THE EFFECTIVENESS OF COMPUTER-ASSISTED LEARNING, 3D SIMULATIONS, VIDEO GAMES, VIRTUAL REALITY, AND AUGMENTED REALITY TECHNOLOGY AS LEARNING TOOLS IN CONSTRUCTION EDUCATION

A Thesis

by

CRUZ MAX BUETTIKER

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Chair of Committee,	Edelmiro F. Escamilla
Committee Members,	Kevin T. Glowacki
	John M. Nichols
Head of Department,	Patrick Suermann

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ABSTRACT

Construction education, like many current educational programs, primarily relies upon teaching methods based on traditional lectures delivered “live” or “face-to-face” by a professor, who may also provide lists of notes about the subject taught. This traditional method, however, can be rather lackluster and unengaging, especially for contemporary students who are used to rapid visual stimulation such as that found on the internet, social media, and in gaming environments. While the construction industry is now adopting advanced virtual reality and augmented reality programs as tools for work, these same technologies have great potential as educational tools that can revolutionize learning methods. This study will analyze current literature about the use of video games in education, computer-based learning methods, and 3D simulations and virtual reality, and augmented reality in education. The objective of this paper is to answer the following questions. First, what is the mean distribution of using computer-assisted learning, 3D Simulations, virtual reality, video games, and augmented reality as educational learning tools have a statistically significant increase in the learning achievement of students? Second, what is the mean distribution of using computer-assisted learning, 3D Simulations, virtual reality, video games, and augmented reality as educational learning tools have a statistically significant increase of student’s attitude towards learning objectives?

CONTRIBUTORS AND FUNDING SOURCES

Contributors

This work was supervised by a thesis committee consisting of Professor Edelmiro F. Escamilla and John M. Nichols of the Department of Construction Science and Professor Kevin T. Glowacki of the Department of Architecture. All other work conducted for the thesis was completed by the student independently.

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1. INTRODUCTION

Construction education mirrors the industry as very traditional and unchanging. Teaching methods generally rely upon a structured lecture from the professor with supplemental notes. At the same time, students need to learn that construction is more than verbal descriptions or details on a two-dimensional drawing. Students may understand the process of construction, but lack the ability to apply, analyze, and evaluate general information efficiently when presented with only static visuals. These visuals are meant to aid in the 3D visualization process but may lack particular perspectives that contain information that could aid the student's ability to learn.

The integration of 3D simulations, virtual reality, augmented reality, video games, and computer-assisted learning as interactive tools with the expressed goal of aiding the process of learning complex concepts is the focus of this study. The meta-analysis of the current literature will analyze the comparative advantages and disadvantages of different 3D simulations, virtual reality, and video game learning methods that are currently employed. This study will analyze the literature to find the distribution statistically significant increases of students learning achievement as well as a statistically significant increase in student attitudes towards the learning systems. The integration of these systems into course learning materials may increase the effectiveness of educational courses to provide a higher quality of understanding of complex industry-related concepts.

1.1. Definitions

The four technologies that will be discussed are as follows, computer-assisted learning, video games, 3D Simulations and virtual reality, and augmented reality. Computer-assisted learning is the term used to encompass systems that use computers as a major learning tool. This can range from management learning systems to direct computer learning. Management learning systems are systems meant to act as a hub for students and instructors to communicate, submit assignments and other course related materials. Direct computer learning is using a computer or other computing device to learn or have a lecture. These two definitions be applied to other technologies, but for the purposes of this paper we will stay with referencing this subject as computer-assisted learning. Video games are defined as programs that involve interaction with a user interface to generate visual feedback on a two- or three-dimensional video display device. These can range from their phones and handheld devices to dedicated consoles and computers. Three-Dimensional Simulations (3D simulations) will be defined as the examination of a problem often not subject to direct experimentation using a simulating device. Virtual Reality will be defined as an artificial environment which is experienced through sensory stimuli (such as sights and sounds) in which one's physical actions partially determine what happens in the environment. Both 3D simulations and virtual reality are very similar and will be used together if not simply as virtual reality. In this study, augmented reality, as defined by Merriam Webster, is the enhanced version of reality created by the use of technology to overlay digital information on an image of something viewed through a device. Augmented reality brings the virtual world into our perception of the physical real world.

2. RESEARCH BACKGROUND

2.1. Introduction

This literature review considers the use of new and available technology to aid students in the learning process. The following sections are included in this literature review:

- Computer-Assisted Learning Management Systems in STEM and Construction Education
- Video Games in STEM and Construction Education
- Virtual Reality and 3D Simulations in STEM and Construction Education
- Augmented Reality in STEM and Construction Education

2.2. Computer-Assisted Learning Management in STEM and Construction Education

Computers are a primary tool in the modern world for work and recreation. It has become a significant source of media and information consumption. It is a possibility to apply this to the academic sphere with the increasing feasibility to rapidly communicate with greater efficiency. Computer-assisted learning can be defined in many ways, but this study will adhere to the definition that computer-assisted learning is the integration of personal computing devices (laptops, phones, home computers) into the class via an interconnected virtual environment containing materials relevant to the class, and avenues of communication between students and teachers as well as between students themselves.

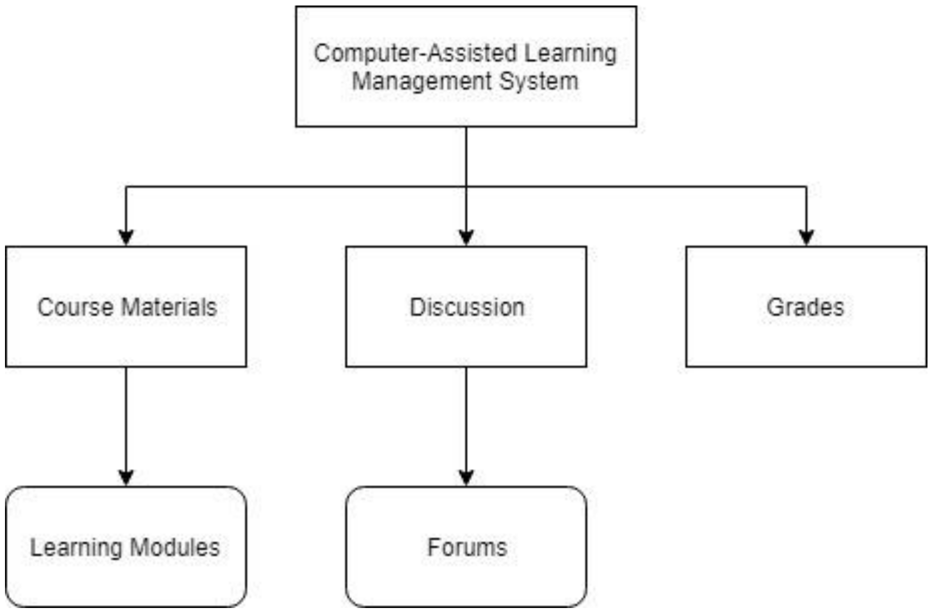

Figure 2.1, Computer-Assisted Learning Management System.

Computer-assisted learning is a learning method that can be adopted into differing variation’s but remains relatively simple in application.

Communication is a significant component of the learning process. As stated before, computer-assisted learning can be a supplementary system of communication between two or more parties simultaneous without the need for physical engagement. A study conducted by Ali AbuSeileek at the Al al-Bayt University used a computer system to facilitate the web-based course, (AbuSeileek, 2011). The study “… examined the effects of disclosing/blinding the participants’ identities while interacting around computers on their post-test,” (AbuSeileek, 2011). The findings of the study revealed that the computer-based environment enabled the participants to blind their identities and reduce their anxiety from the face-to-face debate, and so was very helpful in developing their communication skills,” (AbuSeileek, 2011). The element of anonymity, or reduction of face-to-face interaction, seems to lower the anxiety of social pressure from perceived weaknesses among students and their peers. Using similar computer-assisted learning methods increase the attitude and achievement of students post use of computer-assisted learning (Pilli, & Aksu, 2013). Student attitude towards their learning environment and materials can affect the outcome of the learning objective. Communication of the objectives and ability to communicate questions and queries to not only teachers but students in a more accessible manner appears to help achieve higher outcomes.

Figure 2.2, Computer Assisted Learning. From yay-1829971-digital(1), https://www.proprofs.com/c/lms/computer-assisted-training-what-is-it/. Copyright 2005 - 2019 ProProfs.[1]

[1] *Reprinted from yay-1829971-digital(1). [digital image]. Retrieved from https://www.proprofs.com/c/lms/computer-assisted-training-what-is-it/.

Another form of computer-assisted learning focuses on the use of supplementary materials. The Institute for Geographical Sciences and Natural Resource Research in Qinghai, China conducted a study to measure the outcome of student's performance for using a computer-assistance system composed of instructional and training videos and games. By having students use the system for forty minutes twice a week, they found that students who used computer-assisted learning had improved scores than control groups (Lai et al., 2015). A similar study was conducted by the National Taipei University of Education which found that students who used the computer-assisted learning system had improved scores than control groups (Huang, Liu, & Chang, 2012). A supplementary computer-assisted learning system is not only lecturing materials but tutoring resources as well. A study conducted by the School of Pharmacy and Chemistry at Liverpool John Moores University used an MS Office application for pharmaceutical students. The application enables tutors to synthesize and email feedback reports to students readily. The results of which showed that students and faculty found the revisions and annotations to be quicker to easier to discern and correct as well as mark reduce the timing of feedback (Denton, Madden, & Rowe, 2008). Computer-assisted learning systems vary according to the measurable outcome. The ease of flow between the students and instructors to facilitate supplementary materials or software is a factor for success. Long-term use of these learning systems has not been studied in detail for the viability of the cost-effectiveness of computer-assisted learning.

The literature contained a few studies that were concerned with the prolonged effects of different types of computer-assisted programs. At the Kings College of

London, they studied the long-term effects of computer-assisted learning as compared to traditional lecturing over five months. Knowledge and Skills scores were found to be similar for both groups leading the study to conclude that computer-assisted learning can match traditional lectures (Bloomfield, Roberts, & While, 2010). The study completed by Kings College lacks evidence of more considerable improvement with computer-assisted learning than with traditional methods. Researchers at BioMed Central discovered in their study that short term knowledge retention was sizeable positive, but after a long-term (5 months) results showed little positive effect (Rondon, Fernanda, & Furquim de Andrade, 2013). To conclude Rondon's findings, computer-assisted learning was beneficial for short term learning but found that traditional methods showed a more significant effect when it came to long-term knowledge retention. At the University of Mercia, they conducted a study using a computer-assisted learning system to facilitate a competitive eLearning environment comparing the acquisition and retention of knowledge with the eLearning system versus traditional methods (Aleman, de Gea, & Mondéjar, 2010). The study resulted in immediate improvement with the experimental group compared to the control group, but after 10-weeks the results showed similar testing and knowledge retention (Aleman, de Gea, & Mondéjar, 2010). Computer-assisted programs show promise of improvements in a particular aspect of the learning process, but it appears to have little improvement when it comes to long-term knowledge retention. The literature for computer-assisted learning systems is vague in its specific definition of what parts of the learning process are being affected. Mixed results from different studies within the literature question its viability as a suitable supplementary learning tool.

2.3. Video Games in STEM and Construction Education

Video games are a spectrum of entertainment that has become widely accessible and versatile. It is a spectrum of entertainment that has limitless applications for storytelling, interactivity, and functionality.

Figure 2.3, Video Games. From gaming-2259191_960_720-e1500464125220 300x172, https://your4ktvguide.com/are-4k-tvs-really-worth-it-9-advantages-of-smart-tvs-you-had-no-idea-about/gaming-2259191_960_720/. Copyright 2019 Your 4K TV Guide.[2]

[2] Reprinted from *gaming-2259191_960_720-e1500464125220 300x172*. [digital image]. Retrieved from https://your4ktvguide.com/are-4k-tvs-really-worth-it-9-advantages-of-smart-tvs-you-had no-idea-about/gaming-2259191_960_720/.

Video games are defined as programs that involve interaction with a user interface to generate visual feedback on a two- or three-dimensional video display device. These can range from their phones and handheld devices to dedicated consoles and computers. Video games are very interactive with the user's input to the central aspect. Researchers from the Department of Civil Engineering of the Faculty of Engineering of the University of Porto designed a study aimed towards using video gaming concepts as educational tools (Dinis, Guimarães, Carvalho, & Poças, 2017). The researchers created virtual models and integrated them into games focused around civil engineering principals. Researchers tested students with the virtual reality game and surveyed them about how different vital parts of the game were. Students surveyed, viewed the significance of the game set to aid the educational process as crucial in efficiently teaching them the concepts of Civil Engineering (Dinis, F. M., Guimarães, Carvalho, & Poças, 2017). Using video games can also streamline the assessment of student by "enabling customization of tests based on students' performance, allowing real-time bidirectional communication between the instructor and students in classrooms, and adopting novel approaches for assessment" (Bellotti, Kapralos, Lee, Moreno-Ger, & Berta, 2013). Streamlining the process of assessing students and being able to customize to each student is a step forward in integrating video games into education. Another form of video game integration is the addition of agency in solving problems. "… being positioned as an individual with an authoritative role, having agency in choosing what actions to take, and having consequential actions that affect the unfolding situation," (Barab et al.,2009). Having students interact and see the consequences of their decisions allows them to apply and evaluate what they are learning.

In learning environments, communication of ideas and concepts between students helps shore up any that may have difficulties with certain concepts that are taught. This forum of ideas and tutoring can be enhanced with creative spaces that can increase the connectivity of students. David Squires proposed this connectivity via users iOS systems as the notion of a Tangible Interface Metaphor. “The notion of a ‘Tangible Interface Metaphor’ is one of the essential ways to improve online learning. By hosting augmented overlays and three-dimensional content onto learning management platforms and online hosting sites, users anywhere in the world can create and share their own digital tags and ideas” (Squires, 2017). This concept replicates massive online multiplayer games by providing a virtual forum for discussion and interactivity that can be used to represent abstract concepts from modules. A similar gaming environment specified for collaboration is the “Mindtool-integrated collaborative educational game.” This system promotes students learning attitudes and motivation as well as improving the organization of knowledge in a cooperative public space (Sung & Wang, 2012). According to a meta-analysis conducted by the University of Lyon, the engagement and motivation of players of serious games cannot be generalized due to the variation of content from educational video games used in previous studies (Girard, Ecalle, & Magnant, 2012). However, studies that have found that students are more motivated to learn and engage when using video games as compared to using traditional methods pencil-and-paper study or face-to-face lecture. “However, previous studies seem to confirm that subjects find games more motivating and engaging than traditional methods such as pencil-and-paper study or face-to-face teaching" (Girard, Ecalle, & Magnant, 2012). Video games are naturally fascinating and stimulating.

An essential aspect of video games is the internal design. A decent video game requires reliable basic controls and concepts that are easy to grasp before the introduction of more complex concepts. According to a study from the University of Genoa, it is an essential aspect of the cycle from research and development to consider all stakeholders that are necessary to develop and deploy effective learning tools (Gloria, Belloti, & Berta, 2014). Stakeholders' references the students, instructors, and game developers who's input about the creation, development, and deployment of effective learning tools. At the University of Thessaly, they used a video game to aid students with learning computer science. "The results suggest that within high school CS, educational computer games can be exploited as effective and motivational learning environments, regardless of students' gender," (Papastergiou, 2008). Matching the design of the video game to the learning environment is vital for completing the objective of improving the learning outcome of students. In the International Journal of Construction Management, a study was conducted using conceptual mapping that led students through the different phases of a construction project (Shanbari, & Issa, 2019). Providing students agency for decision making appears to be the direction many studies using augmented reality take.

Evaluating student's improvement in abilities is the main objective of using video games as an alternative or additional learning tool. At Dr. Lee at the National

Taiwan Normal University performed a study measuring students' ability to perform non-routine mathematical problem solving comparing two groups, those with high prior knowledge and those with little prior knowledge (Lee, & Chen, 2009). Students that had high prior-knowledge had higher performance increases than those that little prior-knowledge (Lee, & Chen, 2009). A similar study conducted by the National Taiwan University of Science and Technology Compared the use of concept mapping to determine improvements between the control group and the experimental group (Hwang, Wang, & Yang, 2013). Hwang and his team found that there was a statistically significant improvement ($F = 5.89$, $p < .05$) after the posttest (Hwang, Wang, & Yang, 2013). Another study conducted a year earlier Dr. Sung, and Dr. Hwang found that collaborative learning environments yield statistically significant improvements after use of the video systems ($F = 11.795$, $p < .001$) after posttest results (Sung & Hwang, 2012). A study conducted jointly by Walden University and the University of Central Florida used video games to test the learning improvement in the mathematics of students. The study found that using a video game to visually practice mathematics after experimentation had statistically significant improvements, ($F(2, 186) = 6.48$, $p < .001$) compared to the control group (Kebritchi, Hirumi, & Bai, 2010). The literature shows a statistically significant improvement in students' abilities with the use of interactive, cooperative learning environments.

2.4. Virtual Reality & 3D Simulations in Construction and STEM Education

The technology that allows our society to create detailed 3D simulations and environments in virtual reality is an achievement of the modern technological revolution.

3D simulations and virtual reality are often used interchangeably and are very similar. For this study, the literature defines 3D simulations as the examination of a problem often not subject to direct experimentation using a simulating device. Virtual Reality will be defined as an artificial environment which is experienced through sensory stimuli (such as sights and sounds) in which one's physical actions partially determine what happens in the environment.

Figure 2.4, Virtual Reality. From *25601-posts.article_lg*, https://www.shortlist.com/news/this-is the-year-virtual-reality-changes everything. Copyright 2019 The Stylist Group.[3]

These technological systems have expanded in the spectrum of entertainment to encompass differing degrees immersing the user in the artificial environment. It may have great potential as educational tools that can revolutionize both teaching and learning.

[3] 25601-posts.article_lg. [digital image]. Retrieved from https://www.shortlist. com/news/this-is the-year-virtual-reality-changes everything.

Although 3D visualizations have great potential for use in education, appropriate software seems to be lacking in educational use, most likely due to the lack of personnel trained with it (Sacks & Barak, 2009). 3D modeling software, sometimes combined with scanning technology, has the potential to create interactive learning environments that static 2D drawings cannot replicate. Construction education has traditionally relied upon the use of 2D drawings (such as plans, sections, elevations), but these may leave a gap in the ability to visualize abstract representations. The adoption of effective teaching and learning methods that can help students apply, analyze, and evaluate should be one of the primary concerns of programs focused on construction education. For example, in a study conducted at Pennsylvania State University, researchers used 4D CAD to analyze the designs of buildings and other projects (Messner, Yerrapathruni, Baratta, & Whisker, 2003). They measured students' ability to find conflicts in the designs, as summarized in Table 2.1.

	From CPM Schedule		**After Completing 3D Model**	
	110-160 (Steel/Slab)	**220 (Wall/Windows)**	**110-160 (Steel/Slab)**	**220 (Wall/Windows)**
# of Student that Identified Conflict	**13**	**7**	**21**	**23**
% of Student that Identified Conflict	**52%**	**28%**	**84%**	**92%**

Table 2.1, Results of 4D CAD Student Experiment at Pennsylvania State University (After Messner, Yerrapathruni, Baratta, & Whisker, 2003, p. 5, table 1).[4]

[4] Messner, J. I., Yerrapathruni, S. C. M., Baratta, A. J., & Whisker, V. E., (2003). "Using Virtual Reality to Improve Construction Engineering Education." Proceedings of the 2003 American Society for Engineering Education Annual Conference & Exposition, Vol. 1121, 1-10.

The findings by the Pennsylvania State University team show that 3D modeling software provides a substantial increase to educational quality and experience. Table 2.1 illustrates the effectiveness of modular 3D models that students can manipulate to see different perspectives as compared to original schedule drawings (Messner, Yerrapathruni, Baratta, & Whisker, 2003). Another experiment in the same paper used virtual reality to see if it is a viable tool for education. The authors concluded:

> "A second experiment was performed to determine the value of using advanced visualization techniques to improve the ability of students to analyze and generate a 4D model. To perform this experiment, a 3D model for a nuclear power plant project, the Westinghouse AP1000 nuclear plant, was placed into the CAVE-like immersive projection display…[Student'] rated the development of the schedule within the environment a 9 out of 10 in ease of use. One of the students who has project engineering experience noted on their survey form that the IPD was extremely helpful in gaining a clear understanding of the project in much less time than blueprints or even 3D models… The results of this experiment suggest that students can quickly understand complex virtual building models and gain experience from planning the construction of these virtual projects. Students are engaged by working in the immersive environment where they can learn and, due to the rich visual environment, develop a detailed understanding of complex design and construction decision processes," (Messner, Yerrapathruni, Baratta, & Whisker, 2003).

While virtual reality been shown to increase focus and interest of students, it requires more significant investment in time and equipment than traditional methods. VR technology has advanced and continues to advance with 3D modeling systems. These systems allow for the visual representation of what is lectured about in class. Architecture, engineering, and construction students differ in their disciplines and educational goals. For example, researchers at the Department of Civil Engineering and Architecture at the Technical University of Lisbon created a learning model that is a prime demonstration of how to facilitate a productive learning environment that uses interactive modules with integrated virtual reality.

> "The virtual model allows students to learn about construction planning concerned to this specific situation. This model is oriented to support teaching construction techniques by means of virtual environments. This model is now shown in classes and it contributes to a better understanding of disciplines concerning Civil Engineering. Another objective in creating this kind of virtual applications is to show in which way new technologies afford fresh perspectives for the development of new tools in the training of construction processes. Visual interaction can do some changes in the way engineering education is performed, both in learning new materials and in terms of explaining construction activities," (Sampaio, Ferreira, Rosário, Martins, & Octávio, 2010).

These simulations are meant to replicate environments found in the industry, but in a general setting that duplicates it to complete detail available. Their goal of using a 3D virtual environment was to provide an in-depth visual representation to enhance the construction safety education and training processes. "Medium and/or high-fidelity simulation using manikins is an effective teaching and learning method," (Cant & Cooper, 2010). Simulations can be advantages to over other learning methods depending on the context and subject of the topics that taught. The interactive aspect of virtual environments allows the experimentation and application of the training from a more personal view that is second only to real applications.

> "However, according to Le and Park [7], most existing virtual systems still had the following limitations: 1) they are offline without the cooperation of educators; 2) traditional construction education approaches of lectures, seminars, and team work have not really taken advantage of the virtual simulation; 3) the inter- action level between users in virtual safety game is still low; 4) the limitation of spaces and students in some virtual room education," (Le, Quang T., Pedro, A, Park, C., 2014).

Such physical demonstrations and applications are time-consuming and costly. When compared to virtual environments that require specific systems and media to be created, physical environments require the procurement of actual materials needed for education and training.

> "The preliminary results indicate that the interviewees agreed that the social VR system–based construction safety has great potentials to enhance experiential learning. However, the educators and construction experts also expressed that the time- consuming game scenario creation and animation problems should be considered. Furthermore, the strongly recommended further studies considering the application of social VR on the construction site as safety training tool. For future work, the comparison between a social VR-based construction safety education method and traditional class room-based lecture will be executed via cognitive workload measurement by using mathematical tools," (Le, Quang T., Pedro, A, Park, C., 2014).

Future generations will be accustomed to entertainment in short continuous bursts, and education must adapt, or it will risk falling in quality and effectiveness to educate. Virtual reality simulation-based education is better for increasing learning performance at the individual level (Merchant et al., 2014). The means and methods for using 3D scanning technology lack the efficiency required by contractors to make the investment profitable. The extra human effort required to build these 3D models accurately is absent from economic incentive (Sacks, Eastman, & Lee, 2004). 3D scanning technology is a feasible method of capturing on-site industry data to create interactive modules for learning environments but has problems of accessibility to data for that. Another method is similar to video games and other 3D entertainment with virtual objects created by designers and artist, but this method creates inaccurate environments. A combination of both real-world data and virtual objects that match the scale of reality is a proposed idea for future use.

2.5. Augmented Reality in Construction and STEM Education

The literature is growing with studies about integrating and using augmented reality in education as learning tools. In this study, augmented reality, as defined by Merriam Webster, is the enhanced version of reality created by the use of technology to overlay digital information on an image of something viewed through a device.

Figure 2.5, Augmented Reality. From *Virtualvalidation*, http://thrustenterprise.com/VirtualValidation.html. Copyright 2018 MIT.[5]

Augmented reality brings the virtual world into our perception of the physical realm. Depending on the interactive and cooperative components, augmented reality learning systems can differ in practice. Either being used as a singular learning system or in conjunction with traditional methods.

At the National Taiwan University of Science and Technology, students in a physics course were subject to the integration of augmented reality as a learning tool.

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[5] Virtualvalidation. [digital image]. Retrieved from http://thrustenterprise.com/VirtualValidation.html.

There were two groups, the control group, and the experimental group. The experimental group used cooperative and interactive learning that allowed the students' the ability to manipulate virtual objects (Lin et al., 2013). The posttest showed that "the participants had significantly better learning achievements," (Lin et al., 2013). The augmented reality system was able to increase students' scores in a constructive manner. The study continues to suggest that,

"Since this study was an initial step toward understanding learners' knowledge construction processes by using the AR system, future researchers are encouraged to adopt different angles or frameworks to unravel a more holistic outlook on learners' knowledge construction processes in the context of mobile AR collaborative learning," (Lin et al, 2013).

A more in-depth study on the fundamentals of the learning process and how augmented reality affects students is the next step. At the University of La Laguna, engineering students were subjected to the integration of augmented reality tools used for aiding in the programs engineering laboratories (Martín-Gutiérrez et al., 2015). Students were surveyed about their attitudes using the augmented reality system. Researchers found mean usability of 80% for students that used the application (Martín-Gutiérrez et al, 2015). "The tools developed in this work have achieved a dual effect as they allow the teacher to improve guidance at the training sessions within the practice laboratory, and to offer attractive and motivational tools to the student during the learning process of contents," (Martín-Gutiérrez et al., 2015). The learning systems seemed to ease the strain of instructors while also motivating students. Augmented reality is best with mobile devices as for their lightweight and constant connectivity. They are using this as the medium for the augmented reality learning system, the National Central University of Taiwan. The study found that the learning achievement of the experimental group was statistically significant after using the innovative learning system (Chiang, Wang, & Hwang, 2014). The study concluded that “the mobile AR approach is helpful to the students in improving their inquiry-based learning achievements,” (Chiang, Wang, & Hwang, 2014). Another innovative way augmented reality has been used as a learning tool was, through a cooperative study between the University of Central Florida and the University of Michigan, “…an innovative pedagogical tool that uses remote videotaping, augmented reality (AR), and ultra-wide band (UWB) [location] to bring live videos of remote construction jobsites to the classroom,” (Bezhadan, & Kamat, 2012). An interesting take for using the technology available. For future development of augmented reality being used as a learning tool Dr. Behzadan and Dr. Kamat recommend “using existing Wi-Fi access points in the classrooms or Bluetooth-enabled mobile cellphones as a replacement for relatively expensive equipment necessary to build a network of data receivers around the projection screen,” (Bezhadan, & Kamat, 2012). Using mobile devices for augmented reality learning is the next step for research. Augmented reality is a fantastic technology that shows promise with the modern student. Using student mobile devices lowers the physical cost for not only research but the development of augmented reality learning systems.

3. METHODOLOGY

3.1. Introduction

This chapter outlines the methodology to analyze the literature that has been available within the last ten years. The studies that meet the requirements will be analyzed to find the rate of reported statistically significant increases in student learning achievement and reported statistically significant increases in student attitudes and behavior.

3.2. Hypothesis

Technology is ever present in every facet of modern life. 3D virtual simulations are now a constant entertainment platform that stimulates the masses. By doing a meta-analysis of current literature, analyzing how learning methods using computer-assisted learning, 3D Simulations, virtual reality, video games, and augmented reality as educational learning tools can be appropriately integrated into current teaching methods efficiently and cost-effectively in ways that will aid students' abilities to apply, analyze, and evaluate complex concepts in construction. These fundamentals of learning have not been studied in detail using these virtual learning systems. This study hypothesizes that using computer-assisted learning, 3D Simulations and virtual reality, video games, and augmented reality as educational learning tools increase the learning achievement and student attitudes towards learning objectives and technology. Do these learning systems show a statistical increase in learning achievement and student attitudes at a rate that is as super majority?

3.3. Problem Statement

Current technology has brought vast amounts of data together that are accessible with an internet connection. However, if this technology can transfer and share knowledge more efficiently, why do we still teach students the same way as we did 50 years ago? This paper will focus on answering a couple of questions. Does using computer-assisted learning, 3D Simulations and virtual reality, video games, and augmented reality as educational learning tools increase the learning achievement and attitudes of students? Does it increase the attitude of students towards learning objectives? These learning systems must show that they are more effective than traditional learning methods.

3.4. Methodology

To achieve our goal, we will focus on the meta-analysis of the current literature relating to STEM and construction education. From the literature, studies have been gathered from the latest in 2008. The study will analyze all papers from the different technology subjects and analyze the literature gathered to find the rate of reported statistically significant increases in student learning achievement. The same will be done for finding the rate of reported statistically significant increases in student attitudes towards learning objectives and technology. This will be done for computer-assisted learning, 3D Simulations and virtual reality, video games, and augmented reality aggregated together. Then we will measure it for each learning system. We will compare our findings accordingly.

4. RESEARCH RESULTS AND DISCUSSION

4.1. Introduction

This chapter outlines the results of the studies analyzed in the meta-analysis to find the rate of reported statistically significant increases in student learning achievement and reported statistically significant increases in student attitudes and behavior.

4.2. Research Results for Learning Achievement

The analysis of the literature yielded 52 studies for computer-assisted learning, video games, 3D simulations, and virtual reality, and augmented reality learning systems used for in construction and STEM education.

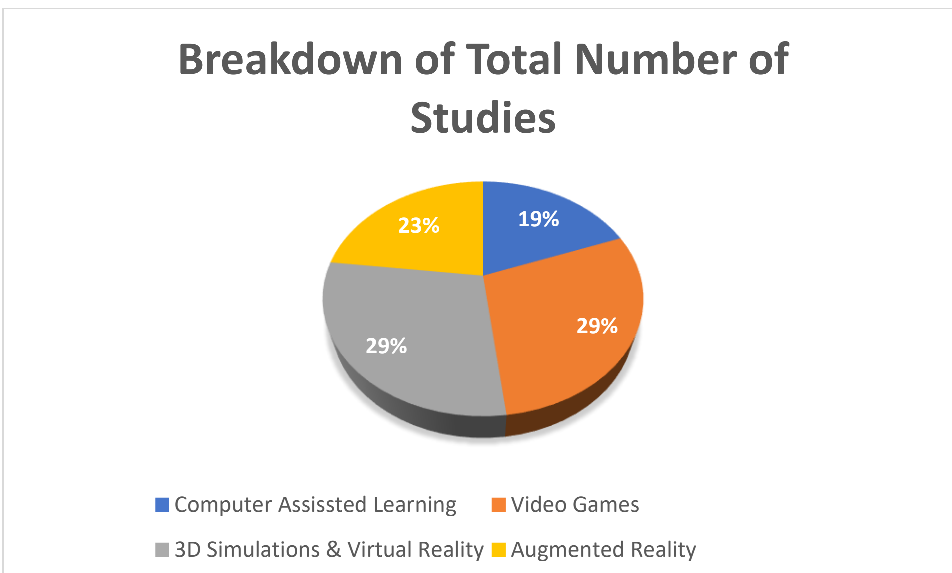

Figure. 4.1, Breakdown of Total Number of Studies

When it came to learning achievement computer-assisted learning had 10 studies, video games had 15 studies, 3D simulations and virtual reality had 15 studies, and augmented reality had 12 studies. The analysis of computer-assisted learning studies found that 80 percent of the studies found statistically significant increases in student learning achievement. The 15 video games studies that were analyzed found that 80 percent of studies reported statistically significant increases in student learning achievement. The 3D simulation and virtual reality studies that were analyzed showed that 80 percent of the 15 studies reported statistically significant increases in student learning achievement. The augmented reality studies that were analyzed showed that 67 percent of the 12 studies reported statistically significant increases in student learning achievement. The average of the 52 studies that reported statistically significant increases in student learning achievement is at 77 percent.

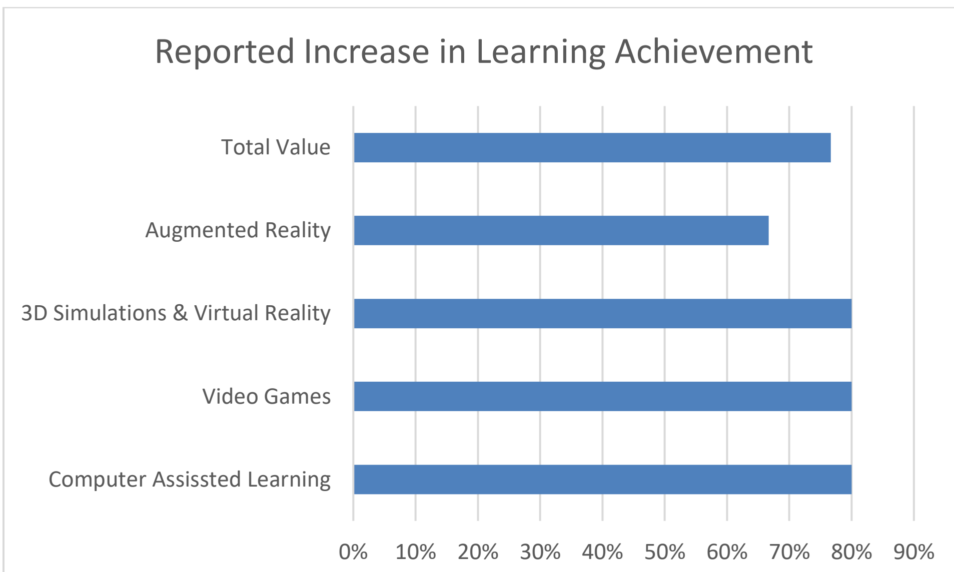

Figure. 4.2, Reported Increase in Learning Achievement

The studies analyzed reported that experimental groups had increased scores in their subject of study. The types of variations between each study have mixed results. Not one version of any learning technology was adversely not successful.

The analysis of the literature found that computer-assisted learning, video games, 3D simulations, and virtual reality showed a 77 percent average of studies reported statistically significant increases in student learning achievement. This proves the hypothesis true for a super majority reported rate of significant increases in student learning achievement. Augmented reality is the only form of learning technology that is lower and sitting at 67 percent. These findings are fascinating as it was not expected for the augmented reality learning systems to report at lower rates of statistically significant increases in student learning achievement. Augmented reality did show the ability for adaptability when it came to integration, but it is still a significant outcome.

4.3. Research Results for Student Attitude

The analysis of the literature yielded 52 studies for computer-assisted learning, video games, 3D simulations, and virtual reality, and augmented reality learning systems used for in construction and STEM education. When it came to student attitudes towards learning objectives and technology computer-assisted learning had 10 studies, video games had 15 studies, 3D simulations and virtual reality had 15 studies, and augmented reality had 12 studies. The analysis of computer-assisted learning studies found that 30 percent of the studies found statistically significant increases in student attitudes towards learning objectives and technology. The 15 video games studies that were analyzed found that 53 percent of studies reported statistically significant increases in student attitudes towards learning objectives and technology. The 3D simulation and virtual reality studies that were analyzed showed that 60 percent of the 15 studies reported statistically significant increases in student attitudes towards learning objectives and technology. The augmented reality studies that were analyzed showed that 58 percent of the 12 studies reported statistically significant increases in student attitudes towards learning objectives and technology. The average of the 52 studies that reported statistically significant increases in student attitudes towards learning objectives and technology is at 52 percent. This proves the hypothesis false for a super majority reported rate of significant increases in student attitudes.

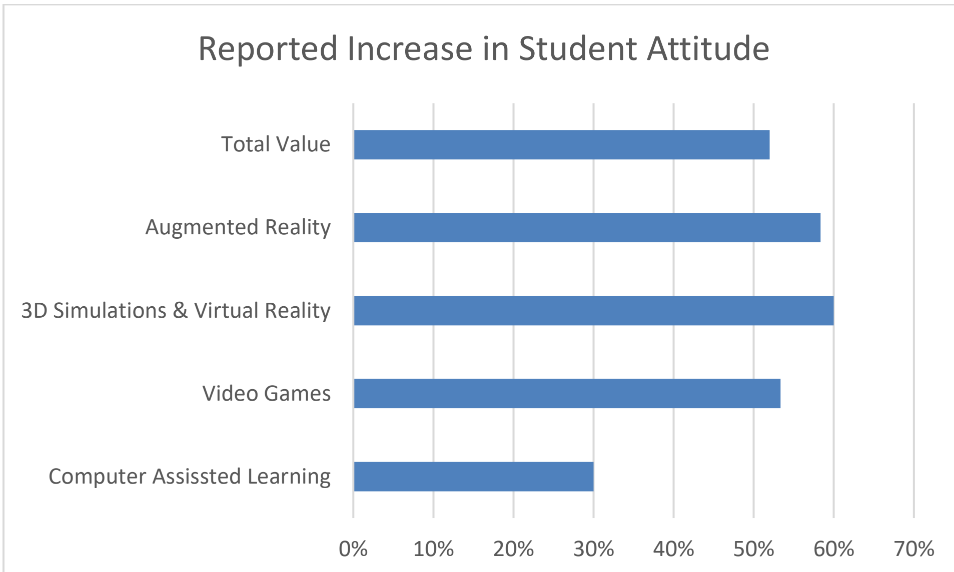

Figure. 4.3, Reported Increase in Student Attitude

The studies analyzed reported that experimental groups had better attitudes towards the technology used or their learning objectives in their subject of study. The types of variations between each study have mixed results. Not one version of any learning technology was adversely not successful.

The analysis of the literature found that video games, 3D simulations, and virtual reality showed a 52 percent average of studies reported statistically significant increases in student attitudes towards learning objectives and technology. Computer-assisted learning studies reported 80 percent average of statistically significant increases in student learning achievement, but report the lowest student attitude increase sitting at 30 percent. That is an exciting outcome to have found from the analysis.

5. CONCLUSION

5.1. Conclusion and Recommendation

The goal of the meta-analysis was to discover the rate of the statistical significance that using computer-assisted learning, 3D Simulations, virtual reality, video games, and augmented reality as educational learning tools increase the learning achievement and student attitudes towards learning objectives and technology. Research in this area is broad with studies using these systems in varied ways for different subjects. Studies sometimes display information on what they used, but not any information about learning achievement or student attitudes towards it. It made it difficult to find studies for the analysis. According to the results, studies that used 3D simulations and virtual reality systems had the best rates of reporting statistically significant increases in both student achievement and student attitudes at 77% and 52% respectively.

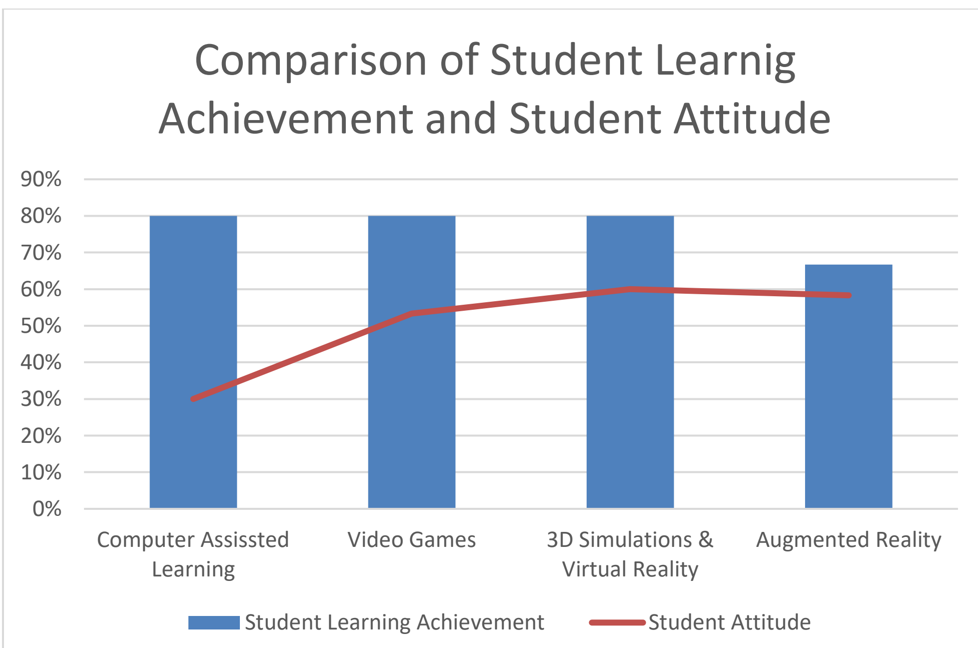

Figure. 5.1, Comparison of Student Learning Achievement and Student Attitude

It would be wise to objectively choose virtual reality as the central system for integrating into the students learning environment, but even the success it has shown is best for training in specialized subjects such as equipment or safety training. It is also quite the cumbersome system when attempted to use en masse. Short group training is best for virtual reality. The costs of these learning systems have many variables. They require hardware and software; the software needs to be developed; the hardware needs to be manufactured cheaply. These two overall factors affect the costs of integrating these technologies into the learning environment.

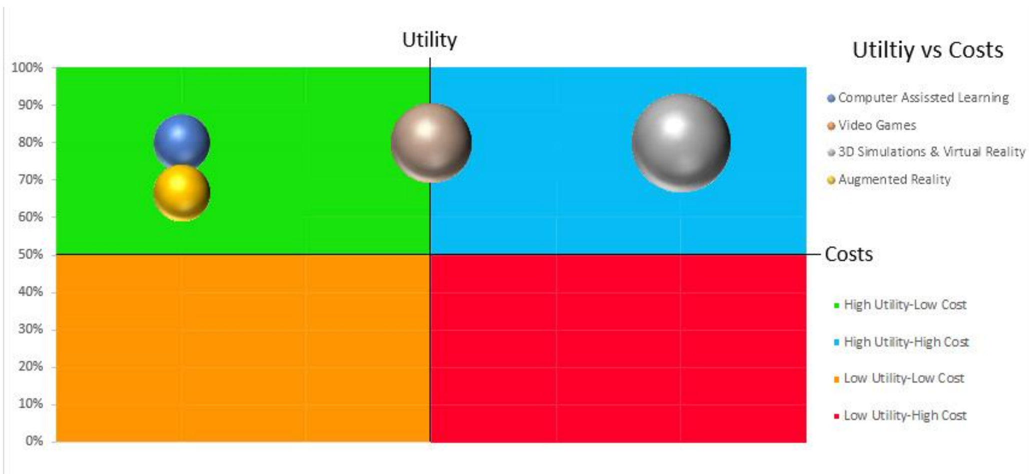

Figure 5.2, Utility vs. Costs

Comparing the cost-effectiveness of each learning system shows where each system is. Augmented reality and computer-assisted learning systems are both lower costs and high utility (student learning achievement). It is highly recommended that if integrating these technologies into the learning environment is the goal, mixing the computer-assisted learning management systems, and augmented reality into a single standardized virtual learning system can be very cost-effective.

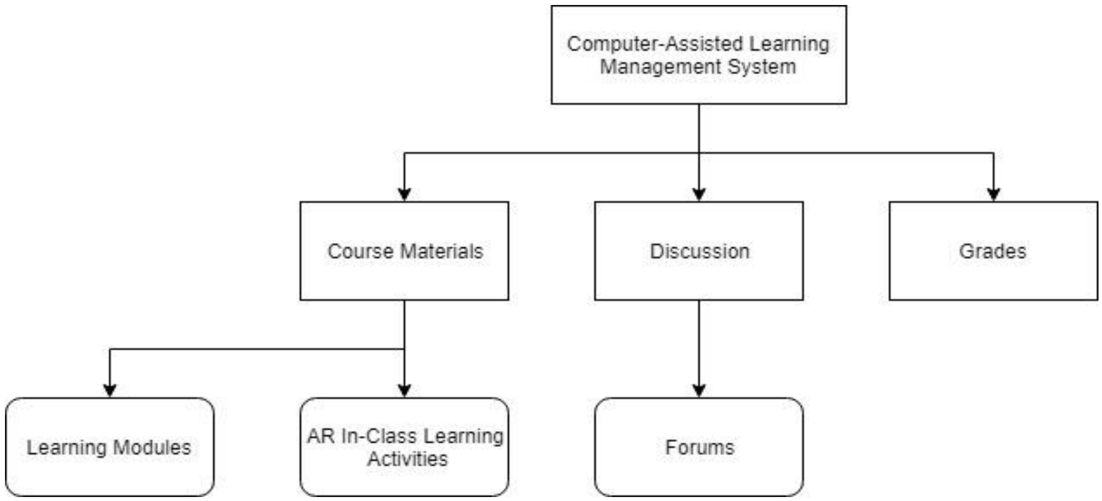

Figure 5.3, Computer-Assisted Learning Management System with Augmented Reality

Computer-assisted learning management systems should be the center of communication and information for the learning system. Video games are more interactive and can be mixed into augmented reality environments, but must follow a design where choices by the student affect the outcome of the exercise. It is recommended that further research in these areas should go farther when it comes to learning about what parts of these learning systems affect the students. Prospective future studies should focus on how these educational learning tools can be appropriately integrated into current teaching methods efficiently and cost-effectively. To look at how it will aid students' abilities to apply, analyze, and evaluate complex concepts in construction and STEM education. It would also be fruitful to record the retention of students during courses using these technologies as compared to traditional methods. Do these learning systems, when integrated, increase student retention or do they still suffer similar attrition? These learning systems have shown that they can have significant increases in student abilities roughly 80 percent of the time, as well as increasing student attitudes around 50 percent. We have to look forward to what makes students better, and how it affects them.

REFERENCES

25601-posts.article_lg. [digital image]. Retrieved from https://www.shortlist.com/news/this-is the-year-virtual-reality-changes everything.

AbuSeileek, Ali Farhan. (2012). "The Effect of Computer-Assisted Cooperative Learning Methods and Group Size on the EFL Learners' Achievement in Communication Skills." *Computers & Education,* Vol. 58.1, 231–239.

Akçayır, M., & Akçayır, G. (2017). "Advantages and Challenges Associated with Augmented Reality for Education: A Systematic Review of the Literature." *Educational Research Review*, 20, 1-11.

Aleman, J. L. F., de Gea, J. M. C., & Mondéjar, J. J. R. (2010). "Effects of Competitive Computer-Assisted Learning Versus Conventional Teaching Methods on the Acquisition and Retention of Knowledge in Medical Surgical Nursing Students." *Nurse education today*, *31*(8), 866-871.

Anderson, J. L., & Barnett, M. (2013). "Learning Physics with Digital Game Simulations in Middle School Science." *Journal of Science Education and Technology*, *22*(6), 914-926.

Barab, S. A., Scott, B., Siyahhan, S., Goldstone, R., Ingram-Goble, A., Zuiker, S. J., & Warren, S. (2009). "Transformational Play as a Curricular scaffold: Using Videogames to Support Science Education." *Journal of Science Education and Technology*, *18*(4), 305.

Barata, G., Gama, S., Jorge, J., & Gonçalves, D. (2013). “Engaging Engineering Students with Gamification.” In *2013 5th International Conference on Games and Virtual Worlds for Serious Applications (VS-GAMES)* (pp. 1-8). IEEE.

Bellotti, F., Kapralos, B., Lee, K., Moreno-Ger, P., & Berta, R. (2013). "Assessment in and of Serious Games: An Overview." *Advances in Human Computer Interaction,* Vol. 2013(1), 1-11.

Behzadan, A. H., & Kamat, V. R. (2013). “Enabling Discovery-Based Learning in Construction using Telepresent Augmented Reality.” *Automation in Construction*, *33*, 3-10.

Bloomfield, J., Roberts, J., & While, A. (2010). “The Effect of Computer-Assisted Learning Versus Conventional Teaching Methods on the Acquisition and Retention of Handwashing Theory and Skills in Pre-Qualification Nursing Students: A Randomized Controlled Trial.” *International Journal of nursing studies*, *47*(3), 287-294.

Bloomfield, J. G., While, A. E., & Roberts, J. D. (2008). “Using Computer Assisted Learning for Clinical Skills Education in Nursing: Integrative Review.” *Journal of advanced nursing*, *63*(3), 222-235.

Braghirolli, L. F., Ribeiro, J. L. D., Weise, A. D., & Pizzolato, M. (2016). “Benefits of Educational Games as an Introductory Activity in Industrial Engineering Education.” *Computers in Human Behavior*, *58*, 315-324.

Cabero Almenara, J., & Barroso, J. (2016). “The Educational Possibilities of Augmented Reality.”

Cagiltay, N. E., Ozcelik, E., & Ozcelik, N. S. (2015). “The Effect of Competition on Learning in Games.” *Computers & Education*, *87*, 35-41.

Cai, S., Chiang, F. K., & Wang, X. (2013). “Using the Augmented Reality 3D Technique for a Convex Imaging Experiment in a Physics Course.” *International Journal of Engineering Education*, *29*(4), 856-865.

Carbonell Carrera, C., & Bermejo Asensio, L. A. (2017). “Augmented Reality as a Digital Teaching Environment to Develop Spatial Thinking.” *Cartography and geographic information science*, *44*(3), 259-270.

Cant, R. P., & Cooper, S. J. (2010). “Simulation-Based Learning in Nurse Education: Systematic Review.” *Journal of advanced nursing*, *66*(1), 3-15.

Chalhoub, J., & Ayer, S. K. (2018). “Using Mixed Reality for Electrical Construction Design Communication.” *Automation in Construction*, *86*, 1-10.

Chang, H. J., Symkhampha, K., Huh, K. H., Yi, W. J., Heo, M. S., Lee, S. S., & Choi, S. C. (2017). “The Development of a Learning Management System for Dental Radiology Education: A Technical Report.” *Imaging science in dentistry*, *47*(1), 51-55.

Chen, C. H., Wang, K. C., & Lin, Y. H. (2015). “The Comparison of Solitary and Collaborative Modes of Game-Based Learning on Students' Science Learning and Motivation.” *Journal of Educational Technology & Society*, *18*(2), 237-248.

Cheng, Y. H., Cheng, J. T., & Chen, D. J. (2012). "The Effect of Multimedia Computer Assisted Instruction and Learning Style on Learning Achievement." *WSEAS transactions on information science and applications*, *9*(1), 24-35.

Chiang, T. H. C., Yang, S. J., & Hwang, G. J. (2014). "An Augmented Reality-Based Mobile Learning System to Improve Students' Learning Achievements and Motivations in Natural Science Inquiry Activities." *Educational Technology & Society*, *17*(4), 352-365.

Cira, N. J., Chung, A. M., Denisin, A. K., Rensi, S., Sanchez, G. N., Quake, S. R., & Riedel Kruse, I. H. (2015). "A Biotic Game Design Project for Integrated Life Science and Engineering Education." *PLoS biology*, 13(3), e1002110.

Dalgarno, B., Bishop, A. G., Adlong, W., & Bedgood Jr, D. R. (2009). "Effectiveness of a Virtual Laboratory as a Preparatory Resource for Distance Education Chemistry Students." *Computers & Education*, *53*(3), 853-865.

Denton, P., Madden, J., Roberts, M., & Rowe, P. (2008). "Students' Response to Traditional and Computer Assisted Formative Feedback: A Comparative Case Study." *British Journal of Educational Technology*, *39*(3), 486-500.

Diegmann, P., Schmidt-Kraepelin, M., Eynden, S., & Basten, D. (2015). "Benefits of Augmented Reality in Educational Environments-a systematic literature review." *Benefits*, 3(6), 1542-1556.

Dinis, F. M., Guimarães, A. S., Carvalho, B. R., & Poças, J. P. M., (2017). "Virtual and Augmented Reality Game-Based Applications to Civil Engineering

Education." *2017 IEEE Global Engineering Education Conference (EDUCON)*, 1-6.

Fernandez, M. (2017). Augmented Virtual Reality: "How to Improve Education Systems." *Higher Learning Research Communications*, 7(1), 1-15.

Forgione, A., & Guraya, S. Y. (2017). "The Cutting-Edge Training Modalities and Educational Platforms for Accredited Surgical Training: A Systematic Review." *Journal of research in medical sciences: the official journal of Isfahan University of Medical Sciences*, 22.

Freire, M., Serrano-Laguna, Á., Iglesias, B. M., Martínez-Ortiz, I., Moreno-Ger, P., & Fernández-Manjón, B. (2016). "Game Learning Analytics: Learning Analytics for Serious Games." *Learning, Design, and Technology: An International Compendium of Theory, Research, Practice, and Policy*, 1-29.

gaming-2259191_960_720-e1500464125220 300x172. [digital image]. Retrieved from https://your4ktvguide.com/are-4k-tvs-really-worth-it-9-advantages-of-smart-tvs you-had no-idea-about/gaming-2259191_960_720/.

Georgilakis, P. S., Orfanos, G. A., & Hatziargyriou, N. D. (2014). "Computer-Assisted Interactive Learning for Teaching Transmission Pricing Methodologies." *IEEE Transactions on Power Systems*, *29*(4), 1972-1980.

Girard, C., Ecalle, J., & Magnant, A., (2012) "Serious Games as New Educational Tools: How Effective Are They? A Meta-Analysis of Recent Studies." *Journal of Computer Assisted Learning*, *Vol.* 29(3), 207–219.

Gloria, A., Bellotti, F., & Berta, R., (2014). "Serious Games for Education and Training." *International Journal of Serious Games*, Vol. 1(1), 1-15.

Hamari, J., Shernoff, D. J., Rowe, E., Coller, B., Asbell-Clarke, J., & Edwards, T. (2016). "Challenging Games Help Students Learn: An Empirical Study on Engagement, Flow and Immersion in Game-Based Learning." *Computers in Human Behavior*, 54, 170-179.

Hanus, M. D., & Fox, J. (2015). "Assessing the Effects of Gamification in the Classroom: A Longitudinal Study on Intrinsic Motivation, Social Comparison, Satisfaction, Effort, and Academic Performance." *Computers & Education*, *80,* 152-161.

Heradio, R., de la Torre, L., Galan, D., Cabrerizo, F. J., Herrera-Viedma, E., & Dormido, S. (2016). Virtual and Remote Labs in Education: A Bibliometric Analysis. *Computers & Education*, 98, 14-38.

Hou, L., Wang, X., & Truijens, M. (2013). "Using Augmented Reality to Facilitate Piping Assembly: An Experiment-Based Evaluation." *Journal of Computing in Civil Engineering*, *29*(1), 05014007.

Hsiao, K. F., Chen, N. S., & Huang, S. Y. (2012). "Learning while Exercising for Science Education in Augmented Reality Among Adolescents." *Interactive learning environments*, *20*(4), 331-349.

Huang, T. C., Chen, C. C., & Chou, Y. W. (2016). “Animating Eco-Education: To See, Feel, and Discover in an Augmented Reality-Based Experiential Learning Environment.” *Computers & Education, 96*, 72-82.

Huang, T.-H., Liu, Y.-C., & Chang, H.-C. (2012). "Learning Achievement in Solving Word Based Mathematical Questions through a Computer-Assisted Learning System." *Educational Technology & Society Vol.* 15.1, 248–259.

Hwang, G. J., Sung, H. Y., Hung, C. M., Huang, I., & Tsai, C. C. (2012). “Development of a Personalized Educational Computer Game Based on Students’ Learning Styles.” *Educational Technology Research and Development*, *60*(4), 623-638.

Hwang, G. J., Wu, P. H., Chen, C. C., & Tu, N. T. (2016). “Effects of an Augmented Reality-Based Educational Game on Students' Learning Achievements and Attitudes in Real-World Observations.” *Interactive Learning Environments*, *24*(8), 1895-1906.

Hwang, G. J., Yang, L. H., & Wang, S. Y. (2013). “A Concept Map-Embedded Educational Computer Game for Improving Students' Learning Performance in Natural Science Courses.” *Computers & Education, 69*, 121-130

Hwang, W. Y., & Hu, S. S. (2013). “Analysis of Peer Learning Behaviors using Multiple Representations in Virtual Reality and Their Impacts on Geometry Problem Solving.” *Computers & Education, 62*, 308-319.

John, L. J. (2013). A Review of Computer Assisted Learning in Medical Undergraduates. *Journal of pharmacology & pharmacotherapeutics*, 4(2), 86.

Jou, M., & Wang, J. (2013). "Investigation of Effects of Virtual Reality Environments on Learning Performance of Technical Skills." *Computers in Human Behavior*, *29*(2), 433-438.

Karakas, E., & Tekindal, S. (2008). "The Effects of Computer-Assisted Learning in Teaching Permanent Magnet Synchronous Motors." *IEEE Transactions on Education*, *51*(4), 448-455.

Kebritchi, M., Hirumi, A., & Bai, H. (2010). "The Effects of Modern Mathematics Computer Games on Mathematics Achievement and Class Motivation." *Computers & education*, *55*(2), 427-443.

Keedy, A. W., Durack, J. C., Sandhu, P., Chen, E. M., O'Sullivan, P. S., & Breiman, R. S. (2011). "Comparison of traditional methods with 3D computer models in the instruction of hepatobiliary anatomy." *Anatomical sciences education*, *4*(2), 84 91.

Kirkwood, A., & Price, L. (2014). "Technology-Enhanced Learning and Teaching in Higher Education: What is 'Enhanced' and How Do We Know? A Critical Literature Review." *Learning, media and technology*, *39*(1), 6-36.

Lai, F., Luo, R., Zhang, L., Huang, X., & Rozelle, S. (2015). "Does Computer-Assisted Learning Improve Learning Outcomes? Evidence from a Randomized Experiment in Migrant Schools in Beijing." *Economics of Education Review*, *47*, 34-48.

Le, Quang T., Pedro, A, Park, C., (2014). “A Social Virtual Reality Based Construction Safety Education System for Experiential Learning.” *Journal of Intelligent & Robotic Systems*, Vol. 79(3–4), 487-506.

Lee, C. Y., & Chen, M. P. (2009). “A computer game as a context for non-routine mathematical problemsolving: The effects of type of question prompt and level of prior knowledge.” *Computers & Education*, *52*(3), 530-542.

Lee, E. A. L., Wong, K. W., & Fung, C. C. (2010). “How Does Desktop Virtual Reality Enhance Learning Outcomes? A Structural Equation Modeling Approach.” *Computers & Education*, *55*(4), 1424-1442.

Lee, E. A. L., & Wong, K. W. (2014). “Learning with Desktop Virtual Reality: Low Spatial Ability Learners are More Positively Affected.” *Computers & Education*, *79*, 49-58.

Lee, K. (2012). “Augmented Reality in Education and Training.” *TechTrends*, *56*(2), 13-21.

Lin, K. Y., Son, J. W., & Rojas, E. M. (2011). “A Pilot Study of a 3D Game Environment for Construction Safety Education.” *Journal of Information Technology in Construction (ITcon)*, *16*(5), 69-84.

Lin, T. J., Duh, H. B. L., Li, N., Wang, H. Y., & Tsai, C. C. (2013). “An Investigation of Learners' Collaborative Knowledge Construction Performances and Behavior Patterns in an Augmented Reality Simulation System.” *Computers & Education*, *68*, 314-321.

Liu, C. C., Cheng, Y. B., & Huang, C. W. (2011). "The Effect of Simulation Games on the Learning of Computational Problem Solving." *Computers & Education, 57*(3), 1907-1918.

Lu, S. J., & Liu, Y. C. (2015). "Integrating Augmented Reality Technology to Enhance Children's Learning in Marine Education." *Environmental Education Research*, *21*(4), 525-541.

Magdalene, R., & Sridharan, D. (2018). "Powering E-Learning through Technology: An Overview of Recent Trends in Educational Technologies." *The Online Journal of Distance Education and e-Learning*, 6(1), 60.

Martín-Gutiérrez, J., Fabiani, P., Benesova, W., Meneses, M. D., & Mora, C. E. (2015). "Augmented Reality to Promote Collaborative and Autonomous Learning in Higher Education." *Computers in human behavior, 51*, 752-761.

Martín-Gutiérrez, J., Mora, C. E., Añorbe-Díaz, B., & González-Marrero, A. (2017). "Virtual Technologies Trends in Education." *EURASIA Journal of Mathematics Science and Technology Education*, 13(2), 469-486.

Merchant, Z., Goetz, E. T., Cifuentes, L., Keeney-Kennicutt, W., & Davis, T. J. (2014). "Effectiveness of Virtual Reality-Based Instruction on Students' Learning Outcomes in K-12 and Higher Education: A Meta-Analysis." *Computers & Education*, *70*, 29-40.

Messner, J. I., Yerrapathruni, S. C. M., Baratta, A. J., & Whisker, V. E., (2003). "Using Virtual Reality to Improve Construction Engineering Education." Proceedings of the 2003 *American Society for Engineering Education Annual Conference & Exposition*, Vol. 1121, 1-10.

Nikolic, D., Jaruhar, S., & Messner, J. I. (2011). “Educational Simulation in Construction: Virtual Construction Simulator.” *Journal of Computing in Civil Engineering*, *25*(6), 421-429.

Papastergiou, M. (2009). “Digital Game-Based Learning in High School Computer Science Education: Impact on Educational Effectiveness and Student Motivation.” *Computers & Education*, *52*(1), 1-12.

Parham, G., Bing, E. G., Cuevas, A., Fisher, B., Skinner, J., Mwanahamuntu, M., & Sullivan, R. (2019). “Creating a Low-Cost Virtual Reality Surgical Simulation to Increase Surgical Oncology Capacity and Capability.” *ecancermedicalscience*, *13*.

Pham, H. C., Pedro, A., Le, Q. T., Lee, D. Y., & Park, C. S. (2017). “Interactive Safety Education Using Building Anatomy Modelling.” *Universal Access in the Information Society*, 1-17.

Pilli, Olga, & Aksu, Meral. (2013). "The Effects of Computer-Assisted Instruction on the Achievement, Attitudes and Retention of Fourth Grade Mathematics Students in North Cyprus." *Computers & Education,* Vol. 62, 62–71.

Richards, D., & Taylor, M. (2015). “A Comparison of Learning Gains when Using a 2D Simulation Tool Versus a 3D Virtual World: An Experiment to Find the Right Representation Involving the Marginal Value Theorem.” *Computers & Education*, *86*, 157-171.

Rondon, S., Fernanda, C., & Furquim de Andrade, C., (2013). "Computer Game-Based and Traditional Learning Method: A Comparison Regarding Students' Knowledge Retention." *BMC Medical Education* Vol. 13.1, 30-38.

Sacks, R., & Barak, R. (2008). "Teaching Building Information Modeling as an Integral Part of Freshman Year Civil Engineering Education." *Journal of Professional Issues in Engineering Education and Practice, Vol. 136*(1), 30-38.

Sacks, R., Eastman, C., Lee, G. (2004). "Parametric 3D Modeling in Building Construction with Examples from Precast Concrete." *Automation in Construction*, Vol.13(3), 291–312.

Sacks, R., Perlman, A., & Barak, R. (2013). "Construction Safety Training using Immersive Virtual Reality." *Construction Management and Economics, 31*(9), 1005-1017.

Sampaio, Alcínia Z., Ferreira, Miguel M., Rosário, Daniel P., & Martins, Octávio P., (2010). "3D And VR Models in Civil Engineering Education: Construction, Rehabilitation and Maintenance." *Automation in Construction*, Vol. 19(7), 819 828.

Schaal, S., Bogner, F. X., & Girwidz, R. (2010). "Concept Mapping Assessment of Media Assisted Learning in Interdisciplinary Science Education." *Research in Science Education, 40*(3), 339-352.

Şendağ, S., & Odabaşı, H. F. (2009). "Effects of an Online Problem-Based Learning Course on Content Knowledge Acquisition and Critical Thinking Skills." *Computers & Education, 53*(1), 132-141.

Shanbari, H., & Issa, R. R. (2019). "Use of Video Games to Enhance Construction Management Education." *International Journal of Construction Management,* 19(3), 206-221.

Solak, E., & Cakir, R. (2015). "Exploring the Effect of Materials Designed with Augmented Reality on Language Learners' Vocabulary Learning." *Journal of Educators Online*, *12*(2), 50-72.

Squires, David. (2017). "Augmented Reality Application Classroom Development: New Technology and New Media, Education and Intelligent Classrooms." *i-Managers Journal of Educational Technology*, Vol. 14(1), 1-6.

Su, C. H. (2016). "The Effects of Students' Motivation, Cognitive Load and Learning Anxiety in Gamification Software Engineering Education: A Structural Equation Modeling Study." *Multimedia Tools and Applications*, *75*(16), 10013-10036.

Sung, H. Y., & Hwang, G. J. (2013). "A Collaborative Game-Based Learning Approach to Improving Students' Learning Performance in Science Courses." *Computers & Education*, *63*, 43-51.

Torrente Vigil, J., Blanco, Á. D., Serrano Laguna, Á., Vallejo Pinto, J. Á., Moreno Ger, P., & Fernández Manjón, B. (2014). "Towards a Low Cost Adaptation of Educational Games for People with Disabilities." *Computer Science and Information Systems*.

Torrente, J., Moreno-Ger, P., Fernández-Manjón, B., & Sierra, J. L. (2008, July). "Instructor oriented Authoring Tools for Educational Videogames." In *2008*

Eighth IEEE International Conference on Advanced Learning Technologies (pp. 516-518). IEEE.

Tüzün, H., Yılmaz-Soylu, M., Karakuş, T., İnal, Y., & Kızılkaya, G. (2009). "The Effects of Computer Games on Primary School Students' Achievement and Motivation in Geography Learning." *Computers & Education*, *52*(1), 68-77.

Tüysüz, C. (2010). "The Effect of the Virtual Laboratory on Students' Achievement and Attitude in Chemistry." *International Online Journal of Educational Sciences*, *2*(1).

Vankipuram, M., Kahol, K., McLaren, A., & Panchanathan, S. (2010). "A Virtual Reality Simulator for Orthopedic Basic Skills: A Design and Validation Study." *Journal of biomedical informatics*, *43*(5), 661-668.

Velev, D., & Zlateva, P. (2017). "Virtual Reality Challenges in Education and Training." *International Journal of Learning and Teaching*, 3(1), 33-37.

Virtualvalidation. [digital image]. Retrieved from http://thrustenterprise.com/VirtualValidation.html.

yay-1829971-digital(1). [digital image]. Retrieved from https://www.proprofs.com/c/lms/computer-assisted-training-what-is-it/.

Yen, J. C., Tsai, C. H., & Wu, M. (2013). "Augmented Reality in the Higher Education: Students' Science Concept Learning and Academic Achievement in Astronomy." *Procedia-social and behavioral sciences*, *103*, 165-173.

Yusuf, M. O., & Afolabi, A. O. (2010). "Effects of Computer Assisted Instruction (CAI) on Secondary School Students' Performance in Biology." *Turkish Online Journal of Educational Technology-TOJET*, *9*(1), 62-69.