A Study of Learning and Motivation in A New Media Enriched Environment For Middle School Science

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Research shows that motivation plays an important role in influencing learning and achievement (Ames, 1990). When sufficiently motivated, students tend to approach challenging tasks more eagerly, persist in difficult situations, and take pleasure in their achievement (Stipek, 1993). Strong correlations have been found between intrinsic motivation and academic achievement (Cordova & Lepper, 1996; Lepper, Iyengar, & Corpus, 2005). Research has also shown that instructional context strongly affects students' motivation. Instructional materials that are challenging, give students choices, and promote perceived autonomy and self-determination can positively effect motivation (Hidi & Harackiewicz, 2000).

Youth in contemporary society have been profoundly impacted by an array of new media applications realized through networked and stand-alone computers, smart phones, and other devices. These applications and the interactions they make possible create new and dynamic "texts" to be read and generated (Carrington, 2004). Digital games and social media play a central and expanding role in the academic and social lives of today's adolescents. Educators and schools that do not utilize these new media based technologies run the risk of failing to leverage the digital literacies of their students, creating contexts that may lead to a "switching off" (Dudfield, 1999), disengagement from classroom activities, or missed opportunities to maximize student potential (Judson, 2010).

We are interested in better understanding how curricula delivered via new media environments engage students in learning activities. In this paper, we examine middle school students' learning and motivation as they experience space science curriculum via a new media enriched problem-based learning (PBL) environment.

Theoretical Framework

Student motivation during instructional episodes is vital in ensuring that the learner persists adequately to successfully complete the task and acquire skills or content knowledge. Motivation to learn is identified by the learner's choice of behavior, latency of the behavior, and the intensity and persistence of engagement in the learning task (Graham & Weiner, 1996). Current literature on achievement motivation suggests that there are two complementary ways to motivate students: through improving the student's belief in her probability of success – known as expectancy, and increasing the subjective value of the task as it relates to areas such as interestingness or intrinsic value. Expectancy beliefs are analogous to: self-concept of ability (Brookover & Paterson, 1964), perceived competence (Harter, 1992), and Bandura's (1986) self-efficacy expectations. These theoretically different constructs are highly related and indistinguishable in real-world school achievement situations (Eccles & Wigfield, 2002) and, thus, can be considered the same construct in most circumstances. Research shows that expectancy is highly correlated with motivation to engage in learning tasks and self-efficacy influences actual achievement that then reciprocally shapes self-perceptions of competency (Pintrich & Schunk, 2002).

Intrinsic/interest value describes the enjoyment of or interest in performing a task. When a student values a task for its own sake or is interested in it, he or she can be said to be intrinsically motivated. Understanding the dynamics of intrinsic motivation in students has been the focus of much motivational research over the last several decades. Researchers have investigated the role of fantasy (Lepper & Malone, 1987), and curiosity (Berlyne, 1978) in motivation to learn. More recently, one perspective on intrinsic motivation, namely self-determination theory (Ryan & Deci, 2000; Ryan, Rigby, & Przybylski, 2006), has risen to prominence. It posits that people are innately motivated to fulfill the needs of competence, autonomy, and relatedness. According to the model, the need to see oneself as competent is met when individuals feel challenged, yet maintain a sense of efficacy in relation to the task and the environment in which it is situated or when a person feels effective in the face of events perceived as nontrivial (White, 1959). The experience of competence is enhanced when individuals acquire new skills or abilities, are optimally challenged, and receive positive feedback (Ryan, et al., 2006). Interestingly, feeling competent, despite its benefits, has not been shown to enhance intrinsic motivation unless accompanied by a sense of volition or autonomy when participating in an activity (Ryan & Deci, 2000). Autonomy is promoted when the task is of interest or personal value, choices are offered, informational feedback is rewarding, and non-controlling instructions are provided (Ryan, et al., 2006). Finally, when students feel secure with themselves and connected to others in learning environments, their relatedness need is met. Numerous studies have demonstrated that cooperative learning and group activities, such as those presented in problem-based learning environments, have a positive effect on students' interest, engagement, and motivation (Shernoff, Csikszentmihalyi, Schneider, & Shernoff, 2003).

In summary, research has shown that intrinsic motivation is influenced by challenge, curiosity, control, fantasy, and relatedness. Popular and emerging technology is often used to create learning environments in hopes of leveraging these elements in the curricular experience. Research has documented a disconcerting decline in students' motivation to learn at school during the middle school years –especially in science (Eccles & Wigfield, 2002; Lepper, Iyengar, & Corpus, 2005; Osborne, Simon, & Collins, 2003; Stake & Mares, 2001). In light of these findings, we are interested in understanding the extent to which utilizing new media applications that allow learners to leverage their digital literacies in the classroom while encouraging characteristics of engaged game play (Hoffman & Nadelson, 2010) might hold the potential to reign in this downward trend and switch students back on to learning, particularly, learning science.

In our previous research (Liu, Toprac, & Yuen, 2009), we investigated student engagement with a new media enriched PBL environment by exploring the factors that students considered motivating. Through in-depth interviews with fifty-seven sixth grade students, we found that eleven key elements of the environment helped evoke motivation: authenticity, challenge, cognitive engagement, competence, choice, fantasy, identity, interactivity, novelty, sensory engagement, and social relations. Based upon the theoretical framework discussed above, these elements, many of which are realized with the assistance of new media technologies, can be grouped into five dimensions describing the sources of intrinsic motivation: problem solving, socializing, playing, voluntary acting, and information processing (see Figure 1).

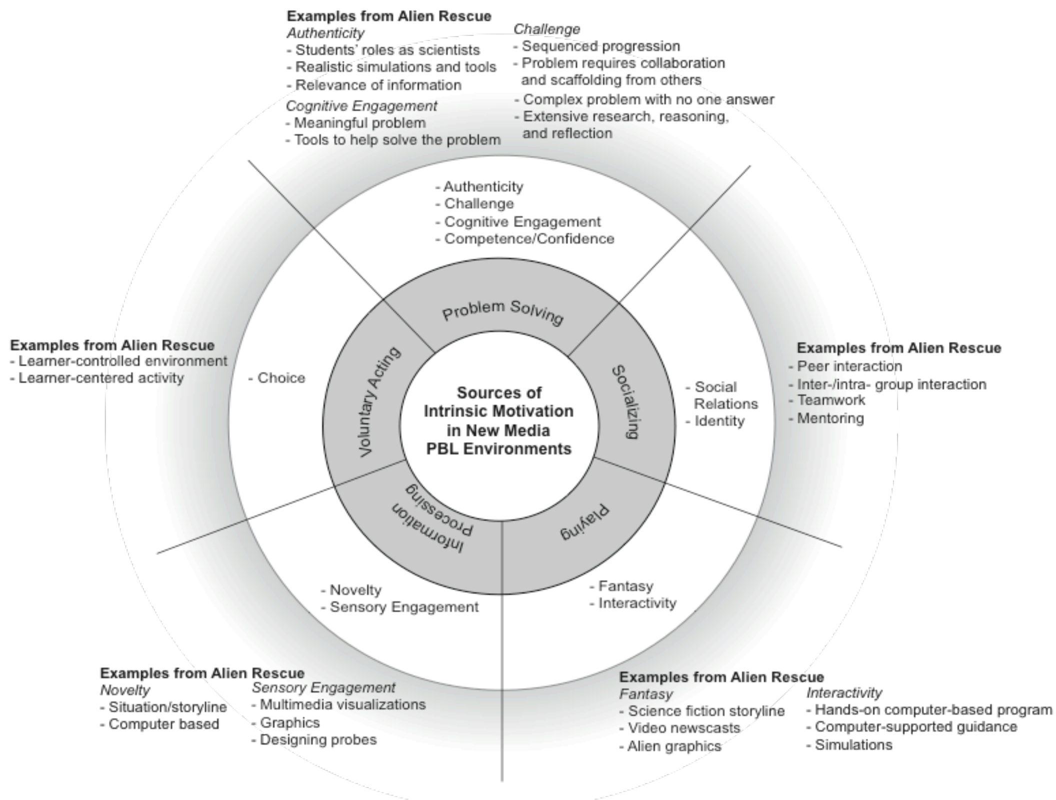


Figure 1. Motivating characteristics as shown in Alien Rescue with relation to theoretical motivational perspectives. Adapted from "What factors make a multimedia learning environment engaging: A case study," by Liu, Toprac, & Yuen, 2009, in R. Zheng, (Ed.) *Cognitive effects of multimedia learning* (pp. 173-192), p.183. Copyright 2009 by Hershey, PA: Idea Group Inc. Reprinted with permission.

Our current study continues that line of inquiry and investigates changes in sixth graders' science learning and connections between their motivation and learning after using a new media enhanced PBL environment, Alien Rescue. Three research questions guided our inquiry:

1. What is the effect of the new media PBL environment on sixth graders' science learning?
2. Are sixth graders motivated to use this new media enhanced PBL environment? In what way?
3. What is the relationship between students' motivation and their science learning?

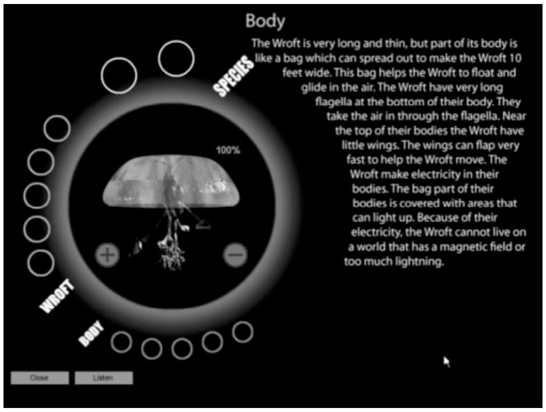
In addressing questions 1 and 2, we also examined gender differences since literature in this area indicates a male bias toward computer-based instruction (Mitra, LaFrance & McCullough, 2001; Mitra, Lenzmeier, Steffensmeier, Avon, Qu, & Hazen, 2001; Kadijevich, 2000).

Method

Research Context

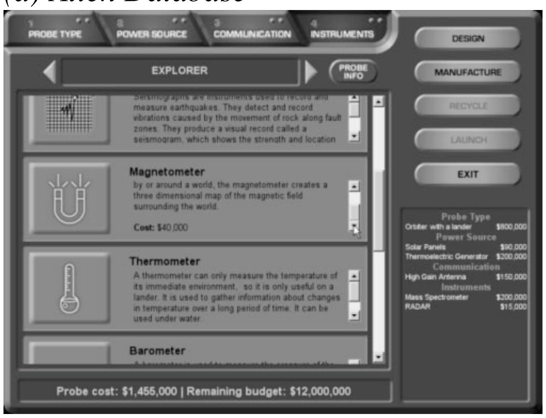
Alien Rescue (Liu, Williams, & Pedersen, 2002) is a new media enhanced PBL environment for sixth-grade space science. The goal of Alien Rescue is to engage sixth-grade students in solving a complex problem that requires them to use the tools, procedures, and knowledge of space and planetary science to learn about our solar system and processes of scientific inquiry.

Beginning with a video presentation, the Alien Rescue curriculum explains that a group of six alien species, each with unique characteristics, have traveled to Earth because their home planets have been destroyed. Students take on the role of scientists who are tasked with the mission of finding a planetary home that can support each alien species, thereby ensuring their survival. To accomplish this goal, students engage in a variety of problem-solving and information-gathering activities. These activities include researching each aliens species' requirements for life and analyzing species-related factors, such as habitable temperature ranges and the basic atmospheric composition needed for survival. Students must also discover some of the critical scientific characteristics of the planets and moons in our solar system by querying the provided databases and collecting direct observations using simulated probes. New media technologies are employed to immerse students in the interactive experience and used to create tools for scaffolding (see Figure 2 for some example features). More information about Alien Rescue can be found at http://alienrescue.edb.utexas.edu.

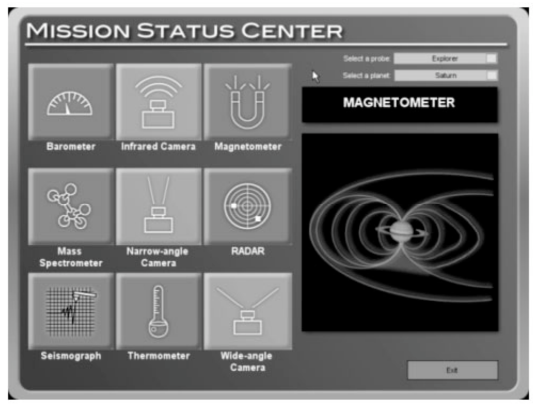


(a) Alien Database

(b) Communication center



(c) Probe Design Room



(d) Mission Status center

Figure 2. Screen Shots Showing Some Program features In Alien Rescue.

Participants and Setting

Sixth graders (*n* = 220) from a middle school in a southwestern US city participated in this study. About 54 % (*n* = 119) were female students and 46 % (*n* = 101) were male. The demographics of students at the school are approximately 8.7% African American, 10.7% Asian, 30% Hispanic, 0.5% Native American, 0.1% Pacific Islander, and 46.2% White. These students were from “Regular Education” classes and they used Alien Rescue as a self-paced curriculum unit for three weeks in their daily 45-minute science classes. Each student had his or her own computer for use, but also worked in a small group (as a suggested instructional strategy for implementing Alien Rescue). Most students were comfortable with computers and have used technology applications in other instructional activities. Two sixth-grade science teachers taught these intact classes. This is the second time these teachers used the program within the science curriculum. Both teachers participated in a professional development workshop in the previous year that focused on how to implement and facilitate a student-centered learning environment like Alien Rescue.

Data Sources and Analyses

To address our research questions, we collected both quantitative and qualitative data for the purpose of triangulation (Creswell, 2009).

Science knowledge test. Learning performance in this study was measured by students' understanding of the various scientific concepts introduced in Alien Rescue. A 20-item test was administered, the content of which reflects what the designers and subject matter experts consider to be important knowledge for the students to acquire after completing the curriculum. The science knowledge test addresses both factual knowledge and application questions, and was used in previous studies with similar samples using the same learning environment (Liu, Bera, Corliss, Svinicki, & Beth, 2004; Liu, Hsieh, Cho, & Schallert, 2006). Examples of the questions are as follows:

Factual: Which of these worlds is a planet (not a moon)?

a. Io

b. Phobos

c. Uranus

c. Not sure

Application: You need to design a probe to go to Titan to find out if it has a magnetic field or earthquakes. Which of the following would you choose to include on your probe?

a. a battery and a solar panel

b. a barometer and a seismograph

c. a magnetometer and a seismograph

d. Not sure

The Cronbach's alpha for the instrument was .77 for pre-test and .87 for post-test for this sample. Each question has four answer choices and one of them is 'not sure.' This option is included because being more certain in answering the questions is also an indication of what students have learned by using the program. The science knowledge test was administered before and after students used Alien Rescue to measure any change.

Motivation questionnaire. Fifteen items from the *Intrinsic Motivation Inventory* (IMI), a seven-point Likert scale with 1 being not at all true and 7 being very true, were used to assess students' motivation (http://www.psych.rochester.edu/SDT/measures/IMI_description.php). IMI has been used in several experiments related to intrinsic motivation and self-regulation (e.g., Ryan, Connell, & Plant, 1990; Ryan, Koestner & Deci, 1991; Deci, Eghrari, Patrick, & Leone, 1994), and reported to be reliable and valid (McAuley, Duncan, & Tammen, 1987). In this study, four subscales on a five-point Likert scale were used because of their connection to the research questions and their Cronbach's alpha values were computed for this sample: interest/enjoyment (four items, a = .95), perceived competence (four items, a = .84), effort/importance (three items, a = .87), and value/usefulness (four items, a = .92). This instrument as a whole had an alpha value of .95 and was administered after the students completed the curriculum.

Open ended response questions. Upon completion of the curriculum, sixth graders were also asked to respond in writing to six open-ended questions: "How would you describe Alien Rescue to a friend?" "What did you learn from Alien Rescue?" "What did you like about Alien Rescue? Why?" "What did you dislike about Alien Rescue? Why?" "Tell us how much you liked Alien Rescue more than other science activities [on a scale of 1-5 with 1 being not at all and 5 being very much]. Why?" and "What parts of Alien Rescue made you want to keep going? Why?" Asking the sixth graders to describe different aspects of their experience in their own words added nuance and contour to the study, enriching it beyond what an analysis of the quantitative data could offer.

To address the first research question, two ANOVA's with repeated measures were conducted with gender as a between-subjects independent variable and time of testing (pretest and posttest) as the repeated measure within-subject variable. The dependent variable was students' science knowledge test scores in one analysis and unsure scores in the other analysis. ANOVA analyses were performed to address research question two, with gender as a between-subjects independent variable and the total motivation score of IMI as well as each subscale as dependent variables. For question three, two multiple regression analyses were conducted with the total IMI motivation scores as the predictor in one, each subscale as the predictor in the other, and science knowledge posttest scores as a dependent variable while factoring in the science knowledge pretest scores.

The analysis of the open ended questions was undertaken based upon a grounded theory (Charmaz, 2006) perspective, employing the constant comparative method of analysis as outlined by Strauss and Corbin (1998) and a multi-level coding scheme by Miles and Huberman (1994). First, responses for each question were read, reformatted, and readied for coding via a qualitative analysis tool. Open codes were created by the research team from a line-by-line analysis of the response data. Over two hundred total base codes were generated during the coding process (Charmaz, 2006). These codes were then mapped and grouped axially before being further analyzed. Common themes and shared relationships were extracted from across the responses and organized using the three research questions as a guide. Three researchers were involved in coding independently the assigned portion of the data and then discussed as a team until 100% interrater reliability was reached on categories, subcategories, themes, and interpretations.

Results

Quantitative Data Findings

Science knowledge test. The two-factor mixed ANOVA with repeated measure indicated that there was a main effect for the time of testing: $F(1,142) = 320.94$, $p < .01$, ES = .69 and for gender: $F(1,142) = 5.47$, $p < .05$, ES = .04. The correct responses in the science knowledge test increased significantly from pretest to posttest for both male and female students and a small but significant difference was observed between males and females ($M_{male} = 83.53$; $M_{female} = 79.36$). There was not a significant two-way interaction between gender and time of testing (see Table 1 and Figure 3). The average gain score from pretest to posttest was 30.31 with $M_{male} = 28.02$ and $M_{female} = 31.85$ and this difference between male and female was not statistically significant: $F(1,142) = 1.32$, $p = .25$. The two-factor mixed ANOVA with repeated measure showed a significant two-way interaction between gender and time of testing for the number of unsure responses in the science knowledge test: $F(1,142) = 11.54$, $p < .01$, ES = .08. There was a main effect for the time of testing: $F(1,142) = 83.13$, $p < .01$, ES = .37 and a between-subjects effect for gender: $F(1,142) = 7.42$, $p < .01$, ES = .05. The number of unsure answers reduced significantly from pretest to posttest for both male and female students. This decrease was more dramatic for female students than for male students (see Table 1 and Figure 3).

Gender differences in motivation. The ANOVA analyses showed students' total motivation scores as well as scores in each subscale were above the mean, and there was no significant difference in the total motivation scores between male and female students: M_{male} = 3.60; M_{female} = 3.75, $F(1, 130) = .97$, $p = .33$, as well as in each subscale of motivation scores (see Table 1).

Motivation and science knowledge. The multiple regression analysis, examining the relationship between students' motivation scores and their science knowledge posttest scores, controlling for the effect of the pretest scores, showed a significant moderate R^2 of .26, F (2, 129) = 23.17, $p < .01$. Students' motivation score was found to significantly predict their science knowledge test scores: $b = 5.43$, $t(129) = 2.6$, $p < .01$. That is, for students with identical science pretest scores, the higher the students' motivation scores, the higher their science knowledge posttest scores. Further multiple regression analysis using the four subscales of IMI as predictors, controlling for the effect of the pretest scores, showed a significant moderate R^2 of .3, F (5, 126) = 11, $p < .01$. The subscale of "perceived competence" appears to be the strongest predictor: $b = 7.64$, $t(126) = 2.8$, $p < .01$. There was not a significant relationship between science knowledge scores and the other three subscales. In other words, for students with identical science pretest scores, the higher a student's perceived competence, the higher their science knowledge posttest scores. Given this finding, simple regression was run to further explore the relationship between each subscale of IMI and science knowledge posttest scores, controlling for the pretest scores. In addition to a significant relationship between the subscale of "perceived competence" and science knowledge posttest scores: R^2 of .3, F (2, 129) = 27.21, $p < .01$; $b = 7.62$, $t(129) = 3.64$, $p < .01$, there was also a significant relationship between the subscale of "effort/importance" and science knowledge posttest scores: R^2 of .26, F (2, 129) = 22.45, $p < .01$; $b = 4.68$, $t(129) = 2.42$, $p < .01$. There was not a significant relationship between the science knowledge posttest scores and the other two subscales. These findings suggest that "perceived competence" contributes the most to the relationship between students' overall motivation scores and their science knowledge posttest scores. There is a tendency that "effort/importance" is also positively related to the science knowledge posttest scores, suggesting that the students who worked harder learned more than those who did not, but this calls for further research.

Table 1

Students' Science Knowledge Test and Motivation Scores

	Boys			Girls			Total		
Measure	*n*	*M (SD)*		*n*	*M (SD)*		*n*	*M (SD)*	
Science Knowledge Score (% on 0-100 scale)	58			86			144		
Pretest		55.52%	(16.51)		47.50%	(13.76)		50.73%	(15.39)
Posttest		83.53%*	(20.90)		79.36%*	(21.07)		81.04%*	(21.03)
Science Knowledge unsure (% on 0-100 scale)	58			86			144		
Pretest		18.45%	(17.63)		31.34%	(18.27)		26.15%	(19.04)
Posttest		7.84%*	(18.38)		8.14%*	(17.52)		8.02%*	(17.81)
Motivation (Scale of 1-5)	54			78			132		
interest/enjoyment		3.45	(1.17)		3.78	(0.98)		3.65	(1.07)
perceived competence		3.80	(0.84)		3.76	(0.80)		3.77	(0.81)
effort/importance		3.93	(1.00)		4.05	(0.77)		4.00	(0.87)
value/usefulness		3.31	(1.13)		3.47	(0.87)		3.41	(1.03)

* Significantly different from the pretest, $P < .01$.

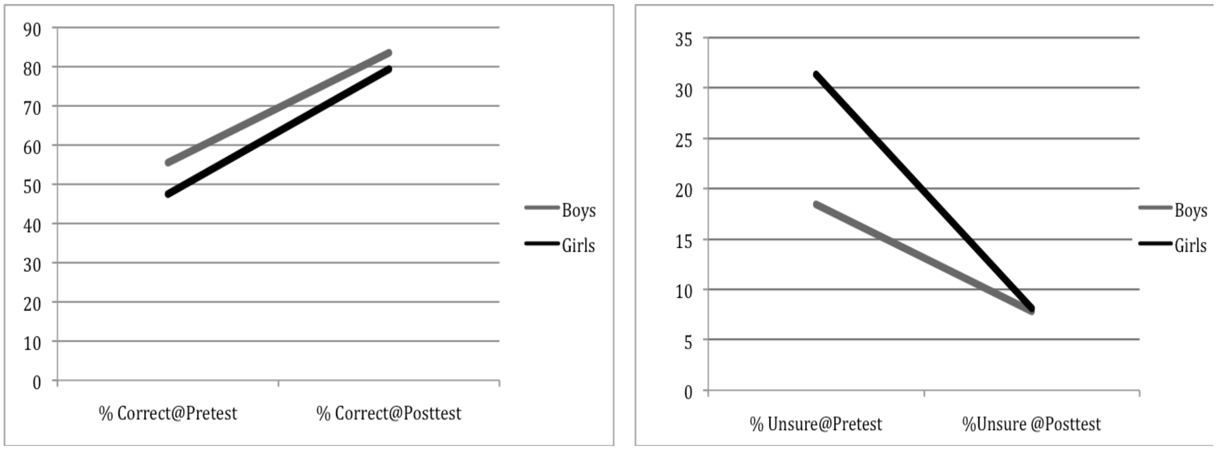


Figure 3. Science knowledge test scores at pretest and posttest times

Qualitative Data Findings

About 180 students responded to the six open-ended questions, giving a variety of written answers that ranged from elaborate to terse, from effusively positive to unquestionably negative. While the range of responses varied, the pervasive student sentiment was that they had a mostly fun experience interacting with the Alien Rescue curriculum. Figure 4 illustrates this point, providing a visual representation of the sixth graders' responses to the question (how would you describe Alien Rescue to a friend?). The word "fun" has the highest frequency in the responses and was mentioned 107 times. The word cloud provides a way of holistically illustrating participant sentiment about Alien Rescue and their experience with it while Table 2 offers selected participant responses containing one or more of the top most frequent descriptors.

Figure 4. Word cloud of students' responses to "How would you describe Alien Rescue to a friend?" produced by coupling word frequency with font size (words such as: to, the, a, an, that… were removed to increase the prominence of relevant adjectives, nouns and verbs).

Table 2

Selected Participant Responses to "How would you describe Alien Rescue to a friend?"

Word	Freq	Participant Quote
fun	107	"It was fun and exciting project. It also gave you a sense of responsibility because you have the lives of these Aliens in your hands."
aliens	62	"…While rescuing these aliens and sending them to a planet you also have to do research so they will survive."
find	29	"I would say that alien rescue is where aliens need new homes and you have to find them. It is a like a big jigsaw puzzle. It is funnnn!!!!!."
planets	22	"It's a game like thing that you use to find aliens a home but at the same time learn about different planets and moons in our solar system!"
very	21	"very fun yet somewhat confusing"
really	21	"It was really interesting but kind of hard."
learn	20	"It's very fun and you learn a lot about the different planets and moons."
game	19	"I would describe alien rescue to a friend as a kind of logic game because you have to find out all of the information before you can actually find out where each alien goes!"
hard	17	"It is hard and lots of fun."
experience	16	"…not a lot of laziness involved. Overall, I thought it was a good learning experience."
boring	13	"boring, and you have to do a lot of work for practically nothing"
Cool	13	"It is really cool. You get to learn more than you would expect. You should try it."

Connected to the overall positive experience, a secondary theme identified was that of excess. During open coding we were struck by the range of ways and the consistency with which participants characterized their experience as excessive in some way. The program was “freaking awesome!!!” “you have to do a lot of work,” “so many moons,” “It took a lot of work!!! :(:(:(:(:(“ “so unique,“ “there was too much note taking,” “so many different things to look in to,” “too time consuming,” “too hard,” “sooooooooo cool!!!!” “waaaayyyyy better than taking notes.” and “sooooooooooooooooooooooooooo FUN!!!!!!!!!!!!!!!!”

The experience, for many sixth graders, seemed to be simultaneously incredibly positive and highly taxing. Success within Alien Rescue requires a substantial amount of problem solving to find an appropriate habitat for each species. This process was neither familiar nor easy for sixth graders. “There were a lot of planets to choose from and that was hard. Then the species were very picky which was annoying,” wrote one student. The PBL environment of Alien Rescue requires students to be self-directed in their work. It is up to the students to decide where to begin their research, how to proceed with their problem-solving process, and which planet is optimal for each alien species. To many students, this control and freedom is what they found motivating: “I liked the challenge that we had to do this by ourselves. I also liked that we got to recommend the planets to the aliens. I liked that we couldn't ask [the teacher] any questions,” and “It was totally different. I liked that. I also liked that we were told what to do then let loose. It felt good to have that freedom.”

Analyses using quantitative data showed that the students’ performance on the science knowledge test improved significantly. In analyzing students’ responses to the question, “What did you learn from Alien Rescue?” over 51% of the responses were related to solar system knowledge (understandings related to the planets, moons, and their characteristics). Additional common themes that emerged in the student responses involved learning about the alien species (15%), problem solving (12%), scientific concepts (such as gravity or temperature scales, 6%), space probes (5%), and scientific instruments (3%). Several less-used codes made up the remaining 8%. Table 3 provides sample responses of what students said they had learned.

Table 3

Selected Participant Responses to "What did you learn from Alien Rescue?"

Codes	Participant Quotes
Problem solving	"i learned that to get the right answer you need to pay attention to the important information!!:)" "That you can't always find the perfect place for aliens or anything. You have to look at every single clue to get the best solution. You also have to trust things that don't seem like it's possible." "well i learned to conserve money. i also learned a lot about the planets. and that you just can't have only one reason for doing something."
Solar System	"I learned that Jupiter has more than fifty moons. Also, Pluto isn't a planet. Lastly, Venus is Earth's sister planet." "I learned a lot about the different moons in our solar system. I now know that Io has active volcanoes and earthquakes."
Solar System/ Aliens/ Scientific Concepts	"I learned many things about the planets AND their moons. Plus I had fun learning about fantasy-aliens. But I learned about the gases, atmospheres, sizes, craters, temperatures and MUCH more."
Aliens/ Solar System	"I learned that there are 6 species of aliens and there are many interesting facts about each species. I also learned new facts about our solar system and i also learned about new planets/moons."
Aliens	"The Sylcari lives in water but can't live in freezing water. And the Wroft can live on Venus."
Scientific Concepts	I learned more about planets. I learned about the Kelvin scale. I learned about magnetic fields.
Other	I learned that you really need to pay attention in Alien Rescue, because if you don't know about all the worlds or characteristics about the alien's...then [you're] going to get behind and going to be confused.

For these sixth graders, Alien Rescue offered a different learning experience than school otherwise afforded. In answering "Tell us how much you liked Alien Rescue more than other science activities [on a scale of 1-5]? Why?," 32% (*n* = 56) of the students responded "very much," 29% (*n* = 52) responded "much," 26% (*n* = 47) responded "somewhat," 6% (*n* = 10) responded “not much,” and 7% (*n* = 13) responded “not at all.” That is, 61% of the sixth graders liked Alien Rescue as compared to other science activities. One student’s statement summarized this well: “alien rescue is like nothing i have ever done before. Also there is a lot you have to do. . .amazing fun using your brain game.” Among the reasons why they liked this science activity over the others, “fun” at 45% (n = 67) is again the top reason. Other reasons given for why they liked it included: being on the computer (16%, *n* = 24), learning from it (14%, *n* =21), the game-like experience (7%, *n* =11), disliking other science activities (5%, *n* =7), the graphics (4%, *n* =6), the control it gave them (3%, *n* =5), and various other reasons (6%, *n* =8).

The three main reasons students gave for disliking Alien Rescue were 1) too much research (“I disliked having to do so much research”), 2) too much reading, writing, or work (“I disliked the fact that it took lots of patience and lots of writing”), and 3) felt frustrated or “it was too hard.” (“i don’t like that it doesn’t really give you clues you have to find every thing.” “I don’t really like it because sometimes your probes don’t work and you get angry and loose money. I also don’t like when you keep recommend aliens and it is the wrong planet! And when you think you got it you don’t!”). These comprised 59% of the responses to “What did you dislike about Alien Rescue and Why. Curiously, one student stated the he didn’t like the experience as compared to other science classroom activities because, “It made me learn” another stated that it was “too educational”.

Discussion

Learning and Motivation

In addressing the first research question about the effect of a new media PBL environment on sixth graders’ science learning, the findings based upon both quantitative and qualitative data showed that both male and female students significantly increased their science knowledge from pretest to posttest after using Alien Rescue, with female students' "unsure" responses decreasing more than male students. Furthermore, the sixth graders articulated in detail those science concepts they learned. Since Alien Rescue was used as self-paced instruction, without teacher intervention beyond minimal scaffolding, the gain in the knowledge score suggests that students acquired an adequate understanding of the scientific concepts through self-directed learning, classroom discussions, and/or peer interaction while using Alien Rescue. The gain in students' knowledge supports previous research examining the effectiveness of Alien Rescue as a new media enhanced PBL environment by showing a positive impact on sixth graders' science learning (Liu, et al., 2004; Liu & Bera, 2005; Liu, et al., 2006), and is consistent with the encouraging results from other new media infused learning environments (Barab, Thomas, Dodge, Carteaux, & Tuzunm, 2005; Ketelhut, 2007).

With respect to the second and third research questions, results of this study indicated that the majority of the sixth graders were motivated to use Alien Rescue as shown in this statement: Alien Rescue "is different from science projects, exams, tests....and it's fun too! Everyday I look forward to going on the internet and logging on to alien rescue." Students' responses to six open-ended questions regarding their Alien Rescue experience revealed more about the interplay of enthusiasm, fatigue, and enjoyment than the quantitative results could show. A significant positive relationship was found between students' motivation scores and their science knowledge posttest scores. A significant, moderate relationship between the subscale of "perceived competence" and science knowledge posttest scores suggests that the more a student feels competent, the higher her science learning scores. This finding supports the research showing that students' self-efficacy and their actual performance are highly correlated (Lane & Lane, 2001; Pajares & Miller, 1994; Pintrich & Schunk, 2002).

Research shows that motivated students are more likely to persist in difficult situations and approach challenging tasks more eagerly than their less motivated peers (Stipek, 1993). Students are motivated to solve problems when they are challenged and have the control of their learning process, and as a result, learning occurs during the problem solving process. Alien Rescue uses a problem-based learning approach that motivates students to learn in a self-directed manner. Important aspects of the program's design include an intentional lack of definitive outcomes and a range of locations with suitable characteristics for placing each of the six alien species. Students must engage in planning and decision-making as they determine how to efficiently use the provided resources and then recommend an appropriate location for relocating each alien species, supporting each choice with a justification. This type of challenging, student-driven situation has been shown to positively impact motivation (Hidi & Harackiewicz, 2000; Hoffman & Nadelson, 2010; Ryan & Deci, 2000; Ryan, et al., 2006).

Motivation and New Media

As shown by their responses in this study, sixth graders described Alien Rescue as a fun computer game. So what made the program fun for many of these sixth graders? The elements of new media used in Alien Rescue included situating the central problem within a science fiction premise using realistic (but fictional) newscast footage to announce the arrival of the aliens, placing students in the role of a scientist within a 3D environment for the student to explore, offering encyclopedic planetary and alien information centers enriched with videos, graphics, and 3D images, and providing simulations of exploratory space probe design and launching (See Figure 2).

Student responses across the six questions indicate that the use of new media supported student learning and motivation in several specific ways. The preponderance of responses supporting student knowledge-building related to the solar system suggests that Alien Rescue's rich media-based presentations of solar system information helped students acquire knowledge in self-directed ways. Students' responses to "What parts of Alien Rescue made you want to keep going [and why]?" revealed two features of the application which were heavily influenced by its PBL foundation and enabled by new media elements, namely designing and sending probes, and the overall task of finding a suitable home for aliens. Over half of the responses are a variation of "launching the probes!!!!!!!!," "launching probes to see what would happen," "When I learned that we had to rescue the aliens I really wanted to help and see how good I could do," and "The chance to save aliens!," while external reasons such as grades, teacher encouragement, or having no choice in the matter accounted for less than 7%. Students' responses to "What did you like about Alien Rescue? [and why]" corroborated this finding as 63% of the reasons related to probes, aliens, and other new media features.

Acting as collaborating scientists, students design probes, outfitting them with a variety of scientific instruments, power supplies, and orbiter/lander capabilities. They determine where probes should be sent and what data they should gather while working within a given budget. They must interpret the data sent back from the probes which, if poorly designed, can malfunction. Many students found the task of saving aliens engaging. Using a new media enriched alien database, they explored each alien species' - anatomy, dietary needs, social systems, and habitat – often feeling a sense of responsibility. As one student stated, "The aliens wanted me to help them." Another said, "the fact that if this was a real life situation, and they were really depending on us to help them, we couldn't just stop and say 'forget it' or something like that." The role of being a scientist, the challenge of solving complex problems (with no absolute or clear answers), the task of saving aliens, and the engaging multisensory environment all sparked students' curiosity and notions of fantasy. Using both quantitative and qualitative data, the results of this study confirmed the findings of a previous interview study (Liu, Toprac, & Yuen, 2009) highlighting the factors that sixth graders considered motivating in a new media PBL environment. Additionally, the findings support research that intrinsic motivation can be enhanced through challenge, curiosity, control, fantasy, and relatedness (Berlyne, 1978; Lepper & Malone, 1987; Malone, 1981; Ryan & Deci, 2000). This type of challenging, student-driven situation has been shown to positively impact motivation

Some students considered the experience "too hard" and complained there was "too much work." Some got frustrated when things did not work, as one student stated, "I disliked the frustration of knowing that the planet you chose for a certain alien was wrong because it would be so frustrating to know all that hard work for that one alien was for nothing." While this finding corroborated other research showing that for many, playing games fulfills recreational needs (Hoffman & Nadelson, 2010) and there should not be work involved, it also suggests more cognitive and motivational scaffolding, specifically more just-in-time feedback, could benefit students using Alien Rescue. However, just-in-time feedback has to be carefully implemented to ensure that the PBL design is not compromised (Toprac, 2011).

Limitations

This study has several limitations and constraints that are often encountered when carrying out research in school classroom settings. First, this study took place in a naturalist setting wherein every section of sixth grade science at the school utilized Alien Rescue as part of their science curriculum and therefore random assignment was not a possibility. Furthermore, the study was implemented during the final weeks of the school year, consequently the experience had to coexist with several other school and course-level activities, which at times cut into class time and demanded their attention. Moreover, students knew that participating in the study did not affect their grades. Due to these factors and others, many students did not complete the post-tests and surveys, thereby non-matching responses had to be dropped, which reduced the sample size. In addition, employing varied qualitative methods, such as individual or group interviews and participant observation would strengthen the study, a factor we will consider in our future research.

Implications for Designing New Media Learning Environments

Research has shown that intrinsic motivation can be an antecedent to learning and is highly correlated with the academic success of students. The findings of this study provided empirically based insights into what sixth graders found engaging and motivating within a new media environment. The findings also shed some light on the relationship between new media, motivation, and learning. More than simply looking to leverage the digital literacies of today's youth, designers of new media learning environments should consider incorporating elements that promote intrinsic motivation. The elements have shown to be important include problem solving, play, information processing, voluntary acting, and socializing.

One teacher shared this encouraging observation with us: "…7th graders told some [sixth grade] students which planets the aliens should be recommended. I'm not sure how students would even remember information from nearly one year ago, but they did." Learning gains and a positive curricular experience can be realized when students are situated in "playful" learning environments. New media technology can be used to create such "playful" environments which combine elements of fantasy, narrative, and scaffolded content while bestowing upon students authentic roles with meaningful activities. The challenge for new media designers is to take advantage of not only new media technology's initial appeal to aesthetics and novelty, but also its capacity to create powerfully engaging interactive experiences that can improve motivation and promote learning. Additional work is needed to further identify potential linkages between motivational research and the theoretical bases underlying problem and inquiry-based approaches to teaching and learning.

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