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Motivating Students to Learn Using A Game-Based Learning Approach: Gaming and Education Issue

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Abstract

This paper describes an immersive 3D multimedia-learning environment, Alien Rescue, which uses a game-based learning approach to support students' learning. The design of Alien Rescue couples a real-world scientific inquiry process with a playful experience delivered through a 3D immersive, discovery, and sensory-rich approach to enhance motivation and support learning. The paper also describes the development model used to create this learning environment and present recent research findings of a series of studies using it in middle school science.

Keywords: game-based learning, immersive 3D multimedia-learning environment, problem solving, motivation, middle school science

Today's students have grown up with digital technologies and various digital tools such as games, social media, and virtual worlds have profoundly impacted the way they study, play, and socialize. Digital games in particular as a form of entertainment are gaining popularity especially since the introduction of mobile devices and are becoming a ubiquitous means of how people spend their leisure time. It has been reported that "in a typical day, 8- to 18-year-olds spend an average of 1:13 playing video games on any of several platforms…" and "On any given day, 60% of young people play video games" (Rideout, Foehr, & Roberts, 2010, p. 25). Educators are therefore increasingly interested in exploring using digital games as a tool to facilitate learning, because if we do not take advantage of these new digital technologies, we run the risk of missing the opportunities to maximize student potentials and addressing digital literacy of today's youth (Judson, 2010). In this paper, I will describe an immersive 3D multimedia-learning environment that uses a game-based learning approach to support students' learning. I will also describe the development model used to create this learning environment and present recent research findings using it.

Game-Based Learning

According to Gee (2008), video games are "virtual experiences centered on problem solving," and "they recruit learning and mastery as a form of pleasure" (p. 36). Squire (2006) considers "game play as a designed experience" which "enables students to develop situated understandings, to learn through failure, and to develop identities as expert problem solvers" (p. 26), and such play experiences can encourage deep learning (Gee, 2008). McGonigal (2011) even argues that games have the potential to solve real-world problems.

Researchers have been investigating the possibilities of using games for educational purposes. For example, Squire and Barab (2004) examined how students played Civilization III, a strategy game, to learn world history. In a study by Barab, Thomas, Dodge, Carteaux, and Tuzun (2005), students were engaged in problem solving by playing a multiuser virtual environment (MUVE), Quest Atlantis. Nelson, Ketelhut, Clarke, Dieterle, Dede, and Erlandson

(2007) discussed various design strategies built in River City, another MUVE, to increase student engagement and motivation for scientific inquiry.

A key tenet of game-based learning is it can potentially motivate students to learning by making learning fun. Research has shown that motivation plays an important role in influencing learning and achievement (Ames, 1990) and is often considered to be a necessary antecedent for learning (Gottfried, 1985; Lepper, Iyengar, & Corpus, 2005). When motivated, students tend to spend more time and effort in learning, persist in completing the challenging tasks, and take pleasure in their achievement (Malone, 1981; Stipek, 1993). Positive correlations have been found between intrinsic motivation and academic achievement (Cordova & Lepper, 1996; Gottfried, 1985; Hidi & Harackiewicz, 2000; Lepper et al., 2005).

Given the affordances of game-based learning, the intention of this research and development project is to design an educational innovation that will foster learning and promote motivation, and investigate the efficacy of this environment as a learning tool. The research question is "Can an immersive 3D multimedia learning environment that uses a game-based learning approach, Alien Rescue, motivate students to learn and in what way?"

Description of Alien Rescue

Alien Rescue (http://alienrescue.edb.utexas.edu/) is an immersive multimedia enhanced problem-based learning (PBL) environment for sixth-grade space science. The goal of Alien Rescue (AR) is to engage sixth-grade students in solving a complex problem that requires them to use the tools, procedures and knowledge of space science and apply processes of scientific inquiry while learning about our solar system. Sixth graders, acting as scientists, are asked to participate in a rescue operation to find suitable relocation sites within our solar system for six different species of aliens who have been displaced from their home planets. Through inquiry-based activities, students practice a variety of problem solving, self-directed, and collaboration skills using multimedia enriched cognitive tools. It is designed to provide an immersive, playful experience while engaging sixth graders in problem solving and learning science.

Designed as a curriculum unit for sixth-grade space science, delivered in about fifteen 50-minute class sessions, Alien Rescue is aligned with National Science Standards and the Texas Essential Knowledge and Skills (TEKS). Although the primary intended population is sixth graders, the use of this program, with proper instructional modifications, has expanded to include 5th through 9th grade populations. Teachers have used it with students of various ability levels with success. From 2012 to present, the program is being used as part of the science curriculum by 16 middle schools in Central Texas with a diverse ethnic base. In addition, schools in at least twenty-nine states (AZ, CA, CO, CT, FL, GA, HI, IA, IL, IN, KS, MA, MD, MI, MN, MO, MS, NC, NM, NJ, NY, OH, OR, PA, SC, TN, UT, WA, WI) and 4 countries (Australia, Canada, China, S. Korea) have used and are using Alien Rescue.

To assist teachers' implementation in the classroom, a comprehensive teacher's manual (over 160 pages and delivered online) is provided to assist teachers in their implementation. The manual details PBL pedagogy, lesson plans for each of the 15 days, additional science content materials, and assessment tools.

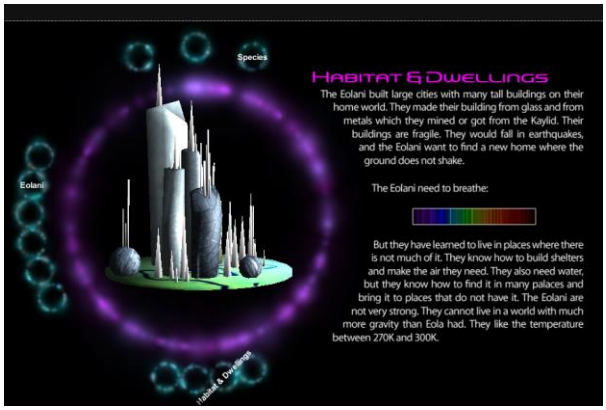
Key Design Features

Alien Rescue delivers a playful experience in an intentional problem-based narrative. It

combines game elements, play, and authenticity for the purpose of engaging students' learning of science and enhancing student motivation. Authenticity is achieved by placing students in the role of young scientists who are asked to join a United Nations rescue operation and charging them with the task of saving distressed aliens. This central problem is presented through a compelling introductory video to create a sense of urgency. As scientists, the students are challenged to find new homes for the aliens by exercising high-level thinking skills, such as goal setting, hypothesis generation, problem solving, self-regulation, evaluation of various possible solutions, and the presentation of evidence. Thus, this problem-solving process requires students to think and act like scientists and work collaboratively in groups. To assist students' problem solving, a set of multimedia-enriched tools is provided in the environment. These tools can be grouped according to their primary function(s) using Lajoie's (1993) four conceptual categories: (a) share cognitive load, (b) support cognitive processes, (c) support cognitive activities that would otherwise be out of reach, and (d) support hypothesis generation and testing. Learning therefore occurs as a result of solving a complex problem. In addition, there is not one single correct answer to the central problem. Some answers are more optimal than others. It is up to the students to present evidence and justify their rationale for solving the problem.

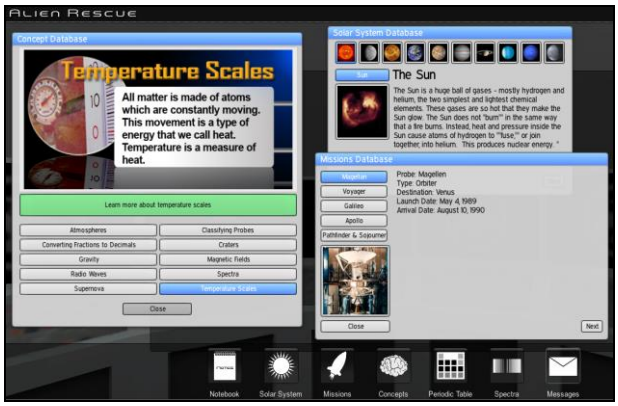
This real-world scientific inquiry process is combined with a playful experience and delivered through a 3D immersive, discovery, and sensory-rich approach. The design of Alien Rescue is guided by the key elements Malone and Lepper (1987) recommended for game environments to keep players motivated: challenge, curiosity, control, and fantasy. Alien Rescue incorporates such game attributes as challenge, control, fantasy, interaction, communication, mystery, role-play, representation, goals, sensory stimuli, adaptation, and 3D (Garris, Ahlers, & Driskell, 2002; Malone & Lepper, 1987; Wilson et al., 2009). Upon starting the program, students are not given explicit instructions on how to proceed to solve the problem. They must explore and discover the available tools, understand their functions and determine when to use which tool at what time. The six alien species are different from each other and each has its own unique characteristics. This design evokes uncertainty, mystery, and curiosity. The Alien Database presents the physique, nutritional needs, and habitats of each species, which are delivered through 3D models designed to create a sense of fantasy. That is, this scientific inquiry process of role-playing is situated in a science fiction fantasy setting. Figure 1 provides screenshots of some tools.

a. The introductory video introduces students to the problem of relocating homeless aliens.



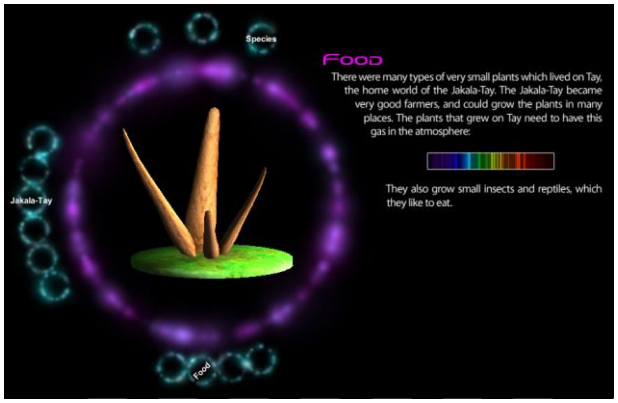
b. Information on alien habitats and dwellings are provided.

c. One of the alien species, called the Sylcari, is depicted in the Alien Database.



d. Students use tools such as the Concept Database, Solar System Database, and Mission Database.

e. Students select probe design options based upon hypotheses.



e. Illustration of alien food showing engaging visuals and detailed descriptions.

Figure 1: Screenshots of tools in Alien Rescue to support scientific inquiry.

Research Findings and Discussion

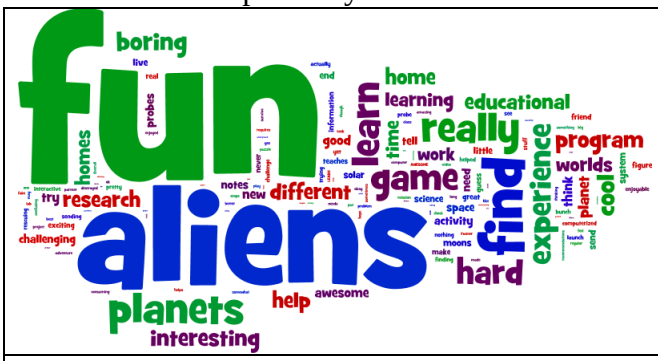
Research has been an essential element and ongoing throughout phases of design, development, implementation, and revision of this research and development project. Studies have been conducted using the program as a research platform to investigate various topics such as the motivational effects of multimedia and game-based learning, self-efficacy, goal orientation and learning, teachers' implementation of problem-based learning, and design of cognitive tools and cognitive tool use patterns. A summary of recent research findings on motivation and learning is presented below (a complete list of studies can be found at http://alienrescue.edb.utexas.edu/researchers.php).

Findings Related to Motivation

Research examining students' motivation, attitude, and learning through the use of Alien Rescue has shown that sixth-graders were highly motivated and engaged while using it (Kimmons, Liu, Kang, & Santana, 2012; Liu, Horton, Kang, Kimmons, & Lee, 2013; Liu, Horton, Olmanson, & Toprac, 2011; Liu, Rosenblum, Horton & Kang, 2014; Liu, Toprac, &

Yuen, 2009). For example, a few typical comments from the sixth graders as shown in Liu et al. (2011) captured the sixth graders' emotion toward the program: The program was "freaking awesome!!!" "so unique," "sooooooooo cool!!!!" and "soooooooooooooooooooooooooo FUN!!!!!!!!!!!!!!!!"

In three separate studies with different groups of sixth graders from different schools, the participants were asked "how do you describe Alien Rescue to a friend" or "what do you think of *Alien Rescue*." Students' responses were tallied and displayed in word a cloud. The word "fun" has the highest frequency in one study with 220 sixth graders (Liu, et al., 2011) and second highest in another with 478 sixth graders (Kimmons et al., 2012). It was mentioned 107 times and 313 times respectively.



Study 1: The word "fun" was mentioned 107 times, and was the most frequently mentioned word.

Study 2: The word "fun" (freq=313) had the second highest frequency after the word "think" (freq=350).

Figure 2. Sixth graders' responses presented in a word cloud.

In a third study (Liu et al., 2013), a total of 1,072 words were extracted out of the 358 statements from 383 sixth graders' responses. The word "fun" has the highest frequency as shown in Table 1.

Table 1

Word Cloud of students' responses to "How would you describe Alien Rescue to a friend?" Or "What do you think of Alien Rescue?"

Word Cloud	Word	Frequency (%)

fun	183 (17%)
learn	108 (10%)
solar-system	93 (8.7%)
aliens	74 (6.9%)
find	46 (4.3%)
helpful	41 (3.8%)
home	38 (2.7%)
information	30 (2.5%)
interesting	29 (2.7%)
probe	27 (2.5%)
game	24 (2.2%)
computer	20 (1.9%)

Note. Word count below 20 is not listed.

Sixth graders' comments through interviews and open-ended responses (unedited) as well as their teachers' comments through interviews from recent studies, students provided further evidence for positive attitude toward the environment and learning:

Sample Comments from Teachers (2012 - present)

Alien Rescue (AR) was a fantastic activity. I've been involved with problem based learning since '95 and this is terrific way to include/integrate 21st century technology and skills. AR takes a problem, allows the students to ask questions and research and then propose possible solutions. The interaction and communication amongst the team members was terrific. It was great listening to them discuss/argue as they researched and collected info from their probes. It allowed them to learn about so many topics as they tried to find new homes for the aliens. Thanks so much for allowing me to use this in my class. I look forward to using this again next year! (Teacher G)

I was amazed at how, after two weeks, all 125 of my students were still so drawn to *Alien Rescue*. They were having conversations about magnetic fields and elements on the periodic table in my classroom during lunch, and kids were going to the Library on their off-time to send probes and take notes in Alien Rescue! The lesson plans provided by Alien Rescue were rigorous, and all the background information I needed was available on the website. We will definitely use Alien Rescue in our Space Unit next year! (Teacher R)

Alien Rescue is engaging for the students. It is a great example of problem-based learning. The students must work as a team to solve a problem so it also encourage[s] collaboration. Our test and quiz grades are higher than the years before when we did not use Alien Rescue. I can tell they are learning the material because of the conversations we have when we debrief at the end of class (Teacher C)

I have never seen middle school students so engaged in reading and using data as when they were 'playing' Alien Rescue. When we were finished they asked if they could do it again because it was so much fun! (Teacher J)

My students have really enjoyed using Alien Rescue. Alien Rescue was a wonderful tool to integrate science in a fun, challenging, and innovative way. Alien Rescue embraces the idea of teacher acting as facilitator as opposed to teaching. Alien Rescue provides the circumstance that definitely keeps the students engaged while the teacher facilitates the learning environment. (Teacher S)

Sample Comments From the Sixth Graders (2012 - present)

I like Alien Rescue much more than other science activities because we're not just sitting at our desk doing work that must be done on our own, it's a fun activity that ties in with what we're learning. (Student 1)

Alien Rescue was better than other activities because I liked learning about the different things. Alien Rescue gave us a chance to work independently on a project by ourselves. I also liked that we could work with different people. Collaboration caused us to debate and come up with more correct answers than if we were working by ourselves. (Student 2)

Because Alien Rescue you can learn what scientist really do and how they learn about all the planets. (Student 3)

I liked Alien Rescue more than other science activities because it was a group project, we got to do it on the computer, and it was like a video game. (Student 4)

I liked doing Alien Rescue more than other activities because you get to do hands on activities. I find it more interesting than reading out of the book. It would prepare me to be an astronaut! (Student 5)

Alien Rescue is educational, but at the same time interactive and fun, like a video game. You are also much more independent in Alien Rescue. (Student 6)

Findings Related to Performance

Before and After Use Comparison. Recent research studies investigating the impact of this learning environment on student learning have been conducted (Kimmons et al., 2012; Liu et al., 2011; Liu et al., 2014). Studies have shown significant increases in science knowledge from pretest to posttest for both male and female students after using Alien Rescue using ANOVA with repeated measure at $p < .01$. The average gain score from pretest to posttest was 30.31 with $M_{male} = 28.02$ and $M_{female} = 31.85$ in Liu et al. (2011, $ES = .69$) and 32 points with $M_{male} = 29$ and $M_{female} = 34$ in Kimmons et al. (2012, $ES = .76$).

In a most recent study (Liu et al., 2014), all sixth grades from two public middle schools (n=430) in a mid-sized southwestern city in the U.S. participated. These sixth graders used *Alien Rescue* in their daily 50-minute science classes as their curriculum for space science for three weeks. The findings using ANOVA with repeated measures showed sixth graders significantly increased their science knowledge scores after using the program. The average gain score from pretest to posttest for School 1 was 24.29 with $M_{male} = 23.34$ and $M_{female} = 25.78$; and 13.31 with $M_{male} = 12.28$ and $M_{female} = 14.46$ for School 2 (see Table 2). It is worth noting that for both schools female students had higher gain in points than their male counterparts.

Table 2

Students' Science Knowledge Test Scores at Pretest and Posttest

	Boys			Girls			Total		
Science Knowledge Score (% on 0-100 scale)	*n*	*M (SD)*		*n*	*M (SD)*		*n*	*M (SD)*	
School 1	69			45			114		
Pretest		57.17%	(22.61)		52.11%	(13.76)		55.18%	(21.69)
Posttest		80.51%*	(18.55)		77.89%*	(22.55)		79.47%*	(20.17)

School 2	134			123			257		
Pretest		49.54%	(21.81)		41.82%	(19.7)		45.85%	(21.15)
Posttest		61.82%*	(19.18)		56.28%*	(16.28)		59.17%*	(18.03)

Note. *Significantly different from the pretest, $p < .01$. Only those who completed both pre- and posttests were reported.

In their open-ended responses, sixth graders stated what they had learned: about our solar system (the planets, moons, and their characteristics) (51% out of 515 units of responses); the scientific instruments (creating and launching probes and various instruments needed for each type of probe) (16%); alien species (8%); scientific concepts such as magnetic fields, gravity, and temperature scales (7%); problem solving (4%); conducting research (4%); managing a budget (2%); and working with others (2%).

Sample statements by the sixth graders describing what they have learned:

> I learned many different facts about the moons and planets in our solar system that I haven't known before, and some were quite interesting. I enjoy learning about outer space; therefore I thought that *Alien Rescue* was a neat game that could help us learn about the solar system. (Student 1)
>
> I learned mostly about magnetic fields, gravity, elements and the solar system. I also learned how the different instruments work for probes. (Student 2)
>
> From *Alien Rescue* how to really research and find information using tools and problem solving hard questions. (Student 3)
>
> I've also learned what I call "matching skills". Such as having to match the aliens' specific needs to a planet or moon that provides those needs. (Student 4)
>
> I also learned that science can be fun. I love science. (Student 5)

Comparing to Those Who Did not Use Alien Rescue. To compare students who used Alien Rescue with those who did not, a study was recently conducted (and is currently being written up) in a school district with two middle schools of comparable demographics. Alien Rescue was used with all sixth-graders in one school while all sixth graders in the other school were taught the space unit in the usual way. Both schools have access to computers and the Internet. At the end of the unit, all students took a school district-created 15-item test on space science. The results showed a significant difference in the test scores between the two groups: $F(1,766)$, $p < .01$, showing the school used Alien Rescue scored significantly higher (see Table 3).

Table 3

Science Knowledge Test Scores by Schools Who Used AR and Who Did Not

	Mean % Score (out of 100)	Scored 66% or better	Scored 90% or better
School did not use AR: *n*=384 (female=174, male=210)	80.11%	89.58%	26.82%
School used AR: *n*=384 (female=195, male=189)	87.56%	94.79%	54.17%

The Development Model

The design and development of Alien Rescue employs a project-based learning approach that emphasizes learners as designers. This approach corresponds with a four-phase model based upon established practices in the multimedia industry and current education technology literature (Liu, Kishi, & Rhodes, 2007; Schoenfeld & Berge, 2004/2005): (1) concept, (2) design, (3) development, and (4) implementation. Planning and evaluation are embedded in each phase (see Figure 3). The development process is also guided by a design-based research framework which aims to generate and refine theories by evaluating reiterative enhancements to an instructional innovation within authentic settings (Brown, 1992; Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003). With this approach, the importance of studying educational innovations within the authentic context is emphasized so that the research findings obtained through classroom evaluation inform the design of next iteration and program enhancement (Collins, Joseph, & Bielaczyc, 2004).

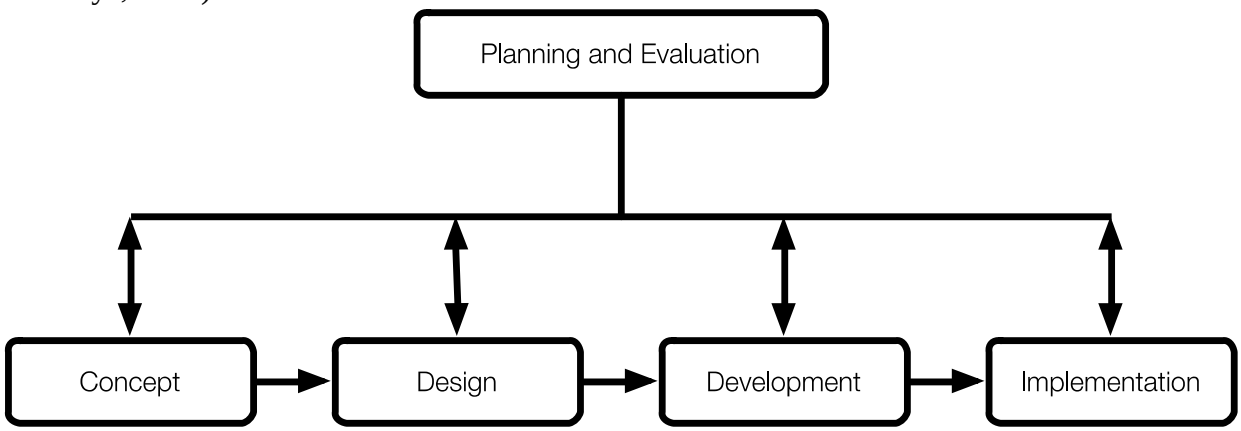


Figure 3. Project development process

Alien Rescue team consists of a group of graduate students working collaboratively under the supervision and guidance of faculty. Harnessing students' diverse talents and ideas is a major characteristic of our development model. Students' engagement in the project is largely driven by their interest in creating a quality technology program to enhance learning while developing multimedia production and research competencies. As the program evolves from one version to another with the advancement of technologies and new understanding in educational research, team members' skills also progress and reflect current industry best practices and trends. This process has provided opportunities for students to gain valuable software design and technical development skills. It has been a training platform for future designers and developers, instructional technologists, and educational researchers. Up to this point, this project has also led to numerous presentations, publications, master's reports, and doctoral dissertations (see a list at http://alienrescue.edb.utexas.edu/researchers.php).

Conclusion

Given the growing interest in game-based learning, educators are exploring the affordances of game-based learning. Can an immersive 3D multimedia learning environment that uses a game-based learning approach, Alien Rescue, motivate students to learn and in what way? The findings from a series of studies examining motivation and learning, comparing both pre- and post- science knowledge scores and scores by the students who used Alien Rescue with

the students who did not have shown promising results with ample empirical evidence. Both quantitative and qualitative data also demonstrated that the sixth graders were motivated toward learning and had fun while learning. The design of Alien Rescue - coupling a real-world scientific inquiry process with a playful experience delivered through a 3D immersive, discovery, and sensory-rich approach - is effective for this age group. Such findings support other research emphasizing the value of play and playfulness (Barab et al., 2005; Garris et al., 2002; Rieber, 1996; Squire, 2003) and suggest game-based learning can be used as a tool to support learning.

In 2012, *Alien Rescue* won the *Interactive Learning Award* for its quality from the national *Association for Educational Communications and Technology* (AECT, a major IT professional organization). Most recently, it has received the *Outstanding Practice Award* 2013 for its design and development model from *Association for Educational Communications and Technology*. We are encouraged by the research findings and intend to continue this pursuit of searching for ways to design effective learning environments with sound pedagogies to support learning.

Dr. Min Liu is Professor in the Learning Technologies Program. Her teaching and research interests center on educational uses of new media and other emerging technologies, particularly the impact of such technologies on teaching and learning; and the design of new media enriched interactive learning environments for learners at all age levels. Dr.Liu's current R&D projects include studying the design and effectiveness of immersive, rich media environments on learning and motivation, examining the affordances and constraints of using mobile technologies in teaching and learning, understanding MOOCs as an emerging online learning tool, and use of Web 2.0 tools to facilitate instruction.

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