Lessons Learned Using Video Games in the Constructivist Undergraduate Engineering Classroom

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ABSTRACT

As constructivism gains more popularity in undergraduate engineering classrooms, video games are used with more frequency for instructional purposes. In fact, many of the principles of constructivism are practiced in the classroom through the use of video games. Since the beginning of this educational trend, several studies have been conducted to evaluate the effect that some learning or recreational games have had on learners and on their mastery of learning objectives. Many of these studies have focused on specific sets of skills that specific video games can promote. Nevertheless, there is evidence that any type of video game, regardless of its learning or recreational nature, can help students develop certain knowledge, skills, and attitudes (KSAs) that could be useful for engineering education. This literature review will describe the KSAs that could be obtained in constructivist-oriented classrooms when learners engage in any type of video game. The following research questions have guided this review: What KSAs do students learn when playing any type of video games? Why can video games be considered constructivist instructional materials? This research paper looks forward to demonstrating that beyond learning objectives that can be assigned to specific video games in the classroom, video games can teach KSAs that are implicit in each gaming opportunity, such as high-order thinking and decision-making skills, persistence, socialization, leadership skills, self-confidence, and autonomy and self-regulation.

Keywords: video games, constructivism, knowledge, skills, attitudes

1. INTRODUCTION

Recreational video games have been widely known as a mechanism of entertainment for decades (Dickey, 2005; Blumberg, 1998; Evans, Norton, Chang, Deater-Deckard, & Balci, 2013). Even though the main objective of these type games has been to entertain, they have also been used in more intentional settings for educational purposes such as classrooms (Durkin et al., 2013). In fact, some video games have been developed and designed primarily for learning purposes and with specific learning objectives for the player. For instance, the game Times Engineer has been developed to help students apply civil, electrical, and mechanical engineering principles to solve problems ("New Video Game," 2009).

As video games of any type gain popularity as learning technologies in classroom settings, including engineering, many educational projects have begun to design and develop video games as instructional media (Evans, Pruett, Chang, & Nino, 2014). For instance, some video games have been used to change attitudes and perceptions in learners about a wide variety of topics and situations (Connolly et al., 2012). Other video games have been used in the engineering classroom to increase the level of engagement in students who find certain courses irrelevant to their curriculum (Coller &Scott, 2009). The adoption of video games for specific projects and achievement of learning objectives has then become a suitable and innovative alternative for teachers and instructors. The popularity of video games in the classroom is related to the high level of engagement learners experience when they play video games (Dickey, 2005). Also, it is possible to link the increasing use of video games and other social media in classrooms to the popularity of constructivism (Paurelle, 2003). Many classrooms are changing their traditional structures to more constructivist ones, which gives a more relevant and independent role to the

learner (Cobern, 1993). Since the intervention of teachers and instructors is limited when learners are playing video games, learners get to practice and develop many of the learning characteristics found in constructivism, such as self-regulation and autonomy. These skills can be really useful for engineers, not only for their courses, but also for the transfer of knowledge that can take place later.

De Grove, Bourgonjon, and Van Looy (2012) have stated that students can effectively gain certain types of knowledge, skills, and attitudes (KSAs) when using video games in the classroom. Furthermore, there are extant studies that have addressed specific KSAs that learners could master when engaging in specific video games (Williamson et al., 2005; de Freitas & Routledge, 2013). Nevertheless, there is scant evidence in the literature that evaluates video games of any type as agents that foster and promote universal KSAs in engineering students. Most of the studies and examples in the literature are focused on specific educational projects. This occurs mainly because once a project is designed and developed, a specific set of assessments and studies are usually conducted to determine the impact of that particular intervention in the learners.

The main goal of this literature review is to answer the two following research questions:

- What KSAs do learners acquire when playing any type of video game?
- Why can video games be considered constructivist instructional materials?

To provide answers to these questions, this paper will start with a theoretical framework that attempts to explain how the constructivist nature of video games fosters and promotes certain KSAs. The following section describes the findings and describes the KSAs that are common to all video games. Finally, the paper provides conclusions and the significance of this review.

2. THEORETICAL FRAMEWORK

Currently, constructivism has become a powerful learning theory and pedagogy in classrooms (Paurelle, 2003). Constructivism places the learner in a more self-aware, self-regulated, and independent role in the learning process (Cunningham & Duffy, 1996). Instead of fostering a traditional learning environment, where the teacher or instructor is responsible for the instruction, constructivism is more focused on how learners connect new knowledge to prior knowledge and how they can determine their own learning goals (Cobern, 1993). In addition, constructivism focuses on sociocultural aspects of learning and how the environment and more knowledgeable people influence learning. This is especially true in the social constructivist theories of Vygotsky (Schifter & Cipollone, 2013).

Constructivism has gained popularity in engineering classrooms because of the set of skills learners get to practice and how it helps engineering students to build their own knowledge and solutions to problems (McHenry et al., 2005). The American Society of Engineering Education (ASEE) has defined engineers as "problem solvers" who use resources in an effective way to overcome challenges (McHenry et al., 2005). In constructivism, learners face authentic problems and they have to find solutions by themselves with a limited amount of guidance (Driscoll, 2005). The use of constructivism in the classroom fosters the skills that fit the definition of the ASEE.

Using a constructivist perspective, current literature about video games, especially in educational settings, has been identified and evaluated. By assessing this literature, it was deduced that several of the skills that gamers engage in during video game play belong to constructivist processes. For instance, social negotiation and sense of self-regulation are skills that get to practice in any video game, regardless of the topic or type of structure (Hoffman & Nadelson, 2010). In addition, participants in video games bring to the game many of the skills and knowledge they have previously acquired and they use the game as an arena to practice these skills and improve them. After several hours of gameplay and several milestones, studies have shown changes in the knowledge, attitudes, and behaviors of gamers because they have constructed them throughout the development of the game (De Grove, Bourgonjon & Van Looy, 2012).

When instructors decide to adopt video games into their curricula, they most likely do it because they see the potential of the video game helping students to meet their learning objectives. Therefore, there is some sort of knowledge that will be used throughout the game. Video games help to construct new knowledge based on these

foundations. To some extent, the use of video games shape the knowledge of participants and help them build new perspectives about how they see themselves and how the see the things they already know (Hamalainen et al., 2006).

Even though many of the studies in the literature highlight specific KSAs gained through particular video games, such as high-order thinking skills, the previously described constructivist process points out that regardless of the nature or specifications of the games, learners are going to apply a constructivist approach when playing these games (Jong, Shang & Lee, 2010). From a constructivist point of view, there is a common ground for all video games in learners that shows some KSAs that are practiced and tested when engaging in video games, educational or not.

3. FINDINGS

This literature review was conducted using academic databases, such as ERIC and EBSCOhost. Several articles were assessed and analyzed to answer the two main research questions, previously described. Findings are divided into two categories: KSAs gained through the usage of video games and video games as constructivist instructional materials.

3.1 KNOWLEDGE, SKILLS, AND ABILITIES

One of the major challenges for the adoption of video games in the classroom was the assumption that video gamers tended to develop negative KSAs in gamers, such as aggression or isolation (Butcher, 2012). Even though there is evidence that certain video games can develop negative attitudes in learners, several studies have also pointed out the benefits of video games in the development of skills such as leadership skills, social skills, communication skills, and others (Dickey, 2005; Thirunarayanan & Vilchez, 2012). Gamers develop certain KSAs because "depending on the genre and individual game, players may be required to analyze, synthesize, and use critical thinking skills in order to play and execute moves (Dickey, 2005, p.67). The challenge for instructors and teachers is to know how to use the technologies of video games into their curricula and not let the curriculum be built based upon the game (Butcher, 2012). Since we can apply this principle universally to any video game, it is possible to infer that there are KSAs associated to video games and that are practiced and tested when playing, such as *high-order thinking and decision-making skills, persistence, socialization, leadership skills, self-confidence, and autonomy and self-regulation.*

3.1.1 HIGH-ORDER THINKING AND DECISION-MAKING SKILLS

One of the reasons why video games are attractive to learners is the balance found in them. They are challenging enough to test several skills in the player, but they also have audiovisual tools that engage players and motivate them to continue throughout the game, testing different strategies and rationales (Hoffman & Nadelson, 2010). For instance, the game *Modeling in Chemistry: The Development of Atomic Theory*, which was actually designed and developed by a teacher, tests the knowledge of students in chemistry. In order to students to be successful at the game, they should not only master basic principles about the atomic theory, but they should also be able to infer, draw conclusions, and create a logical and sequenced logical mental models based on the knowledge acquired in the lessons (Annetta, 2008). On the other hand, the game NIU-Torcs, developed by Northern Illinois University, has been used to develop complex problem solving skills in mechanical engineering undergraduate students. Students find in games like this one scenarios that are even more challenging that the material covered in assignments and homework (Coller & Scott, 2009).

Researchers have studied that many of the higher-order thinking skills, such as decision-making, intertextuality, and problem solving, are not necessarily taking place in the classroom, but during the time students devote at home to play video games (Hommel, 2010). This occurs because many of the scenarios in which students could practice these skills are not possible to be replicated in the classroom; for this reason, video games offer students unique opportunities to use high-order and critical thinking skills that could not be practiced and tested otherwise. As a result, many instructors and teachers are using video games to allow students face certain challenges and scenarios that cannot be seen on a daily basis.

Video games develop high-order thinking and decision-making skills in learners because the games can be personalized to the needs and level of skills of each gamer. Instructors usually use this feature to present challenges to students that require them to think about problems and find a wide variety of solutions to them. Also, the presence of a challenge and the sense of achievement are linked to motivation. When a student is motivated, he or she uses more of these skills until finding a solution or achieving the specified goal (Hommel, 2010).

In some cases, instructors have taken further the benefits of video games and have engaged in participatory design with learners. Playing a video game makes students practice and develop high-order thinking skills, but being ask to modify existing items in a game take this skill to the next level. This type of strategy is known as game modification or modding (Moshirnia, 2007) and has become an elementary part of many participatory design projects. In other instances, teachers have substituted conventional assessments such as research papers and ask students to create their own games in order to teach the content of a lesson to other students (Annetta, 2008). This type of assessments does not only show that students are able to master the content of a lesson, but they also have enough background to challenge others and build problem-based projects to which they know the answer or solution.

It is relevant to point out that not only educational video games have found to be beneficial for players in terms of acquiring high-order thinking skills. Some studies have also pointed out that even playing mainstream, controversial, and popular games such as Super Mario and The Sims can be beneficial for players (Antonucci, 2005). It has been concluded that players of these popular and commercial games "...can handle more information, can synthesize more complex data, [and] solve operational design problems…"(Antonucci, 2005)

3.1.2   PERSISTENCE

Obstacles and challenges in video games, and any other instance, are overcome through persistence. Persistence is a skill that is developed and drastically tested in video games, especially at the highest levels of the games, since it can be very difficult to complete certain tasks and overcome some difficulties in a game (Hoffman & Nadelson, 2010). All video games are designed using different levels that gamers should master before moving to the next one. Rewards are often presented at the conclusion of each level as motivators and they are an indicator that gamers are ready to move forward in the game. However, as the gamer moves forward, persistence is sometimes the only skill that allows an individual to complete a task. In many games, it is not only a matter of mastering the content of the game or interacting with other participants, but of carefully planning and organizing. This is a fact in all video games; therefore, teachers who want to develop this skill in learners can use them. Persistence is also linked to achievement. As a gamer moves forward in the game and obtains rewards, this is a motivator for his or her persistence to continue. In addition, feedback from the game and the instructors develop the persistence of the gamer and give additional information that is useful to face new challenges in the game (Hoffman & Nadelson, 2010). Since engineering students are responsible for the completion of many projects, persistence is a skill that would help them succeed.

3.1.3   SOCIALIZATION

When video games were first developed, the level of interaction and collaboration was very limited. Players could spend hours by themselves going through the game without the assistance or collaboration of other players. In some cases, there was the possibility to add certain players into the game by plugging their controls to the console of the games, thus creating a more competitive environment. As social media evolved and the interconnection of gamers using the Internet became a reality, gamers started to practice social skills with more frequency. As a matter of fact, the success in certain games is highly related to the level of social interaction and collaboration among gamers (Weigel, Straughn & Gardner, 2013). When using video games, players are encouraged to use social skills in order to master and achieve goals in the game. Social collaboration is necessary in today's video games because they are an efficient way of sharing information, tips, and ideas. In many instances, teamwork is enforced in order to succeed in video games and it is a key aspect of success in video games. Finally, in many other instances, social relationships and friendships are developed after the interaction of players in these social platforms due to the high level of collaboration found in the games (Thirunarayanan & Vilchez, 2012).

Additionally, when playing video games, learners tend to have a better performance when becoming part of a larger group, as pointed out in a study that was aimed at evaluating the skills acquired by people who have participated in video games tournaments (Thirunarayanan & Vilchez, 2012). Players also develop a sense of satisfaction and community when they are part of the group and they get to share the outcomes of the efforts in these group projects (Hoffman & Nadelson, 2010). Even if participants do not find a video game project useful to them, they can still feel accomplished if they see the project is relevant to other people (Evans, Jones & Akalin, "in progress"). For this reason, video games are very useful to build collaboration and cooperation.

3.1.4 LEADERSHIP SKILLS

Teamwork and collaboration can be considered two of the strongest skills developed in video gamers. In terms of socialization, it has been also reported that video gamers develop strong leadership skills (Thirunarayanan & Vilchez, 2012). These leadership skills are developed because gamers understand how a whole system works and how different parts need to interact in order to achieve a particular goal. Having a strong understanding of how each step, milestone, or member of the video game contributes to the overall performance and allows a gamer to make more informed decisions and plan strategies to guide a team to success (de Freitas & Routledge, 2010).

3.1.5 SELF-CONFIDENCE

Video games require nowadays a lot of collaboration and teamwork, as previously stated. When teachers and instructors use video games in the classroom, members of a group benefit from all the variety of skills that each learner can bring to the game. As this collaboration progresses, each learner has the ability to be aware of the skills and knowledge that he or she is bringing to the group, thus building a strong sense of self-confidence (Moshirnia, 2007). One of the positive aspects of video games is that they offer something to everyone, regardless of the level or type of skill that he or she might have (De Grove, Bourgonjon, Van Looy, 2012). This is significant in the classroom because it means that any learner can develop self-confidence based on the skills already possessed.

On the other hand, video games provide feedback to learners about their actions. This type of feedback does not only offer an opportunity to point out areas for improvement, but it also focuses on the positive aspects of the performance of the player (Criswell, 2009). By being aware of the positive aspect of performance, learners build a sense of self-confidence about certain skills that can be transferred to other scenarios. For this reason, it is important for instructors to determine the set of skills that learners are going to be using during the game and they should not only let the game be the only source of feedback (Criswell, 2009). Feedback from instructors is also fundamental, especially when helping students be more confident. Another important source of feedback in games is observed through achievements in the game. As a gamer moves forward in the game and obtains rewards for doing so, there is an indication that he or she is doing the right things; therefore, a stronger sense of self-confidence would be developed (Hoffman & Nadelson, 2010).

Furthermore, feedback when playing a video game is extremely important because it gives a sense of accountability to the gamer. When a gamer receives feedback about his or her performance, he or she develops a sense of having power to change the situation of the game. This can have an impact on the self-confidence of the gamer because he or she would be able to link actions to outcomes (Hamalainen et al., 2006).

When using video games, instructors and teachers play an important role in building self-confidence in participants. Overall goals for a project should be determined ahead of time and students should be able to recognize if they have achieved these goals. In some studies, students are required to create video games and it is clearly stated that this is their overall goal. Once they achieve this objective, students feel successful because they know they have accomplished the goal (Evans, et al., "in progress").

3.1.6 AUTONOMY AND SELF-REGULATION

Video games are an excellent tool to foster collaboration and teamwork, with the additional benefit that they allow gamers to be accountable for their own performance and progress (Hoffman & Nadelson, 2010). Gamers always need to have some sort of strategic planning, organization, and sense of direction when playing. This skill

is enforced with the sense of choice in video games. Throughout the development of a video game, players face several choices and opportunities for decision-making. In many instances, the choices they make are based on personal information and strategy and the consequences of this game will bring consequences that are related to their own performance, even if they are in a group environment. Because of these facts, players develop a true sense of autonomy and self-regulation that is always present in video games, regardless of the topic or nature.

3.2 VIDEO GAMES AS CONSTRUCTIVIST INSTRUCTIONAL MATERIALS

Several of the KSAs found in this literature review are part of the learning conditions that should be promoted in constructivism. A constructivist environment is based on knowledge, rather than teaching (Paurelle, 2003), and this can be fostered through high-order thinking skills. In addition, social negotiation is an important aspect of constructivism (Driscoll, 2005). Learners in constructivist classrooms are required to use social skills to acquire knowledge from other peers. In video games, it is possible to practice these social skills. Also, one of the main points of constructivism is to develop a sense of autonomy and self-regulation (Sink, n.d.). Through the use of video games in the classrooms, learners are responsible for completing the tasks related to the game, to manage their time, and to make decisions on how to prepare them to face challenges. Teachers usually offer guidance, which gives more control to the student in the learning process.

Even though constructivism focuses more on the individual/learner than on the teacher or instructor (Sink, n.d.), there is still a role for the instructor, as a facilitator or guidance (Paurelle, 2003). In the case of video games, the instructor still has a role, since he or she will be deciding what type of video game should be played and how much time in class will be used for the game. In addition, the instructor would provide general instructions, guidelines, and assistance when needed. However, the actual gaming experience and the decisions made during the game will depend on the player.

Using Vygotsky's principle of *zone of proximal development*, which is the difference between what a student can do and cannot do with help of a more knowledgeable person (Driscoll, 2005), it is possible to see why video games fit into the description of constructivism. Students start with some guidance, and as they move forward in the game, the level of assistance or guidance can be drastically reduced. It is important to point out that in constructivism, the more knowledgeable person that assists in the *zone of proximal development* can be a human being or a machine (Jong et al., 2010). Many video games are designed and developed, in such a way, that feedback is simply guidance, but the most relevant decisions of the game depend on the gamer. The type of feedback and assistance offered through the game is a fundamental aspect of the learning process, according to constructivism (Jong et al., 2010).

4. SIGNIFICANCE AND CONCLUSIONS

One of the limitations when adopting video games in the classroom is the fact that teachers and instructors might not be completely confident about the benefits and real impact they can have on engineering students. There has been so many negative research studies conducted around video games that it has also significantly decreased the respectability they should have. In addition, there is the common misconception that only certain educational video games are relevant to the classroom and are useful for the learners. Since these learning video games can be more expensive than others, some instructors, teachers, and decision-makers could refrain from using them. The objective of this literature review was to point out that any video game could have a positive impact on the engineering classroom if they are properly implemented. The challenge for instructors is to identify the KSAs that they want their students to practice and improve, and based on that, they can make more informed decisions in the classroom. Regardless of all the negative aspects that have been linked to video games, they can still bring a positive experience and they can help students gained KSAs that could not be gained otherwise. Since engineering students need to develop several skills, beyond the theoretical knowledge offered in courses, video games are innovative tools to develop and practice them.

A study conducted by Northern Illinois University with undergraduate engineering students compared students who took a game-based course with students who took a more traditional course for mechanical engineering. The

study showed that students in the game-based course spend about twice the time students in the traditional course (Coller & Scott, 2009). This type of study clearly indicates that the level of engagement in students is important for their success and the time they spend studying and working on projects. The use of video games can definitely help undergraduate engineering students become better students and develop more skills.

As constructivism gains popularity in the classroom and it becomes relevant for engineering, video games can definitely be a tool to promote more profound knowledge in engineering students. Using the engagement that video games provoke in most learners can be a positive reason to help them be more self-regulated in the learning process. It would be positive for students to be more accountable for their learning experiences, but it is not an easy task when the instructor is fully responsible for the process. Video games are entertaining ways of giving responsibility and power of decision to learners, as constructivism suggests.

On the other hand, one of the major concerns of engineering is making effective connections with real-world scenarios (Kolodner, 2004), and video games provide an arena for learners to practice in simulated real-world scenarios. The knowledge students acquire from books and lessons can be, in many instances, transferred to the scenarios portrayed in video games. Many of the scenarios that engineering students explore in the classroom cannot be easily replicated, but video games give a creative alternative to imitate them. For this reason, as constructivism gains more relevance in engineering classrooms, it would be beneficial to find more and effective ways of incorporating any types of video games in the curricula of engineering courses.

Another of the limitations for video games and KSAs, as previously stated, is the lack of more studies that evaluate all video games as a instructional strategy that foster universal KSAs. In addition, the focus of the vast majority of research studies is educational video games; however, it is relevant to prove that any video game can be useful in the classroom if they are properly implemented. The development of studies that could assess the potential KSAs found in gamers of any type of video game could help teachers and instructors to make more informed decisions in the classrooms. It would also open the level of acceptance towards certain video games, technologies, and social media. As more studies reveal the benefits of emerging technologies and how much time learners spend using them (Hommel, 2010), they are going to be able to develop their skills to their fullest potential with the appropriate guidance of teachers and instructors.

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