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Examining the Performance and Attitudes of Sixth Graders During Their Use of A Problem-Based Hypermedia Learning Environment

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ABSTRACT

The purpose of this study was to examine the impact of a problem-based hypermedia learning environment on sixth graders' performance and attitudes. We were interested in finding the ways hypermedia technology could be used as cognitive tools to share the responsibilities of teachers to provide necessary scaffolding to support students' learning in a problem-based learning (PBL) environment. Of particular interest to this study was to understand if non-gifted students could succeed in a PBL environment where scaffolding was provided through technology in addition to that from a teacher. Since this environment was multimedia rich and game like, we also wanted to find out if girls would perform as well as boys. Both quantitative and qualitative data were used. The findings have shown that the enriched presentation of the knowledge base and the more effective delivery of cognitive tools through hypermedia technology have provided needed scaffolding to all students in the 6th grade classrooms. As a result, not only students in gifted education but also students in regular education performed well in this technology enhanced PBL environment. In addition, students, who speak English as a second language or have some learning disability, also benefited from using it. The amount of gain in students' science knowledge and problem-solving skills was related to their prior knowledge level. This study has also indicated that due to a large amount of reading involved, slow readers found this PBL environment challenging. More support, via technology or teachers, is needed for these students. To our encouragement, and contrary to the recent computer attitude and gender research, no gender difference was found in the performance, nor in the attitudes among the students in this study. Girls performed equally well and had positive attitudes toward the PBL environment and learning science as a result of using it.

(Keywords: problem-based learning, hypermedia technology, cognitive tools, problem solving, performance and attitudes)

RESEARCH FRAMEWORK

In the past decade, we have seen an increased use of computer technology in different aspects of K-12 curricula. However, creating student-centered learning environments with technology remains to be a challenge for educators (Land & Hannafin, 2000). Instructional designers, technologists, and teachers are searching for new and innovative ways to design such environments effectively. One promising approach, deeply rooted in the constructivist theory and increasingly attracting attention in K-12 education, is problem-based learning. In this study, a problem-based hypermedia learning environment for middle school science was examined to understand how it affected students' performance and their attitudes as they used the program.

Problem-Based Learning

Problem-based learning (PBL) is an instructional approach that exemplifies authentic learning and emphasizes solving problems in rich contexts. According to Howard Barrows (1996), PBL has the following main characteristics:

- Learning is student-centered as students assume a major responsibility for their own learning;
- Learning occurs in small groups;
- Teachers are facilitators or guides;
- Problems form the organizing focus and stimulus for learning;
- Problems, similar to those one would face in future professions, are a vehicle for the development of problem-solving skills
- New information is acquired through self-directed learning (p. 5-6).

Problem-based learning was originally developed in medical education in the late 1960s to address the practical concern that the traditional curriculum was inadequate in preparing students to solve complex problems and transfer classroom learning to real world situations (Barrows, 2000; Schmidt, 1995). The interest in using PBL in other disciplines including K-12 education has been steadily increasing (Gallagher, 1997). This increase is partly due to the realization that PBL provides a meaningful and concrete way to apply the essential principles of

the constructivist theory, which states that learning is essentially an act of active knowledge construction on the part of a learner (Savery & Duffy, 1995). It is also because many educators believe that the benefits of PBL can lead to the development of higher order thinking skills, an important goal in education (Hoffman & Richie, 1997). PBL emphasizes the importance of active and self-directed learning from the learners and everyday relevance of the problems under investigation (Schmidt, 1995). The aspect of anchoring learning in real world contexts in PBL has been found to provide opportunities for transferring knowledge and skills from the classroom to workplace more easily (Stepien, Gallagher, & Workman, 1993). In medical education, studies have shown that PBL is more effective in resulting in long-term content retention than traditional instruction (Martensen, Eriksson, & Ingleman-Sundberg, 1985; Norman & Schmidt, 1992), and can help students apply and integrate knowledge more effectively (Patel, Groen, & Norman, 1991). Students who received PBL training are also found to have higher motivation and better attitudes toward learning (Albanese, & Mitchell, 1993; Norman & Schmidt, 1992). Blumberg (2000) concluded, after reviewing numerous studies in the medical professional, that there is strong enough evidence to indicate that PBL helps the development of self-directed study skills. In K-12 education, PBL has been found to be successful with mature gifted middle and high school students in developing their problem solving skills (Gallagher, 1996; Gallagher, Stepien, & Rosenthal, 1994; Gallagher, Sher, Stepien, & Workman, 1995; Hmelo & Ferrari, 1997). While there is a belief that PBL is applicable to all levels and facets of the educational spectrum (Evensen & Hmelo, 2000), there is a lack of research evidence to show if non-gifted K-12 students can also be successful in a PBL environment as PBL requires a learner to be independent, self-directed, and able to pursue her own learning goals.

The benefits of PBL are also accompanied by its implementation challenges (Hoffman & Richie, 1997). These challenges include (1) the use of oral or written statements as a primary means to present the problem, which is not only inefficient, but also "may have dysfunctional consequences for the learner" (Bridge, 1992, p.97); (2) the initial discomfort with the increased degree of freedom as exhibited in some students; (3) different assessment forms required to

address learners' problem solving skills; and (4) large amount of time and effort required to develop and implement a PBL unit in a classroom (Hoffman & Richie, 1997). Farnsworth (1994) stated the implementation challenges of PBL as follows: "(1) PBL is an inefficient method of instruction since it requires students to gather information through self-directed learning, (2) PBL is perceived as costly since it requires a greater investment of faculty time to function as tutors, and (3) PBL is more difficult and costly in terms of evaluation of student learning" (p.137). Such challenges become even more critical for teachers in K-12 education, where class sizes are typically large, and a teacher's teaching schedule is full. The typical 45-minute class periods are often insufficient if students have to gather a variety of information needed to solve a problem from different sources and locations. In addition, some teachers are unfamiliar and/or uncomfortable with the shifted role of an instructor to that of a facilitator as required in PBL.

The challenges of implementing PBL in a classroom require scaffolding (Koschmann, Kelson, Feltovich, & Barrows, 1996). Typically, the scaffolding comes from the instructor as shown in the practice of medical schools. However, given the demands of time, resources, and expertise needed to develop and implement a PBL unit as discussed above, it is often unrealistic to expect a K-12 teacher to use PBL without additional support. What can we do to help teachers in their use of PBL so as to extend PBL benefits to all students, not just those in the gifted education?

Technological tools can be used as a form of scaffolding to support learners in their information processing and knowledge construction process. Being used in such a way, technology serves as cognitive tools to assist learners in accomplishing complex cognitive tasks (Lajoie, 1993) and in enhancing "the cognitive powers of learners during thinking, problem-solving, and learning" (Jonassen & Reeves, 1996, p. 693). Hoffman and Richie (1997) suggested the use of hypermedia technology to overcome some difficulties with PBL. They believed problem scenarios could be presented using hypermedia to increase the fidelity of problem presentation. The use of different media can help "students comprehend the situation and see the relevance of various contextual elements" (p. 102). The nonlinear, associative, and interactive

capabilities of hypermedia could allow students to access information according to their own learning needs, hence individualized learning and present multiple related problems in one environment (Hoffman & Richie, 1997). As cognitive tools, it is possible with technology to allow learners to access knowledge bases and engage in cognitive activities that would be out of their reach otherwise, such as accessing experts and expensive scientific tools; and assist learners to generate and test hypotheses through simulations. Hypermedia enhanced PBL could provide richer information resources using different media in a more efficient way. Can hypermedia technology be used as cognitive tools to share the responsibilities of teachers in providing necessary scaffolding to students at different ability levels in a PBL environment?

Attitudes and Gender Differences

Computer attitude has been consistently found to be an important variable in educational computing research (Lim, 2002); and plays a role in student success in computer-related tasks (Loyd & Gressard, 1984). Attitudes can be related to a number of factors such as computer experience, age, gender, and academic performance. There has been a great deal of research on the relationship between genders and attitudes toward computers. Early studies have shown that females tended to have more negative views toward computers than males (Chen, 1985; Gattiker & Nelligan, 1988; Koohang, 1987). Theses studies suggested that males were less anxious, more confident and like using computers more than females. When computer experience was taken into consideration, however, research found that gender did not directly affect a student's attitude toward computers (Chen, 1985; Hunt & Bohlin, 1993; Levin & Gordon, 1989; Teo & Lim, 1996). Since the increased computer uses in schools and homes in the 1990s, especially with the widespread use of email and internet, studies have shown that the gap in attitudes toward computers between the genders has disappeared (Dyck & Smither, 1994; Houle, 1996; Todman & Monaghan, 1994). However, most recent studies have indicated a trend more consistent with the early findings. In a longitudinal study investigating the relationships between gender, categories of computer use and attitudes toward computers, Mitra and her colleagues found that females were less positive about computers than males, and used computers less frequently

(Mitra, Lenzmeier, Steffensmeier, Avon, Qu, & Hazen, 2000). In another longitudinal study, it was found that men were more willing to take a positive attitude toward the technological innovations (Mitra, LaFrance & McCullough, 2001). In his study, Kadijevich (2000) found that ninth-grade male students showed a more positive attitude toward computers than females, even when computer experience was controlled.

Some researchers asked the question if females and males held the same attitude toward all types of computer use (Mitra, Lenzmeier, Steffensmeier, Avon, Qu, & Hazen, 2000; Scott & Rockwell; 1997). Lockheed (1985) found that males used computers for programming and game playing more than females. A study by Scott and Rockwell suggested that males reported liking to play video games more than females (1997). Mitra, LaFrance, and McCullough (2001) suggested that genders might differ in attitudes toward computers in terms of the types of computer use. How do male and female students feel toward a hypermedia enriched PBL environment? Research in medical education showed that students had better attitudes toward learning after receiving PBL training (Albanese, & Mitchell, 1993; Norman & Schmidt, 1992). Would the students' attitude toward the subject matter be affected as a result of being immersed in a hypermedia PBL environment?

RESEARCH QUESTIONS

The purpose of this study was to examine the impact of a problem-based hypermedia learning environment, Alien Rescue, on sixth graders' performance and attitudes. In Alien Rescue, a complex, and ill-structured problem was presented. To assist students in solving this problem, rich information resources in the form of cognitive tools were provided through hypermedia technology. Designed based upon current educational literature and research findings, Alien Rescue was developed in a university setting for use in 6th grade science curriculum. As a research and development project, we were interested in finding the ways hypermedia technology could be used as cognitive tools to share the responsibilities of teachers to provide necessary scaffolding to support students' learning in a PBL environment. Of particular interest to this study was to understand if non-gifted students could succeed in a PBL

environment where scaffolding was provided through technology in addition to that from a teacher. Since this environment was multimedia rich and game like, we also wanted to find out if girls would perform as well as boys. A description of <u>Alien Rescue</u> is in the "instructional material" section. This study sought to address the following three research questions:

- 1. How do sixth graders of different ability levels perform in this environment?
- 2. Are there any differences in the performance between male and female students?
- 3. What are students' attitudes toward this environment and toward science learning as a result of using this PBL environment?

METHOD

Sample

The participants were 155 sixth graders from a middle school in a mid-sized Southwestern city. The school has the demographics of 16% Hispanic, 6% African-American, 73% Caucasians, and 5% other ethnic backgrounds. Students' ability level was determined by a classification system used by the school district through a formal nomination and testing procedure. Of the 155 students, 17% (n = 26) were in the Talented and Gifted (TAG) classes. 10% (n = 15) were identified as students needing additional academic help. These students were those who speak English as a second language or have learning disability (ESL/LD). Approximately 73% of the students (n = 114) were in regular education (RegEd) classes. 47% of the students were female (n = 73). There were six male and four female students in the TAG group; forty-five male and forty-one female students in the RegEd group; and nine male and five female students in the ESL/LD group. Two teachers taught the six grade science classes. These students were familiar with the basic computer applications such as word-processing. A majority of the students had played computers games and used such programs as Powerpoint prior to the study.

Instructional Material

A PBL hypermedia program, <u>Alien Rescue</u>, was used as the science curriculum in a 3-week period. A detailed description of <u>Alien Rescue</u>, its design considerations, and its cognitive

tools can be found on its web site (http://www.alienrescue.com) and in the article by Liu, Williams, and Pedersen (2002). Guided by the theories and research on problem-based learning in its design, Alien Rescue engages 6th grade students in scientific investigations aimed at finding solutions to complex and meaningful problems. The software is CD-based, and designed for approximately fifteen 45-minute class sessions. It begins with a presentation of an ill-structured problem for students to solve. A group of six species of aliens, different in their characteristics, have arrived in Earth orbit, due to the explosion of their home planets. They must find new homes that can support their life forms or they will die. Students, acting as scientists, are asked to participate in this rescue operation, and their task is to determine the most suitable relocation site for each alien species. To solve this problem, students must engage in a variety of problemsolving activities. They need to research about the aliens' needs, what planets in our solar system can offer, and find possible matches. To assist the students, a set of thirteen cognitive tools is provided to scaffold students' problem-solving process. The tools include a concept database, probe design tool, expert modeling, alien needs database, solar system database, and notebook. It is purposely built that more information than needed in solving this problem is available in the environment. Students must sift through the vast information and decide what is relevant and important. Alien Rescue is currently being used by over 2000 sixth graders in Central Texas. We are interested in understanding the learning benefits of such an environment.

Data Sources

Multiple data sources, both quantitative and qualitative, were used for the purpose of data triangulation.

Science Education Standards and the Texas Essential Knowledge and Skills guidelines. A 25-item multiple-choice test was developed to assess students' understanding of the various scientific concepts introduced in the program. This knowledge test was used in a previous pilot study (Williams, 1999), using a similar sample to the one in this study. It was then revised numerous times according to the suggestions from the classroom teachers who pilot-tested the

program and university faculty in astronomy education. The test (r=.73) was given before and after the use of <u>Alien Rescue</u> to measure the gain in students' factual knowledge. Since no direct teaching should be involved in using <u>Alien Rescue</u>, a good score on the test would indicate the student has acquired a good understanding of the scientific topics included in the program through her self-directed learning, classroom discussions, and/or peer interaction.

Recommendation Form. Students provided their solutions to the problem through entering their recommendations of a possible new home for each of the alien species. An online solution form was provided in the program. Students must select a world for the species as its new home (via online form or paper and pencil), and provide their justification why this world is a good choice. The software program was intentionally developed in such a way that there is more than one good choice for each alien species. Some choices of the worlds are better than the others, and some have obvious drawbacks. Students' justification skills are emphasized in writing and grading the rationale. "The process of justification requires the [problem] solvers to identify the various perspectives that impact the problem situation, provide supporting arguments and evidence about opposing perspectives, evaluate information, and develop and argue for a reasonable solution" (Shin, Jonassen, & McGee, 2003). Through the process of justifying their solutions, students are to practice their analyzing, synthesizing, and argument making skills (Beyer, 1991). This emphasis on reasoning skills is aligned with National Science Education Standards which states that students at every grade level should have the opportunity to use scientific inquiry and be able to communicate scientific arguments effectively (National Committee on Science Education Standards and Assessment, National Research Council, 1996). In this study, the teachers opted to use a paper version of the recommendation form, not the online version, due to technical constraints of printing from multiple computers simultaneously and computer crashes.

The teachers developed the following grading rubric to judge whether students placed the aliens successfully (see Table 1). Students must first select the correct or acceptable world(s) for the species. Then they must write three complete sentences discussing three reasons an alien

should be placed on a certain planet. This rubric was always present on the board in the classrooms. In grading students' solutions, one teacher stated, "I usually had to give the forms back for more information on [alien's] needs and how the world supported those needs. I had them go back and do more research to complete their recommendation forms. Once this was done, I wrote okay at the top of their paper and stapled them together to keep up with grades."

Insert Table 1 here

Attitude toward Learning Environment Questionnaire. To assess students' attitude toward this PBL environment, a 9-item questionnaire was used. This questionnaire addressed two aspects of students' attitude toward Alien Rescue: (1) Enjoyment of Alien Rescue (4 items, r=.83, .77); and (2) Educational value of Alien Rescue (5 items, r=.77, .70). This 9-item questionnaire uses a 5-point Likert scale with responses ranging from 1 for Disagree Strongly to 5 for Agree Strongly. Sample items include "The Alien Rescue computer program is interesting," and "I didn't learn any science by working on Alien Rescue." The construction of this instrument evolved over several phases. Based on a questionnaire developed by S. Williams (1992) to assess sixth graders' attitude toward a mathematics software environment, D. Williams (1999) adapted it to assess attitude toward the Alien Rescue environment. The questionnaire was further refined and tested based upon pilot testing results (Pedersen & Liu, 2002). This instrument was given out after the use of Alien Rescue.

Attitude Toward Science in School Assessment (ATSSA). Students' attitude toward science was measured using Germann's Attitude Toward Science in School Assessment (1988). ATSSA intents to measure how students feel toward science as a subject (Germann, 1988). During its development, the instrument was evaluated by a panel of three experts for its construct validity and clarity, and used with 7th to 10th graders in science classes for four different studies (Germann). The instrument consists of 14 Likert scale items with Cronbach's alpha of 0.95. Sample statements include "Science is fun," and "During science classes, I usually am

interested." The instrument was given before and after the use of <u>Alien Rescue</u>. When given out as a post-survey, students were asked to think about "science" in each statement as science taught like <u>Alien Rescue</u>.

Observations and Interviews. Observations of the class activities were made throughout the three-week period of using Alien Rescue. Multiple interviews were conducted with both the students and the teachers. Interviews were conducted during and after the use of the program. The interview questions concentrated on the following aspects: (1) the science concepts students learned through using Alien Rescue, (2) the parts of the program they liked or disliked (3) the comparison between using this program and other activities they did, and (4) their interest in using a similar program in the future. The time for each interview ranged from 5 minutes to 30 minutes. Two researchers, advance doctoral students who are well versed in qualitative methods, made the observations and interviews.

Procedure and Context

The study took place over a three-week time period. Students used <u>Alien Rescue</u> in their daily forty-five minute science class. Students worked on Dell wireless laptops in their science classrooms. Two or three students shared a laptop, sat around a table, and worked as a group. The teachers made the group assignments. Most groups consisted of a male and a female student. Students divided tasks among themselves as to how to proceed. The two teachers are experienced science teachers, but novice computer users. They went through a two-day training workshop on using <u>Alien Rescue</u> and its PBL approach. Two researchers were in the classrooms to do observations during the use.

Analysis of the Data

To determine how students of different ability levels performed (Research question 1), a one-way ANOVA was conducted with ability levels (TAG vs. RegEd vs. ESL/LD) as the independent variable and students' solution scores as the dependent variable. A two-factor mixed ANOVA was run with the ability levels as a between-subjects independent variable and the data

collection points (pre vs. post) as the repeated measure independent variable. The dependent variable was students' science knowledge test.

To determine how male and female students performed (Research question 2), a one-way ANOVA was conducted with gender as the independent variable and students' solution scores as the dependent variable. A two-factor mixed ANOVA was run with gender as a between-subjects independent variable and the data collection points (pre vs. post) as the repeated measure independent variable. The dependent variable was students' science knowledge test.

To determine students' attitudes toward science and <u>Alien Rescue</u> (Research question 3), two one-way ANOVAs were conducted with the ability levels and gender as the independent variables respectively and students' attitude toward <u>Alien Rescue</u> as the dependent variable. Two two-factor mixed ANOVAs were run with the ability levels and gender as a between-subjects independent variable respectively and the data collection points (pre vs. post) as the repeated measure independent variable. The dependent variable was students' attitude toward science.

To analyze the interview data, the data were first transcribed, then chunked, coded, and categorized following the guidelines by Miles and Huberman (1994). A two-level scheme, as described by Miles and Huberman, was used. At a more general level, a start list of codes was constructed using the research questions as a guide. At a more specific level, codes generated directly from the interview data were nested in the more general codes. During the coding processing, the codes were refined, revised, and new codes for emerging themes were added. Patterns from the data were extracted and relationships between coded segments were studied. The data was then sorted into categories and sub-categories according to their common themes and shared relationships. Observation notes were written up and analyzed to corroborate the patterns generated from the interviews.

RESULTS

Findings from the Quantitative Data Sources

Solution to the Problem. The results of the ANOVAs revealed significant differences among the three ability levels in their performance as shown in the recommendation forms:

F(2,152) = 10.68, p < .01. TAG students' scores were significantly higher than the scores by both RegEd students and ESL/LD students: Mean_{TAG} =95.39; Mean_{RegEd} =89.25; Mean_{Resource} =85.33 (see Table 2). The difference between male and female students' performance was not significant: F(1,153) = 3.31, p= .07 (see Table 2).

Insert Table 2 here

Science Knowledge Test. The results of the two-factor mixed ANOVA indicated that there was a significant two-way interaction between the ability levels and the data collection points (pre vs. post) for the science knowledge tests: F(2,152) = 3.94, p < .05. Although the posttest scores among the three levels were statistically different from each other as shown in the post hoc Scheffe comparison tests (see Table 2 and Figure 1), it is clear that the three levels had different starting points as shown in their pretest scores. The gain from pre to post was statistically significant for all three levels. That is, TAG students outperformed the RegEd, and RegEd students outperformed ESL/LD students, but all levels gained significantly from their starting levels. The mean scores indicated that both RegEd and ESL/LD students doubled their scores from pre to post while TAG students did not. There was no significant two-way interaction between gender and the data collection points (pre vs. post) for the science knowledge tests: F(2,152) = 2.98, p = .09; although the post scores were significantly higher than the pre scores for all three levels at p < .01 (see Table 2 and Figure 1).

Insert Figure 1 here

Attitudes Toward <u>Alien Rescue</u> Environment. The results of the ANOVAs revealed no significant differences among the three ability levels in the subscale of enjoyment: $F(2,152)_{enjoyment} = 1.77$, p= .17; but a significant difference in the subscale of educational value $F(2,152)_{EdValue} = 6.62$, p < .01 (see Table 3). All groups of students, whether they were TAG,

RegEd or ESL/LD students, held similar views toward <u>Alien Rescue</u> in terms of whether it was an enjoyable experience. TAG and RegEd students considered <u>Alien Rescue</u> environment educationally more valuable than ESL/LD students did as shown in Post hoc Scheffe comparison tests (see Table 2). There were no significant differences between male and female students in their attitudes toward <u>Alien Rescue</u>: $F(1,153)_{enjoyment} = .55$, p=.46; $F(1,153)_{EdValue} = .99$, p=.32.

Insert Table 3 here

Attitudes Toward Science Learning. The results of the two-factor mixed ANOVA indicated that there was no significant two-way interaction between the ability levels and the data collection points (pre vs. post) for attitudes toward science learning: F(2,152) = 2.18, p = .12. The gain from pre to post scores for all three levels reached a near significance level: F(1,152) = 3.85, p = .0517. That is, the post scores were higher than the pre scores (see Table 2). Judging from the means, the increased scores from pre to post by RegEd and ESL/LD students contributed to this near significance. There was no significant two-way interaction between the gender and the data collection points (pre vs. post) for attitudes toward science learning: F(1,153) = 1.60, p = .21. The gain from pre to post scores for all three levels reached a near significance level: F(1,153) = 3.80, p = .053. This near significance level appeared to be explained by the increase from pre to post in attitude scores by the female students (see Table 3).

Findings from the Qualitative Data Sources

Science Concepts Learned Through Using Alien Rescue. In the interviews, the students cited many science concepts they learned using Alien Rescue. Students specifically mentioned they learned about the planets (e.g. their temperatures, atmospheres, magnetic fields etc.), about converting the temperatures in different scales, about the aliens (e.g. their food, habitats, etc.) and about probes and related instruments in designing a probe. Many were able to give details as to what they have learned. Here are a few sample quotes from the students:

I like the part where you get to go into the temperature scales and everything, and then get to know how to convert Celsius into Kelvin and Kelvin into Celsius.

I learned a lot about space. I didn't really know that much about it before, and I really like it. My favorite planet is Saturn, and now I know a lot about the planets and stuff. I found out that it's really like a big gas giant and stuff, and I found out that I used to think that it had rings of gas, and I found out they have like rocks...

Students' Likes and Dislikes of <u>Alien Rescue</u>. "It's fun," and "It's cool," over ninety percent of the students replied, regardless of the gender, when they were asked what they thought of <u>Alien Rescue</u>. When the students were asked why they liked using <u>Alien Rescue</u>, some students cited they were able to send probes, learn about the planets; and others mentioned they were able to solve the complex problem:

It's much easier than the teacher talking and [inaudible]... It's a much more fun, handson activity where you get to do it all yourself. Try to learn. Like, at first it was confusing because like, I didn't even know what a probe was...

I like the part where you would actually have to research on a certain alien. You'd click on the body, and you would read about the body and then take notes on it and everything. It's really cool. I like the forms of them. It's really cool.

Interestingly enough, when the students were asked which part(s) of the program they liked the least, several mentioned the challenging aspect of solving this complex problem. They said there was too much information, there was no ready answers they could find and they had to spend a lot of time solving it. "The game's too hard," as put by one student. Another student said, "I don't like researching about everything and trying to fit it all together. It takes forever." Several students were frustrated as the answer to the problem was not readily available in the program and they could not get it easily from their teachers as well. A few mentioned such technical problems as computer crashes.

Over fifty percent of the students said they talked about <u>Alien Rescue</u> and compared their notes during their lunch period, advisor period, and/or outside school. One student commented, "... like when you're researching it, and you finally figure out the stuff that you never knew about, and how each one of y'all can tell stuff that the other person did not know about." The following responses from a group of a male and female students clearly showed students' enthusiasm in using <u>Alien Rescue</u>.

[Interviewer: Do you talk about this program after class, during advisory or lunch? If so, what do you talk about?]

[male student] Yeah, we talk about it on the bus. We all tell each other where, me and some friends, we all talk about like where they go and stuff. Because sometimes we need help. So we all talk about it, and they go, "I'll give ya a hint... They go on a place that erupts a lot." Yeah, so... it's sorta cool.

[female student] I've talked about it a lot outside of class. In fact, I've talked about it with my mom's boyfriend, and that's when we came up with the other ways it could be like a game to play [this student made suggestions about how to make the program more like a game if it were to be sold]. And we also talked about where aliens might go and how many other places you could put them and stuff like that.

Alien Rescue and Other Science Activities. Students agreed using Alien Rescue was different from many other science activities they did. They considered it more fun. A main reason was that they got to use computers when they were working on Alien Rescue. The opportunity of using a computer appeared to be a motivational factor for these students. They considered computer activities more fun than non-computer activities. Students also cited that being able to work on their own and at their own pace were important reasons that they liked Alien Rescue environment.

I mean, it's [Alien Rescue] pretty fun... in science class, you don't usually get to do like hands-on. You just listen to the teacher talk and tell you about whatever, but this one, you actually get to learn it yourself, so, like, you *should* understand it. I mean, you're learning it yourself, so it's easier to understand because you're doing it yourself, but you're still explaining what to do.

[It is different from a regular science class] Because you kind of got to do it on your own and at your own pace.

Students interviewed agreed that they would recommend <u>Alien Rescue</u> to other 6th graders. A number of students gave an emphatic 'yes' when they were asked if they would recommend other 6th graders using the program. "Yes, most definitely. It's challenging. Usually, we get challenges, but not this challenging. It takes a while. It's fun to learn more and explore." Another student stated that other 6th graders should use it "Because it's really fun and it makes you think." Students thought other grades could benefit from using <u>Alien Rescue</u> as well: "I think other 6th graders could definitely use <u>Alien Rescue</u> and maybe even the 7th grades and stuff like that, so older kids could too."

Teachers' Comments on Students' Learning and Their Teaching. Reflecting on how students with different ability levels worked in this environment, the teachers agreed that students with different abilities have benefited from using Alien Rescue and perhaps to a different degree, which confirmed the findings from the quantitative data sources. Grouping students with different ability levels together was not always easy, but the teachers observed that the majority of the students appeared to work well with their peers. One teacher made the following observation: "A situation with an LD student (boy) and TAG (girl) was interesting. She was getting fed up with him not helping very much and then losing any notes he did manage to get. After their first recommendation form together, I put them on their own. Surprisingly, after a few days the boy started getting involved and decided to put forth effort. He wrote up his own recommendation form and then the next thing I knew [was] they were working together again and dividing up the rest of the Aliens..." The teachers were particularly pleased with the increased post scores in the science test by the ESL/LD students. One teacher said, "Overall, I feel that the students really enjoyed this program," and another stated, "Thanks for the opportunity to share this terrific program with my students. I really feel that they learned a lot and had fun in the process."

The teachers were asked to reflect on how boys and girls worked in this environment. "I really noticed that the girls really were involved in this program more so than the boys," one teacher said. "Some girls just sped through this and were really excited to place all their aliens. Once they found a method, it didn't take long to complete it. One other girl was so into this that she stayed after school many afternoons to make sure she was able to place all her aliens. She did a great job writing up her recommendation forms." Interview data and the classroom observation notes revealed no gender differences in students' interest and performance.

During the two-day workshop on <u>Alien Rescue</u>, pedagogy considerations in designing this PBL environment and teaching strategies to successfully implement it in the classroom were shared between the designers and teachers and discussed extensively. Information about the software, suggested lesson plans, and related astronomy concepts were made available to the

teachers through a comprehensive teacher's manual. Teachers could use such information as a starting point and develop their own teaching strategies to suit their classroom needs. The observation and interview data showed that the two teachers in this study worked closely on this project. As a team, they decided not to instruct students how to solve the problem, but to allow the students to discover and find their own ways of reaching the answers. One teacher relied more on class discussions than the other. She said, "we had great discussions on the needs of the aliens and to this date [4 months later] a lot still remember the aliens' needs. It was brought up recently when we were studying earthquakes and when we were studying caves." The following observation notes captured how the two teachers facilitated students' learning in their own ways:

Teacher L is a great facilitator and seems comfortable in the role. When a student asks a question, she redirects the question to the entire class. After different students answer, the teacher adds a few leading comments as well. Furthermore, she is careful to address all of her students. She is constantly walking around the room asking students about their progress. She also encourages students to ask each other or discuss aspects of aliens with each other, however it seems that many students are often asking her for her attention.

Teacher R is younger, and does not seem as confident. Her main goal seems to provide feedback, as she is constantly reading incoming recommendation forms, writing comments, and looking for the authors with whom she will discuss the details of the recommendation. She does not get sidetracked with students asking for help. Students rarely ask her for help, and often look to each other to get the answers they want. The teacher seems to have a very good assessment of where each student is, and let the responsibility of a student "wasting time" in class fall upon the student's shoulders. However, some students seem stuck, and become disinterested. The teacher has decided to let the students decide on their goals. If their goal is to only place one alien, that is okay. They could stop working after that point.

DISCUSSION

Students' Performance and Their Attitudes

The findings from both the quantitative and qualitative data suggest that the students from all three ability groups have gained in their science knowledge after using <u>Alien Rescue</u>. Each group has made a significant gain in their science concepts test from pre to post, and the qualitative data showed that the student could articulate in detail what science concepts they have learned. Although the TAG students' scores in their science test are higher than those by the RegEd and ESL/LD students, it is important to point out that the three groups had a different starting point as shown in their pre-test scores. Both RegEd and ESL/LD students have doubled

their scores from pre to post while TAG students have not (see Figure 1). Given the rubric used by the teachers in evaluating the recommendation forms, it is clear that, on the average, TAG students found homes for five aliens, RegEd students found homes for four aliens and ESL/LD students found homes for three aliens. The differences among the three groups suggested that the students had set different goals for themselves. It appears that it takes more time for RegEd and ESL/LD students to successfully place the aliens. This is perhaps due to the large amount of reading involved. Although there is a difference in the number of new homes found by the three ability groups for the aliens, we are pleased with the overall quality of the rationales provided by the students from all levels. The two sample recommendation forms included in Table 4 are from three RegEd and one LD students. It is particularly encouraging to see that the students were able to reason why certain features of a world was good or not as good for a species.

Insert Table 4 here

It is worth mentioning that in using <u>Alien Rescue</u>, much emphasis is placed on students taking control of their own learning. No direct teaching should be involved. Students are free to take any paths they want; and providing a good rationale is more important than merely finding the "correct" worlds. Given the results from the multiple data sources used in this study, we feel comfortable to say that certain amount of self-directed learning by the students is exhibited, and students learned relevant scientific concepts as they were seeking a solution to the problem. The findings from both quantitative and qualitative data sources suggest that all students have increased their science knowledge and problem solving skills after using <u>Alien Rescue</u>. This gain from pre to post is more apparent in the RegEd and LD students.

There is little difference in how different ability groups felt toward the <u>Alien Rescue</u> environment. All felt positively toward it and enjoyed using it, with the exception that ESL/LD considered it less valuable than the other groups (see Table 2). This is probably due to the large quantity of information to be sifted through and large amount of reading involved, which makes

it more challenging for the ESL/LD students. This finding is confirmed by the observations from the teachers involved in using <u>Alien Rescue</u> from other schools. When feedback was sought from the teachers in implementing <u>Alien Rescue</u> in other schools, one recommendation was to provide more support via technology for ESL/LD students (Pedersen & Liu, in press). As educators, we need to continue to search for ways to individualize the learning paths for students—providing additional support for ESL/LD students, while maximizing the learning opportunities for TAG and RegEd students at the same time. After using <u>Alien Rescue</u>, RegEd and ESL/LD appeared to have a better attitude toward science learning. Qualitative data provided more concrete evidence as to why the students liked <u>Alien Rescue</u> and why they would like to use a similar program in other subjects.

Given that Alien Rescue is computer-based and game-like, we wondered how female students felt about it. It is very encouraging to note that both male and female students have doubled their posttest scores in their science knowledge test, and little difference is observed in their solution scores. The results showed that male as well as female students enjoyed this PBL environment. Overall, no gender difference is found. This finding is consistent with the research on computer attitude and gender in the 1990s (Dyck & Smither, 1994; Houle, 1996; Todman & Monaghan, 1994). In fact, female students' attitude toward science, after using Alien Rescue, reached a near significance level of p=.0530. Alien Rescue is currently being used by a number of middle schools. This finding of "little gender difference in attitudes and performance" is being confirmed by the data from other schools. Three teachers from different schools specifically mentioned that girls were excited about using Alien Rescue because they wanted to "save those aliens." The theme of saving other creatures used in Alien Rescue seems to work very well with the female students.

The Use of PBL Approach in 6th Grade Classrooms

Literature has shown that problem-based learning is an effective instructional strategy. Research has also indicated that using PBL in K-12 classrooms is challenging (Hmelo & Ferrari, 1997) and requires access to rich knowledge bases and cognitive tools. The data from this study

showed that many students liked <u>Alien Rescue</u> because they liked solving this complex problem where they had to take charge, and think hard. On the other hand, a few students did not like <u>Alien Rescue</u> for the very same reason as they could not find the answers without thinking hard and doing research; and the teacher was not there to give the answers. These students were not comfortable with "the increased degree of freedom" encouraged in PBL (Hoffman & Richie, 1997). Some teachers are also worried that sixth graders may not be ready for student-centered learning environments like <u>Alien Rescue</u> (Pedersen & Liu, in press).

Implementing environments like Alien Rescue calls for a different way of learning and teaching, which some students and teachers are not used to. To solve the complex problem in Alien Rescue, students must learn about the aliens and identify the basic needs of each species. They must investigate the planets and moons of our solar system, searching them for possible matches with the needs of the aliens. Students must also engage in collaborative planning and decision-making as they determine how to use the resources of the solar system effectively. Although a set of rich cognitive tools are built into Alien Rescue, which intend to share learners' cognitive load, and support their cognitive processes, the use of the tools depends on the learners, who must decide which one to access and which path to take. The program is designed in such a way that there is no one solution to the problem. For each species, there are good and acceptable choices, some of which are better than the others. Students' reasoning in justifying their selections is emphasized here. The goal is not just to find a home, but more importantly, why the choice is a good one. Students are encouraged to debate and present their rationales. The process of solving this complex problem requires exercising multiple cognitive skills in one single meaningful environment and presents the opportunity for the learner to take control of her own learning. This learning situation is a departure from the traditional curriculum where lectures and passive knowledge acquisition dominate.

It is apparent that the students who benefit more from this PBL environment are those who are able to engage in certain extent of self-directed learning and enjoy tackling challenging problems (Blumberg, 2000). This study has shown that these students are from both the TAG

and RegEd groups. In using Alien rescue, a number of students got frustrated initially as they did not know how to proceed to solve the problem. For example, one [RegEd] student said that "first I didn't know Kelvin, I didn't know what that was, so I had to, um... then I found [it] out on the concepts [database, a cognitive tool built in] that you can convert it, so that helped. But in the beginning, that frustrated me." The same student went on explaining why he considered the problem challenging, but he liked solving it: "Well, it's not like you can just go somewhere and find the answer. You have to, like um, first take a guess, and then look around that area to see if it's [the correct choice]... I've never done stuff like this in science before." The following responses showed why many students are intrigued by the challenging nature of solving this ill-structured problem. The findings also indicated that scaffolding provided by technology assisted the students' problem solving.

[female RegEd student]: I think it was challenging because, because it was [laughs]... Because you had to put aliens on a planet, you knew nothing about these aliens unless you researched them, and you probably didn't know much about the planets unless you researched on that too.

[male RegEd student]: It was challenging because you had to like find out these different aliens that just showed up all of a sudden, and you have to go on this, go in this place and find out everything about it, and then you get them on their planets, all 6 aliens on their planets, and like, in 3 weeks. So... it was pretty challenging.

As educators, one of our important responsibilities is to find ways to help students develop higher-level cognitive skills. It is hoped by engaging in the problem-solving process through learning environments like <u>Alien Rescue</u>, students have the opportunity to develop and practice multiple cognitive skills, and make better connections between their classroom learning and real-world challenges. We should continue to explore ways to create technology-enhanced scaffolds in a PBL environment to support learning of all students.

SUMMARY AND FUTURE RESEARCH

Literature has documented the benefits of PBL, especially at the college level, and for mature middle and high students in gifted education (Albanese, & Mitchell, 1993; Blumberg, 2000; Gallagher, Sher, Stepien, & Workman, 1995; Hmelo & Ferrari, 1997; Norman & Schmidt, 1992). This study has shown that the enriched presentation of the knowledge base and the more

effective delivery of cognitive tools through hypermedia technology in <u>Alien Rescue</u> have provided needed scaffolding to all students in the 6th grade classrooms. As a result, not only TAG students but also RegEd students performed well in this technology enhanced PBL environment. In addition, ESL/LD students benefited from using <u>Alien Rescue</u>. The amount of gain in students' science knowledge and problem-solving skills was related to their prior knowledge level. This study has also indicated that due to a large amount of reading involved, slow readers found a PBL environment like <u>Alien Rescue</u> challenging. More support, via technology or teachers, is needed for these students. To our encouragement, and contrary to the recent computer attitude and gender research, no gender difference was found in the performance, nor in the attitudes among the students in this study. Girls performed equally well and had positive attitudes toward <u>Alien Rescue</u> and learning science as a result of using <u>Alien Rescue</u>.

Given this is classroom-based research, a limitation of the study is that it used intact classes. As a result, the three ability levels had unequal group sizes. The RegEd group had many more students than the TAG and ESL/LD groups. Readers should keep such a limitation in mind when interpreting the results of the study.

As designers, we used current learning theories and research findings as our design guidelines (Liu, Williams, & Pedersen, 2002) and created <u>Alien Rescue</u> according to our understanding of how best to facilitate middle school students' learning in a PBL environment. As researchers, we are interested in finding out if such an environment has any effects on its target audience. In this study, we examined the performance and attitudes of students with different ability levels and different genders. To better understand if and how middle school students can benefit from a PBL environment such as <u>Alien Rescue</u>, we intend to replicate this study in the near future with a different sample. We also intend to study other aspects of the learning environment and examine such issues as the use of hypermedia-based cognitive tools to support problem-solving, collaborative learning as facilitated through <u>Alien Rescue</u>, and teachers' perspective toward and their role in a PBL environment like <u>Alien Rescue</u>. In this study we examined how the sixth graders felt toward the environment using surveys and interview

data. In a study underway (Liu & Bera, 2003), we are investigating how the students have used the program using the actual log usage data to understand how the cognitive tools assisted in students' learning process. We believe that the interactions among the learners, the environment, and the teachers must be encouraged and promoted for the environment to be effective. To enhance such interactions, we must continuously conduct research to improve our understanding, and support students and teachers in implementing such an environment.

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Figure 1. Results of the Science Knowledge Test by Ability Levels

Table 1. Teachers' Grading Rubric on Recommendation Forms

Criteria	Points	Explanation
Successfully place 1 species	75	Successfully placed =Students selected the correct/acceptable worlds. They explained in detail the needs of the aliens and then compared those needs to the world they selected.
Successfully place 2 species	80	Same as above
Successfully place 3 species	85	Same as above
Successfully place 4 species	90	Same as above
Successfully place 5 species	95	Same as above
Successfully place 6 species	100	Same as above

Table 2. Means and Standard Deviations (in Parenthesis) for the Solution Scores and Science Concept Tests

	n	Solution	Science Test		
		Score	Pre-	Post-	
Ability					
TĂG	26	95.39* (4.22)	61.23 (14.79)	97.54*++ (3.59)	
RegEd	114	89.25 (7.56)	41.97 (13.07)	85.42*++ (15.27)	
ESL/LD	15	85.33 (9.35)	30.93 (10.95)	64.00*++ (24.84)	
Gender					
Male	82	88.84 (7.79)	43.34 (14.77)	86.81++ (17.25)	
Female	73	91.10 (7.60)	45.01 (16.42)	83.78++ (17.29)	

^{*=} significantly different from other levels, P < .05.

⁺⁺⁼ significantly different from pretest, P < .01.

Table 3. Means and Standard Deviations (in Parenthesis) for Attitudes Toward <u>Alien Rescue</u> Environment and Attitudes Toward Science

n	Attitude to	Attitude toward AR		oward Science
	[Enjoyment] [Ed Value]		Pre-	Post-
26	4.11	4.22	4.28	4.19
	(.80)	(.76)	(.75)	(.76)
114	3.89	4.11	3.87	4.00
	(1.04)	(.80)	(.82)	(.72)
15	3.5	3.33*	3.73	4.18
	(.92)	(1.04)	(.67)	(.51)
82	3.83	3.99	4.04	4.09
	(1.11)	(.92)	(.74)	(.70)
73	3.95	4.13	3.80	4.00**
	(.86)	(.76)	(.85)	(.72)
	26 114 15	[Enjoyment] 26	[Enjoyment] [Ed Value] 26	[Enjoyment] [Ed Value] Pre- 26

^{*=} significantly from other levels, P < .01.

^{**=}a tendency of difference from pretest, P = .0530

Table 4. Sample Solutions to the Problem by the Students

Students: Two RegEd students (both female)

Alien: Jakala-Tay

World: Ic

Rationale: We think that Io is a good home for the Jakala-Tay because the Jakala-Tay

need Sulfur in their atmosphere which Io has a lot of. Another thing is that Io does not have hydrogen. This is a very good thing because if the Jakala-Tay breath in hydrogen, they die. They eat plants and those plants need nitrogen. Io doesn't have nitrogen, so plants can't grow, but the Jakala-Tay can also eat insects and reptiles. Therefore, the food situation is okay. The Jakala-Tay lived in a world with lots of volcanoes, in which Io has lots of volcanoes also. So it will be kind of like their old world.

Parts of Io are over 500°C but most of it is below freezing. So that is good for Jakala-Tay. We strongly believe that this is a good world for the

Jakala-Tay

Students: One <u>LD</u> student and one <u>RegEd</u> student (both female)

Alien: Wroft World: Titan

Rationale: We are sending the Wroft to the Titan. Why? Titan has 327°C

temperature. The Wroft can survive in that temperature. The food that the Wroft likes to eat [is] Carbon. Titan has some Methane, which is a compound made of Carbon and Hydrogen. The Wroft lives in a thick atmosphere. Titan has a very thick atmosphere. Lighting can kill them. Because of its thick atmosphere you can not see the sun. They don't care about the gravity. The gravity of the Titan is .14 of Earth's. There is no

magnetic field.