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ABSTRACT

This study investigated the use of tools and design features as employed in a problem-based learning (PBL) environment and their effectiveness on seventh grade students' learning of science concepts. Specifically, the study examined: (1) the effect of the computer-supported PBL environment on the achievement of middle school students; (2) the effect of the computer-based PBL environment on middle school students' attitudes toward science; and (3) the relationship between students' math or reading ability and their achievement in the PBL environment. Dependent measures were achievement, degree and frequency of access to the tools/features, and attitude toward learning science. The treatment consisted of three groups: computer-supported PBL environment, paper-based PBL, and a control group. Results indicated that: both the groups that used the computer-supported and paper-based PBL significantly improved their achievement scores, while the increase for the control group was not significant; there was no significant difference between the computer-supported and paper groups; students' reading ability is a better predictor for students' achievement in a PBL environment than their math ability; and students' attitude toward learning science was not affected by the introduction of PBL. Two tables and a graph present data. Contains 14 references. (DLS)

Examining How Middle School Students Use Problem-Based Learning Software

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Abstract: A nagging problem concerning school-based learning is the difficulty many students experience in applying what they have learned to everyday situations. Problem-based learning (PBL) emphasizes solving authentic problems in authentic contexts and has been shown to be an effective instructional method. Though literature supports the efficacy of problem-based learning and the benefits of problem-based learning are obvious, little research exists which investigates the types of tools or features that are effective in supporting students working in PBL environments. This study examines how middle school students use and interact with a computer-supported PBL environment.

1. Research Framework

Historically, schools have attempted to teach the content and skills essential for individuals to function in society. Since the Industrial Revolution schools have emphasized the learning of basic skills. Yet today it is clear that this type learning is not enough. More jobs than ever require problem solving and critical thinking. Dewey [Dewey 1938] argued that intelligence is the ability to clarify a goal and develop a plan for its attainment. Authentic learning environments such as problem-based learning embody this in its problem definition and resolution.

With the shift from a behavioral to a cognitive perspective of learning, researchers have become increasingly interested in cognitive processes and their effect on the construction of knowledge [Driscoll 1994]. Many cognitive psychologists and constructivists believe that learning cannot be separated from the learning activity and context [Bednar, Cunningham, Duffy, & Perry 1992].

A nagging problem concerning school-based learning is the difficulty many students experience in applying what they have learned to everyday situations. Many schools are concerned with the transfer of abstract, decontextualized concepts where knowledge is viewed as a discrete object residing outside of the individual [Brown, Collins, & Duguid 1989]. Increasing amounts of research indicate that the inability of students to apply concepts learned in formal contexts is due to the abstraction and decontextualization of learning [Cognition and Technology Group at Vanderbilt 1992]. Spiro and Jehng [Spiro & Jehng 1990) argue that the decontextualization of knowledge creates inflexible understandings. But it is not the abstraction of knowledge as such that distracts learners, but that the abstractions are not illuminated with examples in context. Understanding is a product of the context and activity [McLellan 1993].

Context provides a framework which guides and supports the learner. The context naturally structures knowledge in a way that suggests its proper use. Traditional instructional design attempts to simplify learning by dividing the content into components and teaching them separately. Situated cognition argues that learning is simplified by embedding concepts in the context in which they will be used [Brown &

Duguid 1993]. The context provides the much needed support when working at the edge of one's ability. Yet authentic context alone is not enough to support student learning. Situated cognition argues that learners must engage in authentic tasks as well [Winn 1993]. Authentic activities are the ordinary practices of the experts in that domain [Brown et al. 1989]. The learning activity is an integral part of what is learned. An activity in which all domains engage is the solving of problems. Experts utilize tools to support problem-solving in context. Active use of a culture's tools provide learners the opportunity to view knowledge from the experts' perspective [Brown et al. 1989]. Active learning in the context of a domain's culture allows the gradual "fleshing out" of concepts over time. Each use of a concept or tool will further develop the learners' understanding.

There has been a growing body of research on authentic and situated learning environments utilizing the problem-based approach to learning [Spiro & Jehng 1990]. Problem-based learning (PBL) emphasizes solving authentic problems in authentic contexts. It is an approach where students are given a problem, replete with all the complexities typically found in real world situations, and work collaboratively to develop a solution. Problem-based learning provides students an opportunity to develop skills in problem definition and problem solving, to reflect on their own learning, and develop a deep understanding of the content domain [Lajoie 1993] [Jacobson & Spiro 1995). This approach was developed in the fifties for medical education, and has since been used in various subject areas such as business, law, education, architecture and engineering. Most recently, there is a growing interest among educators to use problem-based learning in the K-12 setting, and a growing need for problem-based educational software to facilitate the development of higher order thinking skills via technology.

Though literature supports the efficacy of problem-based learning and the benefits of problem-based learning are obvious, little research exists which investigates the types of tools or features that are effective in supporting students working in PBL environments. In order to design an effective computer-supported PBL learning environment, it is important to understand the tools and design features included in the software, and their impact on learning. It is, therefore, the purpose of this study to examine and understand how middle school students use and interact with a recently available computer-supported PBL environment developed by a major publishing company.

2. Research Questions

This study investigates the use of tools and design features as employed in a problem-based learning environment and their effectiveness on middle school students' learning of science concepts. Specifically, the study asked the following questions: (1) What is the effect of the computer-supported problem-based learning environment on the achievement of middle school science students?, (2) What is the effect of the computer supported problem-based learning environment on the middle school students' attitudes toward science?, (3) Is there a relationship between students' math or reading ability and their achievement in the problem-based learning environment?

3. Design of Study

3.1 Sample

The participants of the study (N = 115) were students enrolled in seventh grade science at a middle school located in a medium-sized city in the southwestern United States. The school has a high percentage of minority students. The participants in the study consisted of 66% Hispanic Americans (N=76), 12% African Americans (N=14) and 22% white (N=25). The age of the students ranged from 12 - 14 years. Of the participants in the study, 50 were male and 65 female.

3.2 Treatment

The treatment consisted of three groups: computer-supported PBL environment, paper-based PBL, and a control group. Students from three intact classes were randomly assigned to each of the conditions described below. Because the treatment was included as a part of the regular science classes, complete random assignment was not possible in this case. There were 59 students in the computer-supported PBL environment, 38 in the paper-based PBL, and 18 in the control group.

3.2.1 Computer-Supported PBL

The computer-supported PBL group used problem-based learning software recently developed by Holt, Rinehart and Winston Publishing Company. The CD-ROM-based program contains eight activities on different topics developed to support the middle school science curriculum. Upon starting the PBL application the students find themselves in a virtual science laboratory. Immediately on entering the laboratory a short video segment plays in which a scientist provides important details about a scientific problem she is working on and solicits the students' help in developing a solution. The activity used in this study is concerned with the classification of a microorganism and was selected because it was related to the topic being studied in the classes participating.

The students are supported in finding a solution to the problem by the availability of tools in the virtual laboratory. An *expert scientist* built into the virtual laboratory provides information about the scenario and takes on the role of a mentor in which she provides hints and feedback during the activity. The *inbox* provides a printed version of the problem scenario thereby supporting students in defining the problem. A *lab manual* provides important information on the use and importance of the tools found in the lab. The lab also furnishes a *computer database* which contains information that is essential for solving the problem. A *notepad* is also provided to support students in note taking during the activity. Most students are able to complete the activity in approximately forty-five minutes.

3.2.2 Paper-based PBL

Other students worked through a problem-solving activity, equivalent in content and available resources to the computer-based software, except that the information given (including the information in the database and the pictures) was print-based. Though identical in the resources provided, the computer and the paper-based PBL are different in that (1) the computer-based version allows interactive access of information while the paper-based does not, and (2) the computer-based version provides information in multimedia format while the paper-based does not.

3.2.3 Control Group

A third class was included as a control group. Students in this class learned the same content on microorganisms using the traditional approach (mostly lecture-based).

3.3 Dependent Measures

There are three dependent measures in the study: (1) achievement, (2) degree and frequency of access to the tools/features, and (3) attitude toward learning science. Students' knowledge about microorganisms was assessed through a pretest and a posttest. Their use of the tools and various design features in the computer version was recorded. Their attitudes toward science were evaluated through a questionnaire entitled "Attitude Toward Science in School Assessment." This attitude questionnaire addresses students' feelings about science as a subject and consists of 14 Likert scale items, with a reported reliability of .95 [Germann 1988]. In addition, the students in both the computer and paper groups were asked to record their steps in solving the problem. Interviews with students from all three groups and with the teacher were conducted. The triangulation of the quantitative and qualitative data sources will help to answer the research questions with richer and more detailed information.

3.4 Procedures and Analyses

Each of the 5 classes involved in this study was assigned randomly to one of the treatment conditions. For students in the computer and paper PBL groups, the entire treatment consisted of two phases. First, the teacher modeled the problem-solving process using another activity from the computer software (for the paper group, the information was presented through paper and pencil). Then the students were divided into groups of four or five and asked to work through the activity on microorganisms collaboratively. Literature on PBL shows that providing necessary scaffolding is a critical step in making PBL successful. The purpose of this teacher modeling phase was to introduce students to the steps of problem solving and provide them with guided practice. This phase was included in both the computer-supported and paper-based environments because we felt that the modeling should be part of problem solving regardless of the media involved and our primary interest in this study was to find out if the hypermedia environment could provide additional support for the students. Therefore, the instruction of the two conditions were held to be same. The control group worked through the regular instruction on microorganisms with no intervention.

In order to answer the first research question, "What is the effect of the computer-supported problem-based learning environment on the achievement of middle school science students?," a two-factor mixed ANOVA was run with the grouping (computer, paper and control) as a between-subjects independent variable, and the data collection points (pre vs. post) as the repeated measure independent variable. The dependent variable was the pre and post achievement scores in the science content test.

In order to answer the second research question, "What is the effect of the computer supported problem-based learning environment on the middle school students' attitudes toward science?," a two-factor mixed ANOVA was run with the grouping (computer, paper and control) as a between-subjects independent variable, and the data collection points (pre vs. post) as the repeated measure independent variable. The dependent variable was the pre and post scores for the attitude questionnaire.

In order to answer the third research question, "Is there a relationship between students' math or reading ability to their achievement in the problem-based learning environment?," a multiple regression was run with students' math and reading ability, measured by their most recent Texas Assessment of Academic Skills (TAAS) as the independent variables and their achievement test as the dependent variable.

In addition, students' use of tools in the hypermedia environment and the problem solving steps students taken in the computer and paper groups were analyzed descriptively. Students were selected for the post interviews after they completed the study. The purpose of the interviews was to find out (1) what the students liked and disliked about the environment; (2) what they found most useful in the environment; (3) what they thought about the process in general. Interviews were included as part of the data sources in order to provide more information on the study and substantiate the quantitative analyses. The interview data will be analyzed according to Miles and Huberman's framework of qualitative data analysis [Miles & Huberman 1994]. Such descriptive analyses and the findings from the qualitative data are being conducted at this point and will be added to the conference presentation.

4. Results and Discussion

The results of the two-factor mixed ANOVA on achievement indicated that there was a significant two-way interaction between the grouping (computer, paper and control) and the data collection points (pre vs. post) for the achievement scores: $F(2, 96) = 5.50$, $p < .01$. All groups increased their achievement scores from pre to post. The gains from pre to post were significantly greater for the computer and paper groups than for the control group [Tab. 1] [Fig. 1]. The gain differences between the computer and the control groups, and the paper and the control groups were significant at $p < .05$ level based upon the Fisher' s PLSD post hoc tests. The gain difference between the paper and the control groups was also significant at $p < .05$

level for the Scheffe post hoc test. This finding shows that both the computer and paper groups have significantly improved their achievement scores after they participated in the study while the increase for the control group was not significant. In other words, there was an effect of the problem-based learning environment on the achievement of middle school science students. Yet the difference between the computer-supported PBL and paper PBL was not significant.

The results of the two-factor mixed ANOVA on attitude indicated that there was not a significant two-way interaction between the grouping (computer, paper and control) and the data collection points (pre vs. post) for the achievement scores: F (2, 95) =.26, p= .77. Although there was a small increase in attitude from pre to post for all groups, there were no differences among the three groups [Tab. 1]. In other words, the treatment did not have an impact on the students' attitudes toward learning science.

	Achievement			Attitude		
	N*	Pre	Post	N	Pre	Post
Computer Group	50	12.7 (12.52)	31.58 (20.7)**	48	28.23 (12.19)	30.00 (14.10)
Paper Group	32	8.22 (12.53)	28.38 (18.43)**	17	31.91 (9.98)	34.76 (11.34)
Control Group	17	27.35 (12.64)	32.47 (13.35)	33	25.82 (8.90)	29.82 (14.33)

* N indicates the number of students who turned in both the pre and post evaluation forms for each group.
** significantly different from the control group, $p < .05$

Table 1: Mean and Standard Deviation (in Parenthesis) on achievement and attitude for the Computer, the Paper and the Control Groups

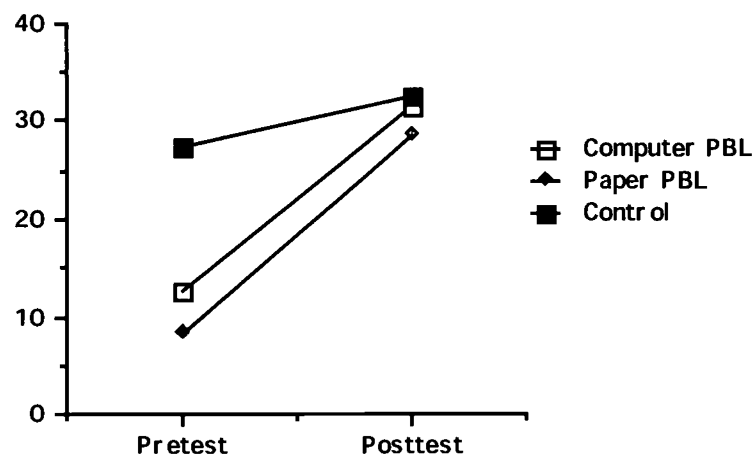

Figure 1: Achievement scores for the groups from pre to post

R	.59		*t* -values	
R2	.35		reading ability	3.46, $p < .1$
F	14.9, $p < .01$		math ability	1.26, p =.21
intercept	4.13			
Beta			Beta Weight	
reading ability		.42	reading ability	.47
math ability		.19	math ability	.17

Table 2: Results of the Multiple Regression Analysis

We were interested in finding out if there existed a relationship between students' math and reading abilities and their achievement when working in PBL environments. Students' scores in reading and math from a most recent TAAS test were used. TAAS is a state-wide testing system that assesses the overall academic achievement of all students in Texas at different grade levels. It provides information on students' reading ability, math ability and writing ability. The results of the multiple regression analysis showed that the significance of the relationship was moderately high among reading ability, math ability and the achievement scores for students using PBL: $r = .59$, $p < .01$. This significant relationship was mainly attributed to students' reading ability $t(72) = 3.46$, $p < .01$ [Tab. 2]. That is, students' reading ability is a better predictor for students' achievement in a PBL environment than their math ability. A PBL environment relies much on problem identification, presentation, problem-solving and student reflection. Though mathematical ability is obviously very important in problem solving, being able to read and comprehend the problem is critical. This finding provides some evidence on this issue and suggests that in order for students to be successful in a PBL environment, we, as teachers, need to make greater efforts to increase students' reading levels.

The findings of this study suggest that problem-based learning can influence the middle school students in their learning of science. When students were exposed to the PBL environment, they increased their achievement scores more than those students who learned the same content in the traditional classroom. Consistent to the literature on PBL, the results of the study provide some evidence in supporting the use of PBL. The findings also suggest that both the computer-supported and paper based PBL are equally effective. An interest of this study was to find out the types of tools or design features that can support students when working in a computer supported PBL environment. Although there was no significant difference between the computer and the paper groups on achievement, initial examinations of the problem solving process by the computer and the paper groups show some differences in the steps and use of available resources/tools. The use of tools/resources are currently being analyzed. The findings of the analyses for tool use and the qualitative data will be added to the result and discussion section for the conference presentation. Together, the findings will provide more insights as to how the tools can or cannot support problem solving in computer-supported PBL environments.

No significant differences among the three groups were found on the middle school students' attitude toward learning science. That is, the middle school students' attitude toward learning science was not affected by the introduction of PBL, computer-supported or paper-based.

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