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CONNECTING THE ARCS MOTIVATIONAL MODEL TO GAME DESIGN FOR MATHEMATICS LEARNING

Mario J. Toussaint
Florida Atlantic University, mtoussa1@fau.edu

Victoria Brown
Florida Atlantic University, vbrown22@fau.edu

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By
Mario J. Toussaint and Victoria Brown
Florida Atlantic University

Introduction

Engaging mathematics students in the learning process continues to be a challenge for mathematics educators and educational leaders. The severity of this problem worsens in distance learning courses where students must learn new concepts either by watching videos or PowerPoint presentations, or by reading text files. This online teaching format mimics the traditional method of teaching mathematics face-to-face through lectures. Research suggests that lecturing may not provide an optimal learning environment for most students (Doyle, 2008; Bonfert-Taylor, 2016). Some manage to learn; however, the majority struggles and a significant number meets with failure. In 2015, 40 % of 4th graders, 33% of 8th graders, and only 25 % of 12th graders performed at or above proficiency in Mathematics (NAEP, n.d; NCES, n.d.).

Bailey (2009) reported that only 31 % of community college students successfully completed the required sequence of mathematics courses to fulfill the requirements for graduation. The completion rates decline to 22% for students who tested below college level into the developmental math sequence. The success rate for community college students placed directly into college-level math courses was higher, but still below 50 % (Bahr, 2008). Currently, students' success rate in entry-level college algebra is around 50 % (The Hechinger Report, n.d.). Gallo and Odu (2009) hypothesized that there is a link between students' failure in mathematics and their lack of engagement and interest in the subject.

Recent technological advancements may provide educators the tools they need to tackle the problem of student disengagement in mathematics, especially in distance learning courses. Serious games have the potential to provide alternative learning environments that cater to the students' needs and interests while enticing them to engage with the course content (Gee, 2003; McGonigal, 2010; Prensky, 2012). The following describes how to increase students' motivation in mathematics using the ARCS model to design Serious Games for mathematics learning.

The Role of Technology in Mathematics Teaching and Learning

Mathematic educators have been trying to harness the power of computer technology to influence students' engagement with course materials. Taylor (2008) successfully used Assessment and Learning in Knowledge Spaces (ALEKS) as a remediation tool for college freshmen. Other researchers have also claimed that ALEKS or other web-based software have improved mathematical performance and student attitudes towards mathematics (Stillson & Alsup, 2003; Stevens & Convalina, 1999; Burch & Kuo, 2010; Zerr, 2007). Contrastingly, Spradlin & Ackerman (2010) found that ALEKS did not improve students' mathematics achievement when compared to students taught using the traditional lecture method. Likewise, Kodipili & Senaratne (2008) concluded that the software titled MyMathLab (MML) did not statistically significantly improve students' outcomes in college algebra. Similarly, other studies concluded that technology innovation did not appear to have an impact on students' performance (Meagher, 2012; Herman, 2007).

One possible explanation for the contradicting results is that, while the web-based technologies have the potential to increase students' performance by providing them opportunities for practice and instant feedback, the design of the software fails to consider the students' motivation to learn mathematics and their attitudes towards the subject. Some studies suggest that students' outcomes improved when technology based software are integrated in mathematics education in a manner that simulates real-world situations (Hoffman & Hunter, 2003; Basson, Krantz, and Thorton, 2006). Gaming strategies can combine both approaches by affording the students with opportunities for practice using mini games to develop automaticity and improve their motivation by embedding the content in scenarios that simulate real-world situations.

Motivation as Stimulus for Learning

One of the primary conditions that must be satisfied for learning to take place in any environment is that the learners must be motivated. The literature identifies two types of motivation: intrinsic and extrinsic motivation (Townley, 2011; Wormington, Corpus, & Anderson, 2012). Extrinsic motivation refers to a person's desire to complete a task because of the external rewards associated with the completion of the task. For example, the expectation of receiving their wages or the desire to remain employed may be the primary stimulus that compels employees to complete assigned tasks. On the other hand, intrinsic motivation comes from within individuals. Factors associated with increasing intrinsic motivation include challenge, curiosity, control, cooperation and competition, and independence (Leadership-Central, 2016). Townley (2011) contended that internal motivation is a better form of stimulus because it stems from intangible forms of reward.

George (2010) asserted that motivation plays an important role in the success or failure of students enrolled in school. Educational stakeholders should apply theories of motivation to promote patterns of interactions with their students that increase their willingness to put forth effort on the tasks necessary to achieve the stated learning goals (Tollefson, 2000). Merseth (2011) identified four factors associated with students' disengagement and lack of motivation. They include (1) students' perception of the material as boring or irrelevant, (2) students' lacking the essential study skills and habits to succeed, (3) Students' lack of confidence in their ability to master the content, and (4) insufficient interactions among students as well as between students and instructors. Game design addresses these challenges by (1) embedding the content in exciting storylines designed to grasp and sustain the students' attention, (2) providing the students opportunities for many drills and practices through mini games, (3) increasing the students' confidence by initially presenting the lower levels concepts and adjusting the level of difficulty in accordance with the learners' skills level, and (4) providing the students with ways to interact instantaneously with one another.

ARCS Motivation Model

Instructional designers utilize John Keller's ARCS Motivation Model to design instructional materials for both classroom and training environments (Keller & Suzuki, 1988). The model consists of four steps, which act as influencers on motivation.

Attention: Building the Bridge from Gaming to Learning

Attracting the learners' attention is important in any learning situation. Drawing and retaining students' attention in mathematics is very difficult; teaching mathematics online adds another level of complexity to the problem. Inserting mathematics content in a fantasy world may provide a solution to the problem of attracting students' attention in online environments. Classroom instructors constantly face the challenge of maintaining the students' attention. Online educators also face the challenge of sustaining the learners' attention. It is a difficult task to keep the students engaged in face-to-face environments; maintaining students' interest in lecture presentations is daunting in distance learning environments where opportunities for open communication dramatically decrease.

Game uses a storyline to arouse the curiosity of the learners. Captivating students' attention is the primary focus of curriculum designers in creating educational games. Without stimulating the students' interests, they will have no desire to continue playing the game. An enticing story line captures the learners' imagination, invites participation, and encourages the use of critical thinking abilities. The story lines allow the educational game designer to incorporate problem-based or authentic types of assessment within the scenarios, which require the mathematic skills to solve. The storylines generate the need to use mathematic skills that the student may need to learn before solving the problem or resolving the situation. Mathsnacks is an excellent example of including storylines within educational games (Mathsnacks, 2016). The games are very short. For example, Ratio Rumbo requires the students to engage in battles to obtain the ingredients for potions. The student must mix the ingredients following recipes using the proper ratios to win the game. This approach promoted significantly higher academic gains sustained over a minimum of a seven-week period (Wiburg et al, 2016).

Relevance: Building the Bridge from Gaming to Learning

Many students perceive mathematics as a boring subject with no relevance to their career goals nor their everyday lives. Fantasy worlds provide unique opportunities for educators to counter student's perceived irrelevance of mathematics in day-to-day life. Games provide mathematics educators the opportunity to expose students to lifelike scenarios in which they need to solve problems that increase their awareness of the usefulness of mathematics in science, technology, engineering, business, and other content areas.

Often, students fail to see the relevance of mathematics from reading word problems from the pages of textbooks. Games and simulations allow educators to provide students with immersive experiences in learning situations where it would be too expensive or too dangerous to carry out the experience in life. Gaming environments can provide learners with the tools necessary to discover important applications of mathematical concepts; facilitate the evaluation of different approaches for solving problems; uncover the connectedness among concepts; and model real-world problem solving.

To arouse students' interest in mathematics, the curriculum must be relevant and meaningful to each individual learner. When students perceive the topic as applicable to their everyday lives or their future careers they are more likely to engage with the material. Students' motivation to learn increase when they can find excitement in the learning activities. One of the primary goals of educational games must be to create exciting learning opportunities that not only motivate the students to learn the content, but also provides application of the concepts in real-world situations that students find interesting. Massachusetts Institute of technology (MIT) developed a massive multiplayer online game titled Radix Endeavor that integrates many concepts in mathematics and the sciences using a simulated world (Radixendeavor, 2016). So far, the game has mixed results with accolades for taking education gaming concepts to a new level. However, the topics covered do not follow the curriculum of general education mathematics courses. Although the game connects to Common Core Standards and Next Generation Science Standards, its intent is only to supplement mathematics and science courses. Questions surround the ability of the game to cover enough content quickly enough for use in a classroom setting (Cavanough, 2013).

Confidence: Building the Bridge from Gaming to Learning

There is a strong link between confidence and motivation. To build the learners' confidence the games must present the problems and challenges with increasing levels of difficulty. The games start with basic skills increasing the difficulty level gradually per the learners' mastery level of the learning objectives. This is the most difficult gaming element to bridge between motivation and educational gaming. In a game, the difficulty level increases the fun in the game. However, in educational games leveling up requires more advanced academic skills, the additional challenge in designing the game is to sustain the level of interest in the topic. A change in subject matter emphasis can affect the learners' willingness to continue playing the game. An educational game needs to carefully consider how quickly new concepts are presented to prevent discouragement when more advanced academic skills are required.

Recreational games build confidence in the integration of short tutorials for new game skills and by gradually encouraging the combination of the gaming skills to solve increasing complex problems. Building confidence in educational games requires development of two sets of skills. One skill is that how to use the gaming skills for that game. The second skill is the educational goals. Prodigy Math helps elementary school children build confidence in various topics in mathematics (Prodigy, n.d.). Classrooms that integrated Prodigy into their curriculum did see 3.0% improvement on third-grade mathematic scores (Mahimker, 2014).

Satisfaction: Building the Bridge from Gaming to Learning

Leveling and awarding badges can provide positive reinforcement every time learners achieve some pre-defined milestones. Giving participants increasing amounts of credit for completing a variety of tasks in the virtual world may provide a sense of satisfaction for small accomplishments and entice them to keep coming back. The total points accumulated for completing the activities could account for a percentage of the students' overall course grade. These external rewards may potentially increase extrinsic motivation and foster engagement with the course content while at the same time fostering intrinsic motivation with interesting story lines, relevant projects, and a visually appealing virtual environment.

Structuring the game so that students will move from low to high difficulty levels may also have a positive effect on extrinsic motivation. People love to compete. Having a leader board that anonymously displays the players with highest achievements may impact the learners' motivation to keep coming back to play the game and their sense of satisfaction for accomplishing a set of difficult tasks. In addition, inserting complex problems that simulate life situations may have a positive impact on students' intrinsic motivation. By solving challenging problems that require persistence, the students' perception of their abilities and self-worth might increase.

An example of this type of game element is MathGirl. This app game allows the parent to select the levels for their girls to begin interactions with the game. As the girls answer the mathematical questions correctly, they receive award stickers to put into their garden. The students level up to receive problems that are more complex. Because the tasks are set up with ten questions maximum, the young girls can receive immediate satisfaction in accomplishing the goals of that level of mathematics. The different types of mathematic processes are divided into different regions allowing multiple paths to success. As multiple levels are met, higher value stickers are given.

Combining the Four Steps Creates Immersive Experience

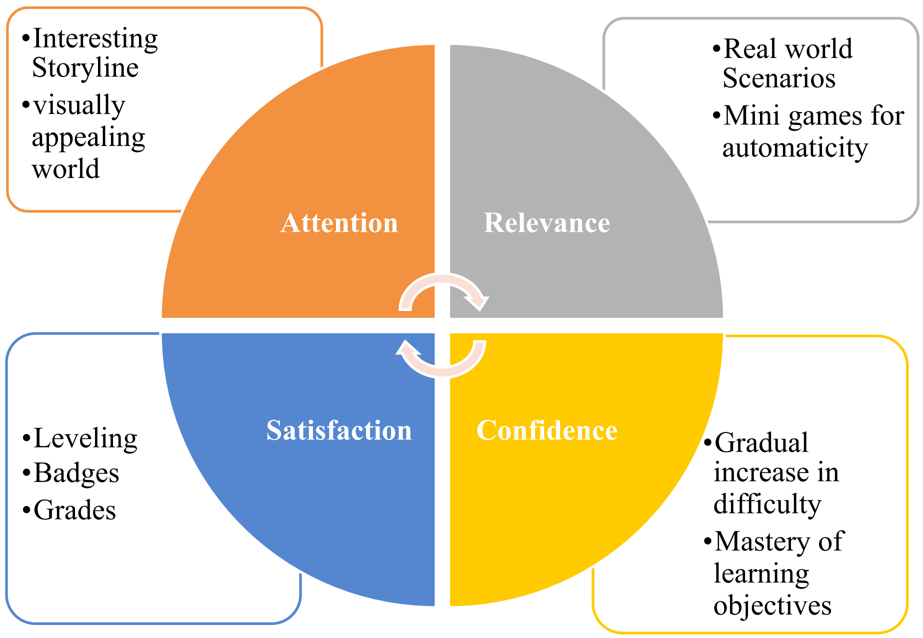
Currently, there are many educational software on the market claiming to make the learning of mathematics fun. However, the majority of the ones that adopt the gaming approach are just drill and practice laced with non-educational games. For example, in the original version of Math Blaster, learners must solve arithmetic problems one after another. For each problem they solve correctly, they earn a bullet. When they have accumulated a certain number of bullets, they can play a shooting game. These types of games target elementary and middle schoolchildren and fail to make learning an intrinsic part of the game.

To design truly educational games, games must incorporate motivational elements in the learning activities within the game. The ARCS model represents the elements that must be present in order to build games that provide authentic motivation to interact with the material and master the content. Presenting the learners with gaming situations that compel them to pay attention must be integral in the design of the game. Once the story and the look and feel of the environment capture the learners' attention, presenting them with situations that are relevant and applicable to their everyday lives or future careers will sustain their engagement. For meaningful learning to take place, the environment must provide the adequate context; contextual understanding of important concepts will help the students retain the information longer and be able to apply that information in new situations.

Presenting the learners with opportunities to solve problems with increasing levels of difficulty will not only build their confidence, but also allow them to develop their critical thinking skills. Giving students the opportunity to critically think and solve problems related to real life situations will help them acquire important problem-solving skills that potential employers actively seek in potential recruits. The ability to explore different solutions with confidence when confronted with problems has benefits beyond the learners' academic traverse.

Satisfaction is one of the intangible rewards associated with the completion of any task. If one is not satisfied after the accomplishment of a task, the desire to undertake similar tasks decreases dramatically. The design of educational games must carefully consider the four principles of the ARCS model. (1) Compel the learners' attention with an enticing storyline, (2) present the learners with content related to their potential careers or everyday lives, (3) give the learners the opportunity to build confidence in the subject matter, and (4) combine these elements together to provide the learners with a sense of satisfaction (Malik, 2014).

The ARCS Model Applied to Educational Game Design



Potential for Future Research

Currently, no game in the market has successfully combined the elements of the ARCS model to build an immersive serious game. Future games intended to teach mathematics should explicitly incorporate these principles into the games. Researchers can study whether the insertion of these principles makes a difference in students' achievement at all levels of the educational spectrum. Further lines of inquiry could include whether these principles make a positive contribution to academic success in mathematics as well as other content areas. Success in any academic discipline eventuates when the learners are engaged in activities that promote learning. Engagement occurs when the learners are motivated. Traditional mathematics courses at tertiary institutions usually suffer from low rates of attendance and participation. Distance learning students in these courses tend to be disengaged, and give up easily because they are unprepared for rigorous work in mathematics. Serious games have the potential to produce viable solutions to the problem of students' disengagement and lack of motivation by providing a lively and interesting learning environment that promotes students' participation. Researchers can undertake many comparative studies to evaluate the truth-value of the above statements.

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