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Using Scaffolds in Problem-based Hypermedia

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This study investigated the use of scaffolds in problem-based hypermedia. Three hundred and twelve undergraduate students enrolled in a computer literacy course worked in project teams to use a problem-based, hypermedia program focused on designing a personal computer. The program included content scaffolds, metacognitive scaffolds, or no scaffolds. Results revealed that posttest scores for students who received content scaffolds were significantly higher than those who received metacognitive scaffolds. Type of scaffolds also had a significant impact on student attitudes. Findings have implications for the design and delivery of problem-based, hypermedia. Content scaffolds can direct student attention to important information and encourage understanding. However, considerations should be given to the difficulty of the task, the time allotted to solve the problem, and other demands students face in a problem-based, hypermedia environment.

USING SCAFFOLDS IN PROBLEM-BASED HYPERMEDIA

Problem-based learning (PBL) is an instructional approach used to prepare students to become better problem solvers for today's information society. An essential characteristic of PBL is the use of a problem to focus and anchor learning. PBL emphasizes active knowledge building while students solve problems rather than exposing them to discipline knowledge before problem solving (Albanese & Mitchell, 1993; Hmelo & Evensen, 2000). Advocates of PBL propose that students who use this approach develop flexible and reusable knowledge, accumulate problem solving skill, gain self-directed learning ability, and generate high intrinsic motivation (Barrows, 1986; Hmelo & Evensen, 2000; Kelson & Distlehorst, 2000).

Research has been conducted to evaluate the effectiveness of PBL or compare it with conventional instructional approaches on various learning outcomes. Norman and Schmidt (1992) reviewed experimental studies on PBL and found that it helped students transfer more concepts and integrate them into problems more effectively than those who did not participate in PBL. Their review also suggested that students' intrinsic interests and self-directed learning skills appeared to be enhanced in PBL. However, they reported that PBL may decrease immediate knowledge acquisition.

A recent meta-analysis by Dochy, Segers, Bossche, and Gijbels (2003) reviewed two major PBL outcomes – declarative information and knowledge application – in 43 empirical studies. Results revealed a robust positive effect for PBL on knowledge application but a slightly negative effect for PBL on declarative information. While students in PBL gained less knowledge immediately after instruction, they recalled more knowledge on delayed retention tests.

While much of the research on PBL has been conducted in classroom settings, studies have also investigated PBL supported by computer technology, especially hypermedia technology. Hypermedia can be used as an "exploration tool to support early unstructured thinking on a problem when many disconnected ideas come to mind" (Conklin, 1987; p.20). It can serve as a resource database to support learners by giving them opportunities to apply ideas, test theories and manipulate concepts in a problem context (Hannfin, 1993; Jonassen, 1986). Hypermedia can also facilitate ill-structured problem solving which requires students to consider problems from multiple perspectives (Hoffman & Ritchie, 1997).

Researchers studying hypermedia-based PBL have identified some of its benefits to learners. Pedersen (2003) developed a hypermedia-based PBL program and investigated student motivation during its implementation. Results indicated that the program significantly promoted intrinsic motivation. PBL students felt more challenge, perceived that they had more control over their learning program, and collaborated more with their classmates, than students in the regular classroom. Waters and Johnson (2004) used a web-delivered PBL program to teach organizational behavior and found that students' computer and Internet skills were improved significantly after using the program. Students also employed deeper learning approaches, such as relating theories to real situations, immediately after the program. Their problem solving skills, critical thinking skills and team work skills increased significantly six months after using the PBL program.

While hypermedia-based PBL can increase student motivation and learning, various problems exist when it is applied in real settings. Disorientation and increased cognitive load are two major problems associated with the richness, variety and freedom of hypermedia (Conklin, 1987; Lawless & Brown, 1997; Shapiro & Niederhauser, 2003). Difficulties with PBL mainly come from the high complexity of learning tasks and students' inability to monitor and control their own learning (Land, 2000; Pedaste & Sarapuu, 2006). Students may also feel a lack of support during PBL (Edelson, Gordin & Pea, 1999). To address these challenges, scaffolding has been proposed (Hogan & Pressley, 1997; Land, 2000; Pedaste & Sarapuu, 2006; Puntambekar & Hübscher, 2005).

Scaffolding shapes the way students interact in a PBL environment by imposing additional structure to their learning (Ge & Land, 2004). However, scaffolds can decrease the flexibility of PBL and may reduce student opportunity to do exploratory learning, which may have a negative effect on learning in a PBL environment (Pea, 2004).

Researchers have proposed different categorizations for scaffolds. Saye and Brush (2002) grouped them into two types based on their flexibility. Soft scaffolds refer to dynamic and situational supports that require teachers to continuously diagnose learners learning situation and provide them with just enough support in a timely manner. Hard scaffolds are static supports that can be predicted and planned in advance based on anticipated student difficulties during learning. Hannafin, Land, and Oliver (1999) categorized hard scaffolds into four types - conceptual, strategic, procedural and metacognitive scaffolds. Azevedo, Cromley, Thomas, Seibert and Tron (2003) made the distinction between two types of hard scaffolds - content scaffolds and process scaffolds.

It has been suggested that PBL students are likely to focus exclusively on problem solutions without paying enough attention to content knowledge (Kuhn, Black, Keselman & Kaplan, 2000; Reiser, 2004). Content scaffolds can support students' understanding of the content, as well as help them formulate strategies and make decisions where they may have difficulty (Azevedo et al., 2003; Pedaste & Sarapuu, 2006; Reid, Zhang, & Chen, 2003). A content scaffold can be a hint or a method that helps learners avoid misunderstanding and clarify misconceptions, a suggestion on the starting point of problem solving, or it can offer links to available resources in the place where problematic understanding might happen (Hannafin et al., 1999; Land, 2000; Simons & Klein, 2007).

Content scaffolds will mainly benefit students' understanding towards content knowledge instead of overall problem-solving performance (Cho & Jonassen, 2002; Davis & Linn, 2000; Pedaste & Sarapuu, 2006; Reid et al., 2003). On the other hand, they may reduce students' cognitive load spent on content learning; therefore, they may have more cognitive resources to manage the problem-solving process.

In a study of scaffolds by Cho and Jonassen (2002), students participated in an online discussion board to discuss and solve problems in groups. A content scaffold was designed to help them post well-structured argumentation. Results indicated that students who received the scaffold produced better quality argumentation, more claims, and more problem-oriented communication during discussion than those who did not have the scaffold. In a follow-up individual problem-solving activity, students from the scaffold group created significantly higher quality argumentation than those in the no scaffold group. However, scaffold-supported students did not outperform no-scaffold students on problem-solving performance.

Simons and Klein (2007) investigated effects of content scaffolds on students' final project performance, posttest achievement and attitudes in hypermedia-based PBL environment. Results indicated that the scaffolding required group performed significantly better on the final project than the no scaffolding group. However, scaffolds did not affect posttest achievement or attitudes. Furthermore, students did not see the value of the scaffolds, viewing them as something extra to do, rather than something helpful.

Metacognitive scaffolds have also been proposed to help students using PBL. Metacognitive skills are especially important in PBL environments because of the student-centered nature of the approach. Land (2000) summarized three metacognitive skills required in open-ended learning environments - (a) identifying appropriate learning issues, (b) monitoring the effectiveness of learning strategies, and (c) monitoring detailed steps in problem-solving while still remaining focused on the task. She further claimed that many students lack these metacognitive skills and suggested that supports should be designed to help them.

Metacognitive scaffolds aim to support students from the aspect of task and process management. They are designed to facilitate learners on how to plan, monitor, evaluate and reflect on their learning (Azevedo et al., 2003; Pedaste & Sarapuu, 2006; Reid et al., 2003; Reiser, 2004). A metacognitive scaffold may be able to release part of students' cognitive resource from managing the task, so that they can invest more resources on learning (Shapiro & Niederhauser, 2003; Wolf, 2000). A metacognitive scaffold can be a suggestion to encourage learners to develop a plan for solving the problem or a prompt, checklist or work chart to have learners to reflect on and evaluate their learning (Davis & Linn, 2000; Hannafin et al., 1999; Pedaste & Sarapuu, 2006).

A study by Wolf (2000) investigated the effects of a metacognitive scaffold on students' problem solving performance and attitudes in an online multimedia resource database. Results showed that students who received the scaffold achieved significantly higher score on problem-solving performance than their peers who didn't receive the scaffold. However, no significant difference was found on student attitudes between two conditions.

Davis and Linn (2000) conducted several studies to examine metacognitive scaffolds (self-monitoring prompts) and content scaffolds (activity prompts). In the first study, the overall quality of projects did not differ; however, students who received both types of scaffolds were more likely to use at least one scientific principle in their project design. In the second study, results indicated that students in the metacognitive scaffold group were more likely to explain phenomena with a scientific principle. However, they were significantly less likely than students in the content scaffold to complete all aspects of the project. In the third study, students who admitted having learning confusion benefited more from metacognitive scaffolds than those who denied difficulty.

In addition to scaffolding, student prior knowledge plays a key role in hypermedia PBL. Shapiro and Niederhauser (2003) consistently found that lower prior knowledge learners tend to benefit more from a hypermedia system with less freedom, whereas higher prior knowledge learners tend to achieve better learning outcomes in a hypermedia system with more freedom. Simons and Klein (2007) found that students with high academic achievement performed better on both posttest and problem-solving than those with low academic achievement. Furthermore, students with high academic achievement reported that they enjoyed working in the PBL program more than low academic achievement students. Azevedo, Cromley, Winters, Moos, and Greene (2005) found that low prior knowledge students using PBL relied on their partners to regulate their learning while high prior knowledge students spent time managing their own learning. Based on these results, the researchers suggested that metacognitive scaffolds should be provided to low prior knowledge learners to help them organize their own study instead of relying on their partners.

While advocates of open-ended learning environments such as hypermedia-based PBL suggest that scaffolds may reduce some of the difficulties students have in these settings, research does not clearly show which scaffolds most benefit learners. The main purpose of the current study was to examine the effect of content scaffolds and metacognitive scaffolds on problem-solving performance, knowledge acquisition and student attitudes during the implementation of a hypermedia-based PBL lesson. Prior knowledge was also examined because other studies have shown that it is related to student outcomes in PBL.

METHOD

Participants & Design

The participants in this study were 312 undergraduate college students enrolled in 20 sections of a computer literacy course at a large southwestern university in the United States. The computer literacy course was offered through the College of Education at the university as a general studies elective. Demographic data showed that 63% of participants were female, 36% were freshmen, 28% were sophomores, 24% were juniors, and 12% were seniors. Most participants were from a non-computer major and 42% were Education majors.

A 3 × 2 factorial research design was used in this study. The independent variables were types of scaffolds (no scaffolds, content scaffolds, metacognitive scaffolds) and prior knowledge (high versus low). Dependent measures included problem solving performance, posttest achievement, attitudes, and time solving the problem. Additional data sources included student navigation patterns and how teams approached the problem solving task. The crossing of the factors of the independent variables resulted in the following six treatment groups: (1) low prior knowledge students with no scaffolds, (2) high prior knowledge students with no scaffolds, (3) low prior knowledge students using content scaffolds, (4) high prior knowledge students using content scaffolds, (5) low prior knowledge students using metacognitive scaffolds, and (6) high prior knowledge students using metacognitive scaffolds.

Materials

The materials in this study included a hypermedia-based PBL lesson, content and metacognitive scaffolds, a teacher guide, and a test of prior knowledge. These materials are described below.

Hypermedia-based PBL Lesson. A web-delivered, hyper-media-based PBL program called *All You Need is a Screwdriver* was used in this study. The content was part of the curriculum of the computer literacy course. At the center of the program was an ill-structured problem scenario which required student teams to design a functional desktop computer for home use within a limited budget. Using this problem as a context, directions were provided and resources were organized into a hypermedia database to facilitate student learning. The program was designed and developed by the principal investigator based on guidelines for open-ended learning environments (Hannafin et al., 1999; Pederson, 2003).

The program included six sections. Students could navigate to each one by selecting a link on a menu bar located at the top of each screen. The *In-*

troduction opened the program; it was designed to gain students' attention and inform them of the purpose of the lesson. The *Directions* introduced the four main units in the lesson and provided information about how grades would be assigned and how much time was allotted for the lesson. The *Project* unit described the problem solving task. Project teams were told that they would design a home computer within a limited budget. They were also told that their team was required to submit a drawing displaying selected computer components and show lines as cables to connect components together. The *Procedure to Follow* gave students a list of ten steps to complete while working on the project. It was designed to explain the steps of problem-based learning. The *Learning Resources* included a collection 28 articles adapted from the Internet introducing computer parts, explaining how they work and suggesting what to consider when shopping for them in the warehouse. The *Hardware Warehouse* simulated an online shopping site listing five to fifteen models for each computer part. Detailed technology specifications and price were also listed for each model. Three version of the PBL program were developed corresponding to the scaffolding conditions under study.

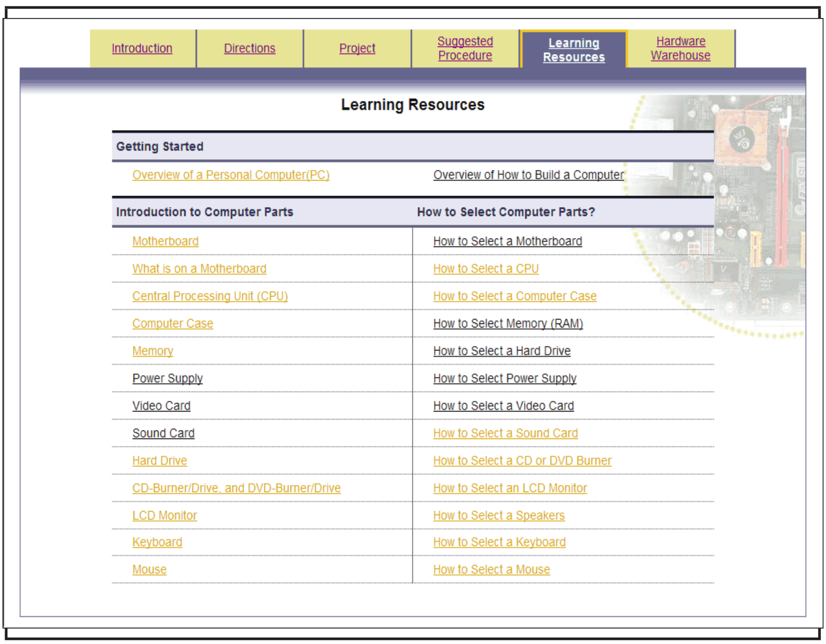

Figure 1. Learning Resources

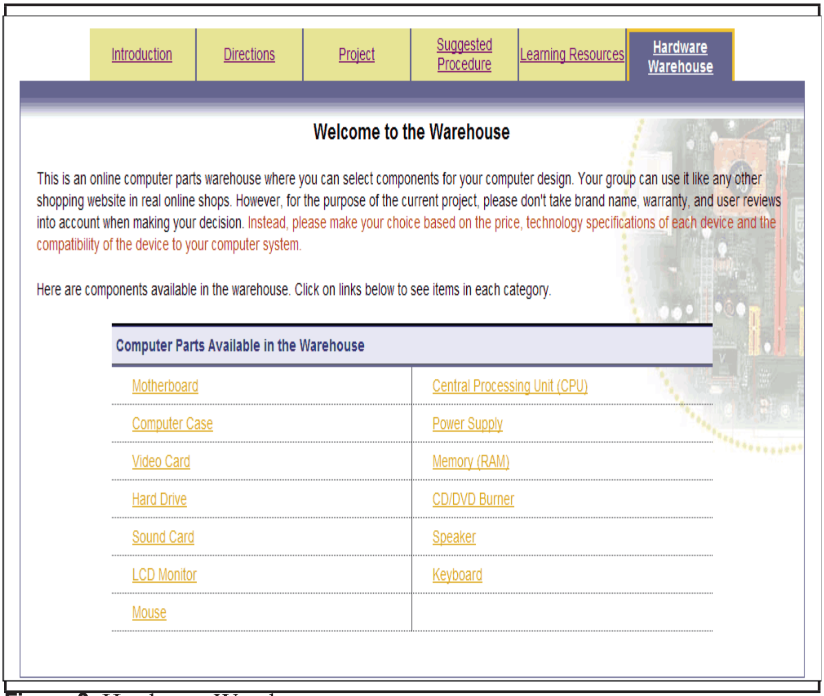

Figure 2. Hardware Warehouse

No Scaffolds. Participants in this treatment group received only the instructional materials described above. These students had no access to scaffolds throughout the PBL lesson and were used as the control group in this study.

Content Scaffolds. Three content scaffolds were provided to students as hard copies in this treatment condition: (1) a warm-up sheet, (2) a note-taking sheet, and (3) a project template. Students were cued in *Procedure to Follow* to use these required scaffolds. The purpose of the *warm-up sheet* was to introduce students to basic computer hardware and prepare them for the project. This scaffold guided students to read two introductory articles in the *Learning Resources* section. It contained two questions about computer parts and their functions and two questions about devices and their connections to ports, socket, and slots on a motherboard. One example of a question on the warm-up sheet is "List main components of a typical desktop computer." The *note-taking* sheet directed student attention to key terms and principles in the content. This content scaffold also contained 18 short-answer questions asking students to describe the functions of certain computer parts or explain technology specifications. One example of a question on the note-taking sheet is “How do you tell if a CPU can be plugged into a motherboard?” The *project template* provided a sample layout for the computer design drawing and listed elements students should address when making purchasing decisions.

Metacognitive Scaffolds. Three metacognitive scaffolds were provided to students in this treatment group: (1) a project planning sheet (2) an information collection log, and (3) a project reflection sheet. They were designed to provide students with guidance in planning, monitoring, and evaluating, three metacognitive skills required in open-ended learning environments (Land, 2000). Students were cued in the *Procedure to Follow* to use these required scaffolds. The *project planning sheet* was developed to guide project teams to identify their goals, define the problem area, and identify available resources. The design of this scaffold was guided by the six-step problem solving approach advocated by Eisenberg and Berkowitz (1990). The *information collection log* was designed to facilitate the metacognitive skill of monitoring. The scaffold explicitly asked students to write down tasks assigned by the team on a sheet and make notes to information they collected during their individual research. Land (2000) argued that by stating tasks and tracking information explicitly, students may be able to perform more goal oriented problem solving activities in a complex learning environment The *reflection sheet* was designed to encourage student teams to summarize, reflect on, and debrief information they learned after finishing the project. This scaffold told students to list things they learned throughout the project. Students were asked to report and illustrate what they learned to their team. The sheet was designed to encourage learner complete the evaluation step identified by Eisenberg and Berkowitz (1990) in their six-step problem solving method.

Teacher Guide. A teacher guide was used to standardize implementation of the program across the 20 sections of the course. This guide provided step-by step directions to help the teacher introduce the unit, form problem-solving teams, announce important issues, collect problem solutions, and administer the posttest and attitude survey.

Prior knowledge test. The prior knowledge test was a 10-question multiple-choice test designed to measure students’ prior knowledge of computer hardware. It was used to block students by ability to ensure equality across the three treatment conditions.

Data Sources

Data sources included an achievement posttest to measure individual knowledge acquisition, a team project to measure problem solving performance, a student attitude survey, a measure of time on the problem solving task, student navigation patterns, and a student interview. Each of these data sources are described below.

Posttest. The posttest contained 20 multiple-choice items to measure individual student learning on declarative knowledge and factual information learning. It contained eight questions on the meaning of technology specifications, six questions on functions of computer parts, three questions on connections among computer parts and directions of the data flow. It also included one question on the component compatibility, one question on the usage purpose, and one question on selecting computer components. The test was administered online after each team finished the group project. Two examples of questions on the posttest are "Which of the following component is "a must" for a personal computer?" and "Which of the following items does NOT have a positive impact on the CPU's performance?"

The posttest was tested in four pilot tests conducted prior to implementation of the study. Item analysis was performed on data collected from each pilot to examine the difficulty index and discrimination index. A few items were removed, while others were modified to better align with the computer-building project and to relate more closely to knowledge students may have acquired during problem-solving.

Problem-solving performance. A rubric was developed by the principal investigator and was used to evaluate problem-solving performance. It was worth a total of 65 points and measured if the computer designed by each project team was functional and met performance and budget requirements. Each computer component was assessed separately in the rubric. There were a total of thirteen components assessed using the criteria of performance, compatibility and connectivity. The rubric also measured if the overall budget fell within the range. To ensure the rubric validly measured the computer building task, it was reviewed be a graduate student majoring in engineering who had experience building computers. Inter-rater reliability was determined by calculating the correlation between two sets of scores from two independent graders on ten projects. Result indicated that the correlation was .99 ($p < .001$).

Attitude survey. The attitude survey had 16 questions designed to investigate student perceptions toward the PBL program, the support provided by the program and their team. These survey items were Likert-type which included a 5-option scale ranging from "strongly disagree" to "strongly agree." The survey also included two open-ended questions asking students what they liked most about the program and what could be done to improve it. The reliability of this attitude survey was .89.

Time on task. Students were asked to write down the time when their team started the project and the time when they finished it on their final project sheets.

Navigation patterns. The number of times each student visited web pages under *Learning Resources* and *Computer Hardware* were recorded into a computer database.

Student interviews. A sample of students was randomly selected from the three treatment groups to conduct interviews. An interview protocol contained questions to probe how student teams approached the problem solving project, for example, "What did your group mostly consider when making decisions?"

Procedures

This study was conducted in computer labs during regular class time of the computer literacy course. Each class section met once per week for a three-hour time block and had an enrollment of 19 to 24 students. Each student had access to a computer.

Each intact class section was randomly assigned to one of the three groups. Two weeks before the treatment, the prior knowledge test was administered to all students. A one-way ANOVA conducted on pretest scores indicated no significant difference between treatment groups $F(2, 309) = .51, p > .05$. In each group, the students were divided into two prior knowledge levels (high and low) by the overall median pretest score. Furthermore, students in each class section were randomly assigned to project teams prior to implementing the treatments.

On the day of the study, the instructor assigned each student to one of the project teams based on the team list given by the lead researcher. Each team consisted of three to four students. Students were then directed to the instructional program website. Each project team was given one sheet of blank paper on which to draw their computer design. For classes in the two scaffold conditions, each project team received an envelope containing hard copies of the appropriate scaffold sheets and was told they were required to use those sheets. Two hours after students started their projects, the instructor collected the computer drawing from each team and directed students to the website where they took the individual posttest and attitude survey. A sample of students from each treatment then participated in an interview.

Data Analysis

Two separate 3×2 ANOVAs were carried out on posttest scores and navigation paths to detect if scaffolds and prior knowledge had an impact on the two dependent variables. Two separate one-way ANOVAs were performed on group project performance and time on task to identify if there was any significant difference among scaffolding types on the two variables. Attitude survey and interview data were also analyzed with appropriate methods.

RESULTS

Posttest Achievement

The first research question investigated the effect of scaffolds and prior knowledge on individual posttest achievement. A 3 × 2 ANOVA revealed significant main effects for type of scaffolding [$F(2, 306) = 3.22$, $p < .05$, partial $ή^2 = .02$] and for prior knowledge [$F(1, 306) = 5.90$, $p < .05$, partial $ή^2 = .02$]. The ANOVA did not show a significant interaction between scaffolds and prior knowledge. A follow-up Tukey HSD test indicated that posttest scores for students in the content scaffolding treatment were significantly higher ($M = 11.89$) than scores for students in the metacognitive scaffolding treatment ($M = 10.82$). Cohen's *f* statistic yielded an effect size estimate of .14 which corresponds to a small effect. Students with high prior knowledge performed significantly better on the posttest ($M = 11.72$) than those with low prior knowledge ($M = 10.88$). Cohen's *f* statistics yielded an effect size estimate of .29 for prior knowledge which indicates a medium effect.

Table 1
Means and Standard Deviations for Individual Posttest

Scaffolding		Prior Knowledge		Total
		Low	High	
No Scaffolding (NS)				
	Mean	10.96	11.54	11.25
	SD	2.72	2.93	2.83
	N	56	56	112
Content Scaffolding (CS)				
	Mean	11.81	11.94	11.89
	SD	2.47	2.63	2.55
	N	43	53	96
Metacognitive Scaffolding (MS)				
	Mean	10.07	11.69	10.82
	SD	2.51	3.42	3.06
	N	56	48	104
Total				
	Mean	**10.88**	**11.72**	**11.30**
	SD	**2.65**	**2.98**	**2.85**
	N	**155**	**157**	**312**

Note. The maximum score possible was 20 points.

Performance on the Problem Solving Task

The second research question examined the impact of scaffolds on problem solving as measured by performance on the team project. A one-way ANOVA revealed a significant effect for type of scaffolding [$F(2, 93) = 3.94$, $p < .05$, partial $ή^2 = .08$]. A follow-up Tukey HSD test revealed that teams in the no scaffolding treatment performed significantly better on the problem solving task ($M = 45.38$) than teams in the content scaffolding treatment ($M = 40.60$). Cohen's *f* statistic yielded an effect size estimate of .59 which corresponds to a large effect. There were no other significant differences between the scaffolding conditions for problem solving performance.

Table 2
Means and Standard Deviations for Performance on the Problem Solving Task

Scaffolding	Mean	SD	N
No Scaffolding (NS)	45.38	7.75	32
Content Scaffolding (CS)	40.60	5.58	31
Metacognitive Scaffolding (MS)	44.47	7.89	33
Total	43.52	7.39	96

Note. The maximum possible score was 65 points.

Student Attitudes

The next research question examined the effect of scaffolding type and prior knowledge on student attitudes. Attitudes were measured using a 16-item survey that included a Likert-type scale ranging from 1 - strongly disagree to 5 - strongly agree. Finding showed that students generally had a neutral attitude toward the PBL program ($M = 2.92$), felt somewhat supported by it ($M = 3.36$), and thought that their team worked fairly well together (M = 3.54).

A principle components analysis was conducted to identify the factors that accounted for most of the variance on the attitude survey. Three factors were identified – (1) attitudes toward the program, (2) perception of support, and (3) team behavior. A set of variables was created from these three summated scales for further analysis. Each summated scale was generated by calculating the means for all of the items that loaded on one of the three principle factors (see Table 3).

Table 3
Summary of Loadings of the Three-Factor Solution for Student Attitudes

Items	Factor Loadings			h^2
	1	2	3	
I liked the "All you need is a Screwdriver" program.	**.74**	.30	.01	.64
I learned a lot about computer hardware from this program.	**.70**	.29	-.01	.57
The program was well designed.	**.57**	.44	.15	.54
I would enjoy working on another project like this again.	**.70**	.30	.06	.59
I am confident that I passed the individual test at the end of the lesson.	**.73**	.08	.18	.58
My group had enough time to complete the project.	-.06	.39	.48	.38
My group planned how to approach the project before we got started on it.	.11	.04	.72	.53
My group distributed our work load fairly among team members.	.00	.01	.71	.51
My group designed the computer using information obtained from our research in the program.	.16	.14	.59	.40
Working with my team helped me do well on the individual test at the end of the lesson.	**.68**	.05	.34	.58
The program included enough information and resources to help me do well on the individual test at the end of the lesson.	**.68**	.34	.11	.60
The program offered enough support to help my team organize our project.	.41	**.73**	.12	.71
t was easy to find information needed to complete the project.	.26	**.75**	.16	.65
The program provided enough support at the beginning to help my team get started on the project.	.32	**.75**	.12	.68
The program included enough support to help me keep track of information I collected to complete the project.	.36	**.82**	.13	.75
My group reflected on what we learned from the program.	.28	.18	.58	.44

Note: Boldface indicates highest factor loadings.

A 3 × 2 ANOVA revealed that scaffolding [$F(2, 298) = 9.94$, $p < .001$, partial $\acute{\eta}^2 = .06$] and prior knowledge [$F(1, 298) = 5.96$, $p < .05$, partial $\acute{\eta}^2 = .02$] had a significant main effect on the factor of team behavior. The ANOVA did not show a significant interaction between scaffolding and prior knowledge. Follow-up tests indicated that students in the content scaffolding treatment responded that they performed significantly less team behaviors (M = 3.35) than students in the metacognitive scaffolding treatment (M = 3.71) and those in the no scaffolding treatment (M = 3.55). Students with high prior knowledge reported that they performed significantly more team behaviors (M = 3.61) than those with low prior knowledge (M = 3.47).

A 3 × 2 ANOVA also indicated that prior knowledge had a significant main effect on the factor of attitudes toward the program, $F(1, 298) = 8.31$, $p < .01$. Students with high prior knowledge had significantly more positive attitude toward the program (M = 3.06) than those with low prior knowledge (M = 2.79). ANOVA did not show a significant main effect for scaffolding or a significant interaction between scaffolding and prior knowledge.

Finally, a 3 × 2 ANOVA conducted to examine the effect of scaffolding and prior knowledge on the perception of support did not show any main effects or interaction.

Approximately 96% (N = 292) of participants who completed the Likert portion of the attitude survey also responded to two open-ended questions. When asked what they liked best about the lesson, 92 students mentioned that they liked learning the new information presented in the program. Sixty-one students also indicated that they liked the well organized and comprehensive information provided by the program. Fifty-one students mentioned that they liked the computer-design project. Other students mentioned enjoyed the team collaboration (n = 31) or that the program was easy to use (n = 28).

When asked if they had any suggestion to improve the program, 98 students responded that they would like to have more time to work on the program or less work to do in two hours. Forty-one students mentioned that the instructions/directions should be clearer. Twenty-two students reported that they wanted more content knowledge before doing the project. Others mentioned that the program could be improved by explaining information better (n = 15) or by giving them a chance to fully understand the whole project from the start (n = 12).

Time Spent on the Problem Solving Task

The next research question examined the influence of scaffolds on the amount of time teams spent on the problem solving task. The average amount of time spent was 110.80 minutes (SD = 12.56) for all project teams. A Welch ANOVA test was conducted on time data to adjust for unequal standard deviations across the three treatment groups. The test indicated a significant effect for scaffolding [$F(2,93) = 5.18$, $p < .01$, partial $ή^2$ = .13]. A follow-up Games-Howell test revealed that teams in the no scaffolding treatment spent significantly less time on the problem solving task (M =

104.56 minutes, *SD* = 15.23) than teams in the content scaffolding treatment (*M* = 114.52 minutes, *SD* = 9.01) and those in the metacognitive scaffolding treatment (*M* = 113.36 minutes, *SD* = 10.40).

Navigation Patterns

Another research question looked at the effect of scaffolds and prior knowledge on student navigation pattern. A 3 × 2 ANOVA test indicated that scaffolding had a significant main effect on the number of times students used learning resources [$F(2, 306) = 3.22$, $p < .05$, partial $\acute{\eta}^2 = .02$] and the number of times they visited hardware warehouse pages [$F(2, 306) = 5.73$, $p < .01$, partial $\acute{\eta}^2 = .04$]. Follow-up Tukey tests revealed that students in the content scaffolding treatment used significantly more learning resources (*M* = 21.05) than those in the metacognitive scaffolding treatment (*M* = 17.58). However, students the content scaffolding condition used significantly less hardware warehouse pages (*M* = 30.76) than students in the metacognitive scaffolding condition (*M* = 42.81) and those in the no scaffolding condition (*M* = 46.85). ANOVA tests did not yield a significant main effect for prior knowledge or a significant interaction between scaffolding and prior knowledge.

Interview Data

To determine how teams approached the PBL project, 25 students from different teams were interviewed. When asked about the approach their team took to do the computer design project, 20 students answered that they distributed the workload among team members. Most of descriptions were similar to the following statement: “We counted how much work we had for the project and just simply split it up.” Furthermore, 23 students indicated that they used information found in “Learning Resources” and “Hardware Warehouse” to complete the project. Three students in the content scaffolding group and two students in the metacognitive scaffolding group also reported that they used the scaffold sheets while working on the project.

When asked how their team made purchasing decisions, 10 students reported that each member made individual judgments on a few devices while 9 answered that their whole team made decisions together on each computer part. When asked what they considered to make a decision, all 25 students reported they thought about price. In addition, 21 students also mentioned compatibility and 10 referred to performance.

When asked if there was a lot of discussion while working on the project, 14 students said “no” or “not a lot” because “we divided the work at the beginning, and we were busy with our own research.” Some students indicated that they “were occupied by the task and did not have time to discuss it.”

Finally, when asked if they felt that posttest questions are related to the project, 12 students answered yes whereas 10 said that the posttest was "sort of" related to the project, because "we only knew the questions we researched in the project."

DISCUSSION

The main purpose of this study was to examine the effect of scaffolds on knowledge acquisition, problem-solving performance, and student attitudes during the implementation of a hypermedia-based PBL lesson. Prior knowledge was also examined because it is often related to student outcomes in PBL.

Findings revealed that posttest scores for students who received content scaffolds were significantly higher than scores for those who received metacognitive scaffolds. As suggested by Hannafin et al. (1999) and Land (2000), the content scaffolds used in this study directed students to important concepts and rules by asking specific and detailed questions. Furthermore, the content scaffolds corresponded to items on the posttest. Thus, after explicitly answering questions posed in the content scaffolds, students were able to acquire specific knowledge which was required on the individual posttest.

Another explanation for results on the posttest relates to the finding that students who received content scaffolds accessed significantly more *Learning Resources* than students who received metacognitive scaffolds. This suggests that additional use of resources in PBL may have a direct benefit on knowledge acquisition.

It is interesting that teams in the no scaffolding condition performed better than teams in the content scaffolding condition on the problem solving task of designing a desktop computer. This most likely occurred because teams that received content scaffolds felt rushed to finish the group project. This explanation is supported by an analysis of the attitude survey item - "My group had enough time to complete the project." More students in the no scaffolding condition (M = 3.54) agreed with this item as compared with those in the content scaffolding condition (M = 2.81). Thus, completing the content scaffolds took time away from finishing the problem-based task itself.

As expected, results indicated that students with high prior knowledge performed better on the individual posttest than those with low prior knowledge. This is consistent with findings from other researchers who reported that prior knowledge is related to achievement in problem-based learning (Albanese & Mitchell, 1993; Norman & Schmidt, 1992; Simon & Klein, 2007).

Turning to attitudes, students mostly had neutral feelings toward many features of the problem-based, hypermedia program and the computer design project. Responses to the open-ended questions on the survey help to explain these results. Many students mentioned they would have liked more time to work on the program or less work to do in the two hours they were given. Others reported that instructions were not clear especially at the beginning of the lesson. The incentives provided to students may have also contributed to results for attitudes. Students were told that scores on the group project and the individual posttest would count toward their final course grade. They were also told that full participation in the PBL program would earn them five extra credit points. Given their concern about the difficulty of the lesson and amount of time allotted to solve the problem, these performance-based incentives may have impacted their perception toward the hyper-mediated, PBL lesson.

Although overall attitude toward the program was neutral, students did report several things they liked about the program. Many mentioned that they liked learning the new information covered in the lesson. Several indicated that the information was well organized and comprehensive. Others said they liked the project of designing a computer. These results are encouraging and suggest that many students perceived the PBL lesson as useful and valuable.

Analysis of the three factors on the attitude survey revealed that students with high prior knowledge had significantly more positive perceptions toward the program and the behaviors exhibited by their teams than those with low prior knowledge. This is not surprising. Researchers have found that prior knowledge and general ability are related to student attitudes in PBL and other learner-centered environments (Hannafin, 1984; Simons & Klein, 2007).

One other finding for attitude is particularly noteworthy. Students in the metacognitive scaffolding condition and those in the no scaffolding treatment reported significantly higher attitudes on the team behavior factor than those in the content scaffolding condition. These items are associated with behaviors that student teams performed while working on the project. It is likely that students provided with content scaffolds did not have as much time to work as a team because they were occupied by the task of completing content related questions. Interview data indicated that students in teams given content scaffolds did not spend lot of time discussing the project with each other.

The results of this study have some implications for the design of hypermedia-based PBL. It can be designed to direct student attention to important content and encourage them to achieve understanding. As findings suggest, content scaffolds should be provided to increase knowledge acquisition from PBL especially when test items are aligned with questions included in the scaffolds. However, these scaffolds should be used with caution, because learning content information does not guarantee success in solving problems in these environments. Designers should critically examine the content and provide scaffolds to help students acquire key concepts, principles and rules directly related to solving the problem.

Future research should continue to examine hypermedia-based PBL and the use of scaffolds. Studies that investigate the impact of specific types of content scaffolds should be conducted. Three different scaffolds were provided to students in the scaffolding treatments in this study. This was done to increase the power of the treatments, but at the same time it increased the degree of complexity. Additional studies could be designed so that students in each treatment group receive only one type of content scaffold.

Hypermedia-based PBL is a complex, student-centered, exploratory learning environment. As these methods become more common, researchers should continue to examine factors that contribute to student motivation, learning and performance in problem-based environments.

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