Chapter X
What Factors Make a Multimedia Learning Environment Engaging: A Case Study

Min Liu
University of Texas at Austin, USA

Paul Toprac
University of Texas at Austin, USA

Timothy T. Yuen
University of Texas at Austin, USA

ABSTRACT

The purpose of this study is to investigate students' engagement with a multimedia enhanced problem-based learning (PBL) environment, Alien Rescue, and to find out in what ways students consider Alien Rescue motivating. Alien Rescue is a PBL environment for students to learn science. Fifty-seven sixth-grade students were interviewed. Analysis of the interviews using the constant comparative method showed that students were intrinsically motivated and that there were 11 key elements of the PBL environment that helped evoke students' motivation: authenticity, challenge, cognitive engagement, competence, choice, fantasy, identity, interactivity, novelty, sensory engagement, and social relations. These elements can be grouped into 5 perspectives of the sources of intrinsic motivation for students using Alien Rescue: problem solving, playing, socializing, information processing, and voluntary acting, with problem solving and playing contributing the highest level of intrinsic motivation. The findings are discussed with respect to designing multimedia learning environments.

INTRODUCTION

In order for technology to positively impact classroom learning, students must be motivated to use the technology in addition to learning the content presented with that technology. Literature on motivation and classroom learning has shown that motivation plays an important role in influencing learning and achievement (Ames, 1990). If motivated, students tend to approach challenging tasks more eagerly, persist in difficult situations, and take pleasure in their achievement (Stipek, 1993). Studies have indicated strong positive correlations between intrinsic motivation and academic achievement (Cordova & Lepper, 1996; Gottfried, 1985; Hidi & Harackiewicz, 2000; Lepper, Iyengar, & Corpus, 2005). This suggests that motivational problems or lack of effort is often a primary explanation for unsatisfactory academic performance (Hidi & Harackiewicz, 2000).

Students' lack of interest in mathematics and science has been cited as one of the primary reasons contributing to U.S. students lagging far behind other high-performing countries in math and science, especially at the middle-school level (National Science Board, 1999). According to Osborne, Simon, and Collins (2003), research has indicated a decline in attitudes toward science from age 11 onward. Other researchers have also found that as children become older, their intrinsic motivation to learn science tends to decline (Eccles & Wigfield, 2002; Gottfried, 1985; Lepper, Iyengar, & Corpus, 2005). Therefore, in order to help students succeed in learning math and science, instructional technologists must create technology enhanced learning environments that can motivate students and facilitate learning.

In an effort to meet this goal, we have designed and developed a multimedia enhanced problem-based learning (PBL) environment for six-grade science, *Alien Rescue* (Liu, Williams, & Pedersen, 2002). This program has been used by thousands of middle school students in multiple states. Our previous research examining the impact of this multimedia PBL environment has primarily focused on its cognitive effects such as its use on acquiring science knowledge and problem-solving skills (Liu, 2004; Liu & Bera, 2005; Li & Liu, 2008), cognitive tools and cognitive processes (Liu, Bera, Corliss, Svinicki, & Beth, 2004), and its effect on reducing cognitive load (Li & Liu, 2007). Studies on *Alien Rescue* have shown it to be an effective learning environment for science knowledge and problem-solving (Liu, 2004, 2005; Liu & Bera, 2005).

As we continued to work with students and teachers in different classrooms, it became apparent that students often considered their experience with *Alien Rescue* "fun" and enjoyed using it. The following quote from a teacher captured the essence of this observation:

Kids are talking about science outside of the classroom. They talk about *Alien Rescue* in the halls and they talk about *Alien Rescue* after school. All of the sixth graders are doing this, and so some of them have friends in different class periods that are working with *Alien Rescue*. They will say, "what did you find out today or have you found where this alien can go?" I think that the most exciting thing is that they are talking science outside of the classroom; I think that is the most impressive thing.

This sentiment led us to ask questions regarding the affective effects of *Alien Rescue*. Why did students like using *Alien Rescue*? What did they find interesting? How did it compare to other school activities they usually do in the classroom? The purpose of this study is to investigate sixth-graders' affective experiences, specifically motivation, as they were using *Alien Rescue* and to find out in what ways *Alien Rescue* was motivating to these students. Our guiding research question was:

*How does a multimedia enhanced problem-based learning (PBL) environment, **Alien Rescue**, motivate students to learn science?*

BACKGROUND

Using Multimedia to Enhance the Delivery of Problem-Based Learning

Problem-based learning emphasizes solving complex problems in rich contexts and aims at developing higher order thinking skills (Savery & Duffy, 1995). According to Savery and Duffy, PBL environments have three primary underlying constructivist propositions: (1) understanding is in our interactions with the environment, (2) cognitive conflict is the stimulus for learning and determines the organization and nature of what is learned, and (3) knowledge evolves through social negotiation and by the evaluation of the viability of one's understanding (Savery & Duffy, 1995). In PBL environments, the focus of learning is not only the knowledge outcome, but also the process by which students become self-reliant and independent.

The benefits of PBL, such as the activation of prior learning, self-directed learning, and motivation, have been documented in medical education and with college and gifted students (Albanese, & Mitchell, 1993; Gallagher, Stepien, & Rosenthal, 1992; Hmelo & Ferrari, 1997; Norman & Schmidt, 1992; Stepien, Gallagher, & Workman, 1993). However, literature has also indicated that implementing complex and ill-structured learning environments such as PBL in K-12 classrooms has been challenging (Airasian & Walsh, 1997).

Multimedia-enhanced PBL environments provide a new and different means that can assist students to develop problem-solving skills, to reflect on their own learning, and to develop a deep understanding of the content domain (Cognition and Technology Group at Vanderbilt, 1997), and if designed well, can also be more motivating to students than text-based delivery methods. Multimedia technology can enhance the PBL delivery through its video, audio, graphics, and animation capabilities as well as its interactive affordances to allow students to access information according to their own learning needs and present multiple related problems in one cohesive environment (Hoffman & Richie, 1997).

Motivation as an Important Factor for Learning

For preschool children, learning is fun. There are no motivational problems for learning in these years (Cordova & Lepper, 1996). Their motivation is manifested by their choice of behavior, latency of behavior, intensity of behavior, and persistence of behavior, and is accompanied with cognitive (e.g. goal setting) and emotional reactions (Graham & Weiner, 1996). Motivation is often considered to be a necessary antecedent for learning (Gottfried, 1985; Lepper, Iyengar, & Corpus, 2005) and is a function of expectancy of attaining a goal that is valued (Klinger, 1977; Pintrich & Schunk, 2002; Weiner, 1991). When students are intrinsically motivated to learn something, they may spend more time and effort learning, feel better about what they learn, and use it more in the future (Malone, 1981; Okan, 2003). An activity is said to be intrinsically motivating if people engage in it 'for its own sake' and if they do not engage in it for extrinsic reasons or motivators (Malone, 1981). Extrinsic motivators, such as external rewards and punishments, can destroy the continuing motivation of students to learn more about subjects outside of class (Greeno, Collins, & Resnick, 1996; Maehr, 1976).

Unfortunately, in later years, instruction in school, rather than being fun, is often boring and dull to students, and students' motivational problems to learn quickly appear: "In a variety of settings and using a variety of measures, investigators have found children's reported intrinsic motivation in school to decrease steadily from at least third grade through high school" (Cordova & Lepper, 1996, p. 715). The problem of motivating students is particularly acute when the subject matter is science (Tuan, Chin, & Shieh, 2005), from the point of entry to secondary school

(Osborne at al., 2003) — when their intrinsic motivation to learn science, interest in science, and attitudes toward science decline (Eccles & Wigfield, 2002; Gottfried, 1985; Lepper, Iyengar, & Corpus, 2005; Stake & Mares, 2001). Thus, promoting intrinsic motivation is critical to help students learn science.

Sources of Intrinsic Motivation for Learning Environments

There are many different perspectives of the sources of intrinsic motivation since it may vary over time, circumstances, and how people view what they are doing (Pintrich & Schunk, 2002). Lepper and Malone (1987) summarized past views of the sources of intrinsic motivation and their characteristics (p. 258):

- Humans as problem solvers: challenge, competence, efficacy or mastery
- Humans as information processors: curiosity, incongruity, or discrepancy
- Humans as players: fantasy involvement using graphics, story, and sound
- Humans as voluntary actors: control and self-determination

These four perspectives on the sources of intrinsic motivation are commonly expressed as challenge, curiosity, fantasy, and control, respectfully (Pintrich & Schunk, 2002). Though listed as separate categories, these perspectives overlap each other. For example, people become curious (i.e. humans as information processors) because of an incongruity in information. This often leads people to want to solve the problem or challenge (i.e. humans as problem solvers) presented by the discrepancy. Each perspective separately cannot sufficiently explain the phenomenon of intrinsic motivation. However, in total, they provide a comprehensive understanding of how learners can be motivated by a learning environment and its implementation in the classroom, which may reduce the need for the teacher as the source of motivation.

Purpose of the Study and Methodology

To address our research question, we used interviews as our primary data source and the constant comparative method as our analysis technique. We also include descriptive statistics to illustrate specific aspects of the multimedia PBL environment that affect motivation and learning.

A Multimedia PBL Environment: *Alien Rescue*

Alien Rescue is a multimedia enhanced PBL environment for 6th grade science and is designed in accordance with the National Science Education Standards and the Texas Essential Knowledge and Skills (TEKS) guidelines (Liu, Williams, & Pedersen, 2002). The learning objectives include increasing knowledge of our solar system and improving problem-solving skills. It typically takes fifteen 45-minute class periods to complete. *Alien Rescue* presents a complex problem for scientific investigation and decision-making by students. The story of *Alien Rescue* has a science fiction premise that allows students to take on the role of a scientist in charge of finding habitats (e.g., the planets and moons) in our solar system for six endangered aliens by using a rich set of technology enriched cognitive tools. *Alien Rescue*'s cognitive tools include information databases with various media, simulation tools, expert modeling, and charts and a notebook tool.

Participants and Research Setting

One hundred and ten sixth graders from a middle school in a mid-sized southwestern city used *Alien Rescue* as part of their science curriculum for three weeks. The demographics of these sixth graders were approximately 71% White, 15 %

Hispanic, 10% Asian/Pacific Islander, and 4% African American. About 50.8% were female students and 49.2% were male students.

We observed students' interaction with *Alien Rescue* for the entire duration, and interviewed roughly 50% of the students (n=57). Both individual and focus group interviews were conducted during and after using the program. Focus groups of two to five students were randomly formed as time and seating arrangement permitted. We made an effort to talk to as many students as the time and situation allowed. Altogether, sixty interviews occurred, including ones performed during and after the completion of the program. The time for each interview ranged from 5 to 20 minutes.

Interviews and Analysis

All interviews were audiotaped and transcribed. The interview questions sought to capture students' cognitive and affective experiences during and after using *Alien Rescue*. As recommended by Suchman (1990), these semi-structured interviews occurred as informal conversations that were open-ended but guided by students' activities. Sample interview questions included the following:

- What are you working on now?
- Have you found a planet for the alien species? Which one? Why do you think it is a good home for species X? How did you reach that conclusion?
- Why did you need to launch probes? What did you find out? Do you understand the data? If you find something you do not know, what do you do?
- Which parts did you like or dislike most about *Alien Rescue*? Why?

Interviews after the completion of the program were also semi-structured and conversational, focusing on students' overall experience and impression of the program. The following were eight core questions used as the interview guides:

- What did you think of *Alien Rescue* (AR)? On a scale of 1 to 5 (highest number meaning the best), how do you like AR?
- Which part did you like the most/least about *Alien Rescue*? Why?
- Did you find the problem challenging? Did you like to solve it? Why?
- What have you learned? Did you think that you learned any science content by using *Alien Rescue*? What scientific topics, concepts, or skills have you learned by using *Alien Rescue*? How did you learn?
- How different is working with *Alien Rescue* from working on other school activities? Did you like researching and how was it different from researching in other classes or subjects?
- Did you choose your own team member? How did you work together?
- Did you talk with your peers about *Alien Rescue* outside of class? If so, what did you talk about?
- Would you want to work on programs like *Alien Rescue* in the future? Why?

Transcribed interviews were analyzed using the constant comparative method (Lincoln & Guba, 1985). Relevant information from the students' utterances or incidents was extracted through a systematic set of methodological procedures that inductively generated and connected raw data to codes, codes to categories, and categories to themes (Creswell, 2005). First, the data was examined for evidence or indicators of motivation and/or affect, since these two psychological concepts are considered to be highly linked (Eccles & Wigfield, 2002). The relevant incidents in the transcripts were coded to describe what the students said about motivation and emotion, a process referred to as "focused coding" (Charmaz, 2006, p. 57). At the next level, the codes were compared with each other and categories emerged at a higher level of abstraction that subsumed these codes. The analyses continued until

an "emergence of regularities" (Lincoln & Guba, 1985, p. 350) was reached. The emerged themes were compared with and against conventional intrinsic motivational theory perspectives with the purpose of framing our categories as well as informing existing knowledge.

RESULTS AND DISCUSSION

Findings

Of the approximately 500 paragraphs of text recording the students' spoken words in the transcript, there were 145 incidents where students spoke of their motivation and affect. A paragraph consisted of as little as one word to as much as several sentences. Some paragraphs contained more than one incident. Of the 145 incidents, 142 incidents expressed positive motivation and affect. Table 1 summarized students' expression of motivation and affect. Beyond these 145 incidents of motivation and affect, there were 288 incidents describing the reasons driving their motivation and affect, such as "I liked researching on the aliens and stuff like finding stuff out."

After analyzing 288 incidents of students' motivational drives, eleven themes emerged that influenced the students' positive motivation and affect while using *Alien Rescue*. The themes for motivation and affect were: authenticity, challenge, cognitive engagement, competence, choice, fantasy, identity, interactivity, novelty, sensory engagement, and social relations. These themes and categories are shown in Table 2, along with the number of incidents and percentages.

Authenticity

Students found situated authentic learning to be motivating and valuable. There were three subcategories for authenticity: authentic activity, scientific practices, and scientific roles. When asked how different was working with *Alien Rescue* from other school activities, some students responded that the activity was different because it was authentic in nature: "It [*Alien Rescue*] was just like doing something that a real scientist would do."

In addition, students were motivated by taking on the role of a scientist and performing what they described as scientific practices. Students were able to role-play as a scientist and work within a space station while using the tools afforded by the environment. When asked questions on what they liked about *Alien Rescue*, students' answers included statements such as: "I liked *Alien Rescue* because how else were you going to learn if you want to be a real scientist because it has a lot of the things you have to do and have to learn how to do" and "I like the program it was neat and… I think it was a good experience if you were going to be scientist some day—it just made you ready for that stuff."

Table 1. Students' expressions of motivation and affect

Categories	No. of Incidents	Percentage of Total
Concentration	3	2%
Fun	50	35%
Interesting	9	6%
Like	67	46%
Persistence	6	4%
Self-esteem	7	5%
Frustration (negative)	3	2%
Total	145	100%

Table 2. Students' sources of motivation while using Alien Rescue

Themes	Categories	No. of Incidents
Authenticity (19 incidents, 7% of total)	Authentic Activity	5
	Scientific Practices	8
	Scientific Roles	6
Challenge (28 incidents, 10% of total)	—	28
Choice (34 incidents, 12% of total)	Confiscation	12
	Control	7
	Freedom	15
Cognitive Engagement (54 incidents, 18% of total)	Learning	18
	Problem solving	10
	Researching	21
	Thinking	5
Competence/Confidence (12 incidents, 4% of total)	—	12
Fantasy (39 incidents, 14% of total)	Empathy	10
	Fiction	29
Identity (11 incidents, 4% of total)	Attainment Value	11
Interactivity (25 incidents, 9% of total)	Activeness	4
	Computer-based	7
	Feedback	4
	Playing	2
	Miscellaneous	8
Novelty (15 incidents, 5% of total)	Novelty	13
	Variety	2
Sensory Engagement (21 incidents, 7% of total)	Multimedia	8
	Probes	13
Social Relations (30 incidents, 10% of total)	Debate	6
	Group Work	10
	Peer Interaction	14

Challenge

In general, students liked the challenge of using *Alien Rescue* and found it motivating: "I thought it was hard, but it was fun at the same time because it was a challenge and I personally like challenges." For some students, *Alien Rescue* was "more of challenge, so you can't give up," which shows a desire to attempt solving the problem. Other responses to whether *Alien Rescue* was challenging

or difficult included "I think it's fun and it's kind of hard" and "*Alien Rescue* gave me a good challenge because it made me exercise my brain more than I would normally if it was an easier game." However, there were a few instances of students expressing frustration that *Alien Rescue* was too challenging or that there was not enough time to complete it. A student said, "I just think that the reason that it [*Alien Rescue*] could probably be better is because it could have been easier."

Choice

Students' feeling of control and choice were important with both positive and negative affective valences. When asked what was liked about *Alien Rescue*, a student replied, "They [probes] were fun because you got to create them and tell them what to do." Students thought it was fun to explore the program, choose what to do, create probes, and launch them to targeted planets and moons. On the flip side, students did not like losing control, such as when using the expert tool for guidance. The expert tool is a set of video clips in which an expert explains how they would address aspects of the problem and share their problem-solving strategies. Students did not like this and were able to explain exactly why:

Student: well the thing I hate about it [*Alien Rescue*] is the expert.

Group: OH! [agreement from the group]

Student (cont.): He would immediately take control of everything. You can't get rid of him, he would just stand there and start talking and he would just take control for some reason…

Cognitive Engagement

The students interviewed liked the cognitive engagement that *Alien Rescue* afforded. In fact, this was the most mentioned reason why they thought *Alien Rescue* was fun. The four main sub-categories expressed by students were learning, problem solving, researching, and thinking. For instance, a student articulated, "…I like the program. It was neat and I learned a lot of terms, a lot of scientific names that I didn't know before…" When asked why they liked researching on *Alien Rescue*, one student summed it up by saying, "I think that it was fun, doing the research on the planets because you got to figure out different things about the planets and you get to send probes and get information that you don't know and then you have to research all the aliens and figure out what they need and then try to match them up." A student appreciated that *Alien Rescue* is "like a puzzle that's kind of hard to solve but kind of easy at the same time, not easy I should say but difficult. Yeah, and it's fun and good." Another student said, "It was neat converting things from Kelvin to Celsius and how you could like figure out their temperatures and stuff."

Competence/Confidence/ Self-Efficacy

Some students felt competent or confident of his or her knowledge of *Alien Rescue* and his or her recommendations of habitats for the aliens. This may also be considered self-efficacy, which according to Eccles and Wigfield (2002), is a person's self-evaluation of his or her ability and beliefs about the probability of success in tasks. During engagement with *Alien Rescue*, students attained the feeling of competence and self-efficacy. After completing *Alien Rescue*, this feeling manifested itself as confidence regarding the selection of habitats for the aliens. One student expressed his or her confidence as, "I'm very confident because I really researched, I'm pretty sure that it was right." Another student said, "I'm pretty confident, well, we are because we think that we researched it a lot and we think that we got it right."

However, not all the students felt confident about their recommendations. For example,

a student who was not expressing confidence because of computer problems said "I was sort of confident on some because the computers we had kept messing up and it erased my notes but we did the best we could and I think that's all that matters."

Fantasy

Fantasy was the second major reason, after cognitive engagement, for why students liked and were motivated to use *Alien Rescue*. Fantasy was expressed in terms of empathy for the aliens and space exploration. With regards to aliens, students were motivated by the fictional narrative of saving the aliens' lives and as students said, "you've got to do it to help save the aliens" and "if you miss something the alien will die for that" and "[I like *Alien Rescue*] because [of the] aliens, 'cause it's also fun to imagine having them and being friends with them." Others expressed positive affect for *Alien Rescue* because it was fictional, such as "I thought *Alien Rescue* was pretty cool because you got to actually have some fiction fun in it."

The science fiction aspect of *Alien Rescue* made one student remark, that in "most other experiments, you don't have this much fun because you have to do it in real life, this is like science fiction or something."

Identity/Attainment Value

According to Eccles and Wigfield (2002), the attainment value is the individual's determination about whether the task confirms or disconfirms the core aspects of the person's beliefs and self-concepts about his or her self. That is, the task confirms or disconfirms an individual's self-identity, which is informed by the communities that the student wishes to participate in, whether in school or beyond.

For some of the students, *Alien Rescue* affirmed their identity. These students were motivated to learn science in order to fulfill their desire to become a scientist or space explorer, or both. *Alien Rescue*'s science fiction narrative brought special personal meanings to the activities for some students. For instance, a student said, "I want to one day go out of space and find a new planet plus the ones already discovered and study asteroids and comets because I really like space 'cause its very interesting". Another student stated, "And considering the fact that I have been wanting to be an astronaut since I was like three or four years old, this was just like the best program for me…" Another student wanted to "know what it would be like standing on the moon or going to other places" and wanted to eventually "go out of space and find a new planet plus the ones already discovered and study asteroids and comets" because of an individual interest in space.

Interactivity

Students were highly engaged with *Alien Rescue* because of its interactive features. Students' comments on interactivity can be broken down to activeness, computer-based, feedback, playing, and miscellaneous. Of these, activeness and being computer-based were the most important for these students. When asked, "How different is working with *Alien Rescue* from working on other school activities?," a student summed up his peers' comments by saying, "It [*Alien Rescue*] was better because instead of being stuck on the desk, you got to play around with the computer and kind of do whatever you wanted." Another student who liked "hands-on projects a lot more than reading out of a book" reiterated this point. One student summed up how interactivity evoked positive affect and motivation, saying"…it's funner because you are not just looking through textbooks you get to actually play around and it's funner than just sitting there in class."

However, a few students did not think there was adequate feedback from the program. One student commented on the lack of feedback, "… I think it should tell you if you got it right and

show how if they like where they live." In other words, *Alien Rescue* did not present the outcomes of the students' recommendations for the habitats of the aliens, and some students desired this feedback.

Novelty

Students liked to have new and different experiences. This was reflected by their preference for the novelty of *Alien Rescue*, especially since it is computer based, and how it varied from regular classroom instruction. For instance, when asked "On a scale of one to five, one being not very much and five being very much, how much do you like *Alien Rescue*?," a student replied, "I would give it a five because I like doing things that are irregular."

Sensory Engagement

Not only did students find cognitive engagement motivating, but also the engagement of their visual and audio senses. Students enjoyed the multimedia presentation in general (e.g. video scenario of the problem at the beginning of the program, graphics), but the aliens (including 3D alien videos) and probe simulations, in particular. For instance, when students were asked, "Did you like researching and how was it different from researching in other classes or subjects?" one student answered, "[I like *Alien Rescue*] because you have fun and you get to look at the aliens, you get to look at the graphs, you get to look at the pictures and then just kind of go from there" and another student answered, "I like this one part about watching probes."

Social Relations

Interaction with fellow classmates and peers was an important feature of *Alien Rescue*. These interactions took the form of debating within groups on where an alien should go, "one of the things that I liked about the research was working in a group because I think it would have been a lot less fun working by ourselves because I think its fun to talk and, it's actually fun to argue because you are actually getting all that information out and its fun all around."

Not only did the debate occur within groups but also between friends from other groups and peers outside of class:

"Well, I talked about it with my friends, because one of my friends was, 'Oh my gosh I'm totally clueless about this one alien. Do you know where they go?' And I said, 'Well I think they go over there' and she said, 'No, that's wrong they need to go here.' And we would have messed up if it weren't for my friends, because my friend stopped me in the hall and she said, 'guess what we finished Alien Rescue today' and I said, 'That's [habitat] what I chose and she said, 'No, it isn't [right]. Then, I figured it out and so my friend ended up being a little bit wrong and then I had to call Lynn. And then they had a big argument with me because they thought I was wrong and my friends were wrong. I said, 'No I'm right' and then I had to do more research."

Students also found that group interaction afforded them the teamwork needed to solve the problem. As a student pointed out, "when you work in groups, you don't have to do all the research" and the different tasks can be distributed to the appropriate people. As an example, the same student cited the conversion of Celsius to Kelvin problem as being a topic one student may know, but another student may not know. The sense of camaraderie is enhanced by the fact that students within the same group can help each other since "your partner tells you information that you don't know." Unfortunately, not all the members of groups were helpful, as a student stated, "I sort of did work by myself because my partner never helped me."

GENERAL DISCUSSION

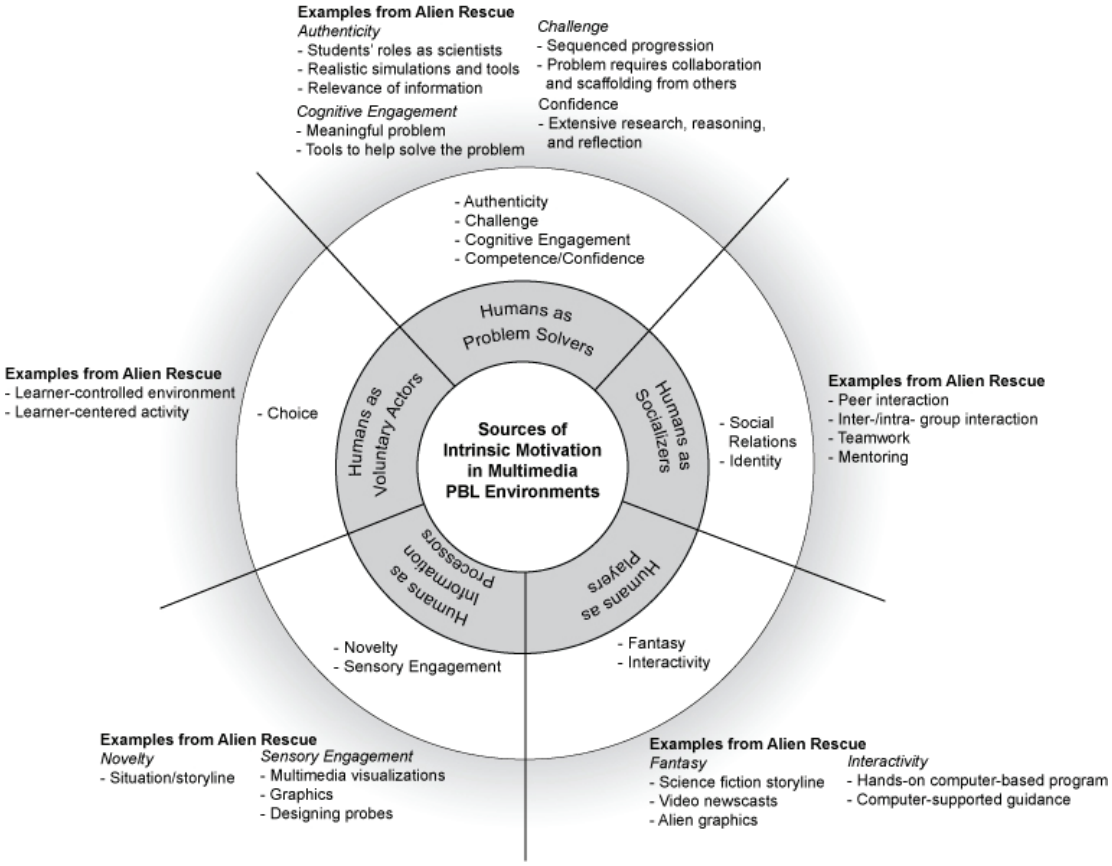
The purpose of this study was to explore the characteristics of a multimedia enhanced problem-based learning environment that intends to provide a rich context for learning science and afford students a motivating experience. The coding and categorizing procedures found eleven key elements that middle-school students considered motivating and/or evoked affect: authenticity, challenge, cognitive engagement, competence, choice, fantasy, identity, interactivity, novelty, sensory engagement, and social relations.

These elements were in congruence with the four sources of intrinsic motivation as discussed in the literature. A new source of intrinsic motivation was revealed through the analysis: humans as socializers - interpersonal relationships, identity, and group membership. Thus, our study was able to expand upon the existing theory on sources of intrinsic motivation with the addition of "humans as socializers" as a fifth source.

Humans as Problem Solvers

Activities are intrinsically motivating when the problems or challenges are personally meaningful. To best promote this motivation, the task should be optimally challenging (Csikszentmihalyi, 1990), and if possible, adaptable to the learner's ability.

Figure 1. Summarizes the motivating characteristics as exhibited in Alien Rescue with their corresponding theoretical motivational perspectives



As the individual masters challenges in an activity, s/he also attains a feeling of competence, mastery, and self-efficacy for accomplishing that activity. Challenges that are too easy bring on boredom and challenges that are too difficult evoke feelings of frustration or helplessness.

The results showed that *Alien Rescue* was able to evoke the humans-as-problem-solvers motivation within students. This was the single largest source of intrinsic motivation. This is not surprising since problem-based learning environments often have been found to be intrinsically motivating (Gallagher, Stepien, & Rosenthal, 1992; Hmelo & Ferrari, 1997; Savery & Duffy, 1995), and the core task of a PBL environment is problem solving.

The sources of motivation in *Alien Rescue* that comprised this perspective were: authenticity, challenge, cognitive engagement, and competence. As has been found by other researchers, challenge was a key source of motivation among students (Lepper & Malone, 1987; Malone & Lepper, 1987; Ryan & Deci, 2000). Cognitive engagement was the single most discussed theme by the students in this study. The students were intrinsically motivated in using *Alien Rescue* because it cognitively engaged them to research and learn new concepts and facts, and to think and solve the complex problem presented. Thus, *Alien Rescue* does not only present a challenge but provides an environment in which students valued the learning and thinking processes required to meet the challenge. The rich set of technology-based tools within *Alien Rescue* (Liu & Bera, 2005) supported the learning and thinking processes as well as encouraged interactivity.

In addition, many students knew that they were engaged in authentic activities and understood that solving the problem in *Alien Rescue* required skills that were authentic to the practices and roles of being a scientist. Results suggested that this authenticity was a source of intrinsic motivation, perhaps because it brought more meaning to the problem-solving exercise. Some students found personal meaning because they valued space exploration and science (i.e. identity/attainment value). However, a learning environment cannot accommodate for all the different, sometimes idiosyncratic, attainment values of students. Instead, the best way to accomplish the inclusion of meaningful activities is to present them in a way that convinces students that the processes employed are authentic in nature.

Finally, some students believed that they found the correct habitats for the endangered species and were confident about their decision. This perceived competence may be viewed as a source of intrinsic motivation and/or the result of intrinsic motivation. *Alien Rescue* scaffolds and reciprocally builds a student's perceived competence as the students proceed to complete the program. This is an important design consideration: students should develop the feeling of self-efficacy as they progress through the learning environment in order to promote intrinsic motivation.

Humans as Players

People play because it is fun. Fantasy involvement using graphics, characters, story, and sound can promote the feeling of play. Fantasy, heightened by using sophisticated multimedia techniques, removes students from everyday (non-play) life, which in turn promotes the feeling that the activity at hand is playing. A playful activity affords the learner to focus on the activity, which drives engagement (Csikszentmihalyi, 1990). However, if the activity is too playful, then the learner may focus on the playing aspects and less on the learning objectives.

Fantasy and interactivity combined, i.e. human as a player, were strong sources of intrinsic motivation for students to use *Alien Rescue*. Fantasy was the second biggest contributor to intrinsic motivation for the students. Fantasy involvement was promoted by using a science fiction narrative that was expressed through multimedia and interactivity. Interactivity is closely aligned with

the concept of playing, and in particular, students liked playing on the computer. Results suggested that the activeness (see Vinter & Perruchet, 2000) and feedback that *Alien Rescue* afforded via computer-based activities evoked positive affect for students. Finally, an indication that the students were experiencing play was that many of them called *Alien Rescue* a computer game and compared it to other games they played.

Humans as Information Processors

We take pleasure in resolving the mystery or disequilibrium and prefer activities that are neither very familiar nor very different (Pintrich & Schunk, 2002). Like challenges, to best promote this motivation is to provide optimal, intermediate levels of surprise and incongruence. Interestingly, curiosity was not explicitly mentioned by students using *Alien Rescue*. Instead, students described being motivated by novelty. That is, they were attracted to novel and different experiences as presented by *Alien Rescue*.

Piaget (1977) theorized that organisms (humans) not only desire experiences that are close to their existing schema, but also radically new experiences that require new cognitive structures or schemata to be accommodated. "Piaget explains how, at times, this process results in a 'reach beyond the grasp' in the search for new knowledge" (Fosnot, 1996, p. 13). Here, it seems that there is some overlap of the metaphor of humans as problem solvers and humans as information processors. Students were not only interested in meaningful challenges but their interest was piqued if the experience was novel to them. This novelty was especially enhanced by the multimedia delivery of *Alien Rescue*. Such use of multimedia effects promotes sensory curiosity (Malone & Lepper, 1987).

Yet, it is interesting that "human as information processors" was not as strong as a source of intrinsic motivation for students using *Alien Rescue* as expected. This could have been because the interpretation and categorization by the researchers may have unintentionally marginalized this source. For instance, perhaps when students expressed their fondness for designing and using probes to find information about specific planetoids, this was an indication of their need to resolve their curiosity instead of preference for fantasy involvement using graphics. Or maybe it was both.

Humans as Voluntary Actors

The sources of intrinsic motivation from the perspective of 'humans as voluntary actors', as stated by Malone and Lepper (1987), are: control and self-determination. People are fond of the feeling that they are in control of their environment. Environments that provide choices and self-direction support the feeling of autonomy, which enhances intrinsic motivation. This motivation is best promoted when the activity provides "a sense of personal control over meaningful outcomes" (Lepper & Malone, 1987, p. 258). Yet, too much control over the outcomes can reduce the meaningfulness of the activity.

The open-ended nature of *Alien Rescue* affords a significant amount of choices. Therefore, it was expected that students would have mentioned choices and control more often than was found. Yet, as an indication of their desire for control, students had a strong negative reaction to the expert-modeling tool, which they felt had confiscated their control.

Humans as Socializers

The theme of social relations was an essential motivating factor of *Alien Rescue* users. Most students found the socializing aspect of working with their peers motivating. Debating and arguing their perspectives about the problem and possible solutions were engaging and fun. Such lively discourse occurred both inside and outside the classroom. Collaboration is an important

aspect of PBL environments. Unfortunately, the difficulty in logistics of performing group assessment in K-12 classrooms often discourages curricula incorporating group work. The results of this study pointed to the need to consider peer collaboration as part of the implementation of learning environments.

Developing and maintaining social relations or socializing is not explicitly stated as a source of motivation in most classical descriptions of intrinsic motivation because it appears to be extrinsic in nature. However, Lepper and Malone implicitly incorporated socializing by including self-determination (Deci and Ryan 1992; Ryan & Deci, 2000) as part of the humans as voluntary actors perspective. Self-determination theory of intrinsic motivation posits that people are innately motivated to seek out optimal stimulation and challenges that meet the needs of autonomy, competence, and relatedness. In self-determination theory, the competence need is the desire to feel capable of acting appropriately in an environment, which overlaps directly with the concept of humans as problem solvers. The autonomy need is the need of humans to feel that they are in control of their environment, as discussed in the metaphor of humans as voluntary actors. Thus, a more accurate portrayal of humans as voluntary actors is that it is about control and autonomy, rather than self-determination.

However, self-determination theory also includes relatedness as a source of intrinsic motivation. Relatedness is the need to feel secure and connected to others in the learning environment. The need for security and connectedness is closely aligned with Maslow's (1955) theory of hierarchy of human needs of safety and belongingness. In Maslow's theory, safety needs can be seen in individual's preference for familiar (e.g. social) surroundings, and belongingness needs involve the need for affectionate relationships and the feeling of being part of a group (Petri, 1981).

In support of the existence of the need to be connected to others and interpersonal relations as a motivator, there have been numerous studies demonstrating that cooperative learning and group activities, such as those provided in problem-based learning environments, have a positive effect on students' interest, engagement, and motivation (Shernoff, Csikszentmihalyi, Schneider, & Shernoff, 2003). And although not mentioned in the above intrinsic motivation metaphors, Lepper and Malone's (1987, p. 248) taxonomy of intrinsic motivations includes interpersonal motivations, which are promoted by organizing activities with cooperation, competition, and recognition. A fundamental design element of PBL environments is organizing the activity so that learners cooperate to solve a problem, which affords the opportunity to enhance interpersonal relations and motivation.

The innate desire of individuals to establish, strengthen, and maintain interpersonal relations—the sense of belonging to and participating in a social group or community—is aligned with the social constructivist view of motivation (Greeno, Collins, & Resnick, 1996; Wentzel, 1999), which is an underlying theory behind problem-based learning environments. In the classroom, this social group comprises of friends and classmates. The super-motive is the reciprocal process of valuing the social group and the development of one's identity within that social group. Individuals have the innate need to belong to a social group or community where they can develop their self-esteem and attain esteem (via social recognition) from others through participation in that social group or community (Bandura, 1986; Hickey, 2003; Maslow, 1955; Ryan & Deci, 2000). Motivation is the process of negotiation of one's identity and participation in a community in order to attain esteem (Lave & Wenger, 1991).

The Significance of Using Technology in PBL Delivery

Within the context of PBL, the eleven elements that the students found to be motivating about

Alien Rescue were, to a large extent, delivered and enhanced with the assistance of technology. Situating the central problem within a science fiction premise, using video newscasts to announce the arrival of the aliens, placing students in the role of a scientist, providing a space station environment for the student to explore, and providing numerous databases of rich information make the learning environment more compelling and engaging for these sixth-graders.

Students' research and problem solving in *Alien Rescue* are assisted with the set of cognitive tools, each with a specific function. These cognitive tools are an important part of enhancing intrinsic motivation. This includes providing tools that students consider are authentic and used in the "adult world" such as the notebook, probe designing, and informational databases about NASA missions, and our solar system. These tools are interactive, supporting fantasy and sensory engagement. They provide necessary cognitive scaffolding during students' problem solving. As students develop more expertise during the process, they feel more confident with their work, which ultimately leads to enhancing students' self-efficacy. The cognitive tools provide students both cognitive scaffolding in assisting them to solve a complex problem, and also motivational scaffolding in making them feel less overwhelmed or helpless. Together with the incorporation of teamwork, students are in control of their own learning, relying less on the teachers, and are encouraged to be self-reliant and independent. The cognitive tools, however, should not be considered to have a one-to-one correspondence to the sources of motivation. Instead, the relationship between the tools and sources of motivations are one-to-many. That is, every tool can afford different sources of intrinsic motivation. For instance, the probe-designing tool supports the fantasy narrative, provides control for the students to test hypotheses and multimedia sensory curiosity while affording the students to continue the process of problem solving. When designing cognitive tools within a learning environment, designers should consider how tools, individually and collectively, support the sources of intrinsic motivation (See Figure 1).

CONCLUSION

Intrinsic motivation is shown to be highly correlated with the academic success of students, and is thought to be the antecedent to learning. Thus, it would behoove designers of multimedia learning environments to consider incorporating elements that promote the five sources of intrinsic motivation: problem solving, playing, information processing, voluntary acting, and socializing.

The findings of this study showed that students using *Alien Rescue* repeatedly described their experience as fun, interesting, and enjoyable, which are the characteristics of being intrinsically motivated. The two strongest sources of intrinsic motivation for students using *Alien Rescue* are their participation in problem solving and playing. The students expressed pleasure in engaging cognitive challenges while problem solving and the environment afforded these middle school students the feeling of playing while problem solving. Thus, removing them from everyday life and immersing them in a fantasy appeared to motivate the students to engage in solving a difficult task. The importance of incorporating these sources of intrinsic motivation into designing multimedia learning environments for this age group is obvious.

Other sources of intrinsic motivation such as social relations, curiosity, and choice—though less mentioned in comparison, also merit attention in designing multimedia learning environments. A learning environment that promotes social relations is important because it is not only a source of intrinsic motivation, but peer collaboration is also a way to scaffold student learning through the zone of proximal development (Vygotsky, 2006). In addition, students are motivated by the novelty of the computer program, as well as

with the sensory curiosity afforded by the rich multimedia design. Finally, choice is an essential source of intrinsic motivation and becomes salient to the students who, as shown in this study, had strong negative reactions when it was insufficient or taken away.

Taken together, the eleven elements (authenticity, challenge, cognitive engagement, competence, choice, fantasy, identity, interactivity, novelty, sensory engagement, and social relations) as exhibited in *Alien Rescue* have shown what makes a learning environment engaging to the sixth-graders, and reflect the five sources of intrinsic motivation. Thus, these motivational factors are important for designers to consider in designing learning environments.

FUTURE RESEARCH DIRECTIONS

This study provided some empirical based insights into how a multimedia learning environment can motivate students to learn academic subject matter. One possible future direction of research relates to how to optimize the sources of intrinsic motivation using multimedia. Is it possible to find an optimal level of motivation for a target group of students or is it better to try to develop an adaptable system to accommodate idiosyncratic motivational levels of each student? If the adaptable system approach is taken, how does one measure the student's motivation without interrupting working/playing and confiscating control?

Another possible future research direction is to determine how to enhance the sources of intrinsic motivation of PBL environments, such as *Alien Rescue*. Socializing, evoking curiosity, and choice-making were appreciably less mentioned by students in this study as compared to other sources such as problem solving and playing. How can these secondary sources be enhanced? Also, will all the sources of intrinsic motivation be enhanced when focusing on improving one or more of the sources' efficacy?

Finally, it is possible to use the five sources of intrinsic motivation as a rubric for evaluating future research on motivational characteristics of multimedia learning environments. Quantitative instruments can be developed to evaluate a wide range of multimedia learning environments to determine which sources were the major contributors for each genre. For instance, how do the results of this study compare to other multimedia enhanced problem-based learning environments? The results from studying each genre of multimedia learning environments can also be compared and contrasted to gain greater understanding of how to motivate students. From this research, we would not only understand how to enhance motivation through multimedia, but we could also be able to add new insights and dimensions to motivational theories as well.

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