how to maintain students' long-term problem-solving projects and how to assist them to overcome obstacles during such projects.

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