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Assessing Priorities in Engineering Design Through Augmented Reality

Mrs. Ibukunoluwa Eunice Salami, University of Nebraska - Lincoln

Ibukunoluwa Eunice Salami is a PhD Student in Engineering Education Research at the University of Nebraska-Lincoln. She has a bachelor's degree in Systems Engineering and a masters in Industrial Engineering. Her research interests include the transfer of learning and how young engineering student transition to the engineering industry.

Dr. Logan Andrew Perry, University of Nebraska - Lincoln

Dr. Perry is an Assistant Professor of Engineering Education in the Department of Civil & Environmental Engineering. His work contains a unique blend of engineering education and civil engineering projects. Dr. Perry's current work centers on understanding how students transfer their knowledge between engineering school and work. This is supplemented by his role in developing assessment techniques for two NSF-funded projects focused on the incorporation of virtual and mixed reality technology into civil engineering education. In addition, his past civil engineering research investigated the behavior of wood shear wall structures under seismic loading conditions. Dr. Perry's expertise in both the engineering education and civil engineering domains provide him with a unique skillset that drives his interests in learning and technical engineering work.

Accessing Priorities of Design Through Augmented Reality
(Work in Progress Paper - A Literature Review)

Abstract

This work in progress paper provides a background on how engineering students make priorities when it comes to performing engineering design. This study provides insight into how augmented reality (AR) can provide realistic scenarios that require students to make informed design decisions similar to those made in industry. The potential of AR as an engineering education tool, particularly in the context of preparing students for industry, cannot be overemphasized. One of the issues that students must face with transitioning into the industry is the application of school knowledge to their real-life practice. Engineering students are expected to think critically, come up with original solutions, and collaborate with other team members on projects. Often, traditional teaching methods are not enough to build these capacities in young engineers, which has led to the introduction of new instructional methods such as the incorporation of virtual reality as an authentic learning technique. Several authentic learning techniques have been used in the past to introduce students to virtual reality. While Virtual Reality (VR) substitutes reality, transporting you to a different environment, Augmented Reality enhances reality by superimposing information onto what is already visible. Augmented reality (AR) is a technology that blends computer-generated elements with live video in real-time hence, incorporating AR in authentic learning activity has the potential to help understand how users view the real world and make informed decisions to improve workplace decisions.

This paper serves as a literature review for a larger study that investigates how engineering students set priorities in engineering design to assess their preparedness for industry. The larger study seeks to answer the following research questions:

- How do students perceive their undergraduate education prepares them to set priorities in engineering design?
- How do authentic learning activities through AR change the way students think about design?

The objective of this research is to give students exposure into real-world practice to understand industry requirements even before they graduate from school. This paper will present a brief literature review on the topic, while more details about the methodology, results, and future directions will be presented in a future paper.

Introduction

Engineering education often focuses on problem solving within the curriculum, which is expected to help prepare engineering students for industry; however, at times this is not enough, as early-career engineers might be faced with complex issues that are far less straightforward than those encountered during their education. As such, this work-in-progress paper focuses on how a learning experience in augmented reality can help students gain the required skills needed for industry.

To date, academia has tried to help students develop strong technical skills by incorporating different analytical and problem-solving skills into the curriculum. As a result, academia has introduced different learning techniques to better prepare students for work after graduation. One such technique is authentic learning with the use of augmented reality. Augmented reality (AR) is a technology that blends computer-generated elements with live video in real-time [1]. Virtual (computer-generated) objects appear to coexist in the same space as the real world are produced by the AR system. While many academics go beyond this concept when defining AR, an AR system can be defined as having the following characteristics: (1) it combines actual and virtual items in a real setting, (2) it operates in real time and in an interactive manner, and (3) it registers (aligns) real and virtual objects, [2], [3].

However, augmented reality is yet to be fully leveraged in engineering on how it can help students with engineering design priorities. This work-in-progress paper is a part of a larger study that examines how students leverage augmented reality to make engineering design decisions for real-world problems. The study will answer the following research questions:

- ***RQ1:*** *How do students perceive their undergraduate education prepares them to set priorities in engineering design?"*
- ***RQ2:*** *How do authentic learning activities through AR change the way students think about design?*

The literature review conducted in this work-in-progress paper will help in understanding how AR has been used in the education sphere and how we can incorporate it as an authentic learning activity to better prepare students for industry. This study is an offshoot of Perry’s study on assessing head- hand- and heart-related competencies through augmented reality; more details about the existing study can be found here [4].

The increasing complexity of society and the world's challenges suggests that engineering graduates must be exceptional problem solvers, designers, and value creators in a variety of business and social settings. The solutions, designs, and systems developed must solve technical problems while also benefiting a wide range of stakeholders with varying financial, social, and environmental interests [5]. This paper will focus on reviewing literature based on how AR has been used to enhance authentic learning activities.

Literature Review

Method of Literature Review: Search Strategy

We searched the following databases for AR over the period of 1983 through the present: Academic Search Premier, Socpus, Eric, IEEE Explore, Web of Science. However, the results were very limited in terms of applicability to engineering education or authentic learning; hence, we did an advanced search on Google and Google scholar. The following search terms were used to generate a search: authentic learning and augmented reality, augmented reality in education, augmented reality and engineering education, augmented reality and design priorities, design priorities in engineering, augmented reality and engineering design, augmented reality and authentic learning, authentic learning and engineering education, authentic learning, augmented reality and engineering industry, augmented reality in the industry and engineering design.

AR in Education

Discussions regarding augmented reality (AR) in education, in the opinion of Wu, Lee, Chang, and Liang, (2013), [6] should be seen as an interactive experience rather than a technology and focus on the possibilities that are afforded, especially as new technological breakthroughs occur. Augmented reality has certain advantages to virtual reality. Whereas virtual reality is termed as being controlled by a computer or a network of computers which tracks the user's movements and adjusts the virtual environment, augmented reality allows the users control how their environment could look in a real-world scenario and easily discern between a real world and a virtual world. This gives AR users a more authentic experience when asked to interact with virtual objects, allowing students to succeed in the environment [7]. Creating AR applications mostly involves creating additional visual, auditory, or other sensory data on top of the real-world using images or text, unlike traditional textbooks, which use 2D models to represent abstract ideas. In contrast to textbooks, AR enables the creation of accurate 3D figures as representations of abstract ideas. The student's eyes can be opened to a wide range of previously unknown possibilities using this new technology, [8], [9], [10].

Many new applications have been made possible by augmented reality technologies. In numerous disciplines, including geography, architecture, medicine, archaeology, and geometry, augmented reality systems have been shown to be extremely useful teaching aids. AR has been used, for instance, in the medical field to instruct students in anatomy and biology as well as to train specialists in the use of new tools and techniques [11], [12], [13]. For applications in architecture and archeological sites, remarkable representations have also been produced. AR technology superimposes digital images on the real-world environment which can be viewed through devices such as smartphones. Architects have been able to utilize this technology to plan their projects and visualize how they will appear in actual settings and in archelogy with the use of AR, it has enhanced tourism to assist in interacting with historical archaeological features [14], [15].

Numerous other examples of AR implementation in education have been studied such as an experiment that used cameras as a tool to improve preschool students' visual experiences. It was demonstrated that utilizing modern technologies helped students become more creative and even improved their social skills. In another study, El Sayed, Zayed, and Sharawy (2011) developed an Augmented Reality Student Card (ARSC), [16] which was designed to present lessons in a 3D format that enables students to visualize learning objects, engage with theories, and interact with information in a unique and effective manner. ARSC utilizes single, static markers (which serves as notable reference points) on a card to assign different objects while enabling the computer application to minimize the tracking process. According to the research, ARSCs improved the students' capacity for visualization [16].

AR in Natural Sciences

An AR approach was created by Nunez, Quiros, Carda, and Camahort (2008), [17] for teaching spatial linkages and chemical issues to college students. Students used markers to change the crystal structures of some substances, including ZrSiO4, in the experiment. However, only static images or structures were rendered in the experiments mentioned above. Recent studies suggest that when using AR technology to its fullest, student-computer interactions are more intriguing and engaging. In Iordache, Pribeanu, and Balog (2012) an Augmented Reality Teaching Platform (ARTP) for chemistry was suggested where students can place colored balls on a periodic table to gauge their understanding on chemistry concepts and the interaction between different compounds [18]. The study discovered that having the students drop colored balls onto various chemical elements on a table gives them a sense of freedom and control, which is beneficial for mastery. The findings indicate that using this tool helps pupils learn concepts more thoroughly and simply [18]. Students were also able to perform chemical experiments in an AR environment created by Wojciechowski and Cellary (2013), such as the reaction between table salt (NaCl) and water when hydrochloric acid (HCl) and sodium hydroxide (NaOH) are combined. The findings demonstrated that the active engagement of students in experiential learning activities was positive and increased their motivation for learning, primarily because of the interactions between the AR environments and the instructional materials [19].

AR in Engineering

Attempts to introduce AR into engineering courses have been made by some researchers. Chen et al., (2011) proposed an AR based system to aid students in an engineering graphics course by including instructions from the AR system so the students could individually control their learning process through the development of spatial abilities [20]. This is similar to Akkus & Arslan's (2022) quasi-experimental design where they studied how to use AR as an intervention in improving technical drawing skills by freshmen mechanical engineering students[21]. Their study revealed that the students who were in the intervention group that required the use of AR were very excited for the opportunity to use the new technology and indicated that the use of AR and the traditional paper simultaneously improved their technical drawing skills [21]. In another study, faculty created resources to aid engineering students in comprehending projection techniques using augmented reality which proved very useful because during the learning process the students demonstrated a higher degree of engagement [22].

Engineering has enjoyed the benefits of AR mostly in simulation and analysis by the biomedical, thermal, electromagnetic, civil and mechanical engineering fields [23]. In Biomedical engineering and surgery, computed tomography (CT) and magnetic resonance imaging (MRI) data are typically imaged in an AR terrain using image overlay, while a volume picture system is included to enhance the data disquisition experience [24],[25]. Augmented Reality (AR) is primarily utilized in civil and urban engineering to view thermal analysis and computational fluid dynamics simulations [23] (Li et al., 2017) while in in the mechanical engineering and manufacturing fields, near real- time result streamlining with detector networks, image processing, and tangible user interfaces are common uses of AR [23].

In civil and construction engineering, AR was used to examine how students could use 2D design plans to understand the sequence of constructing a wall in a typical residential building. This experiment had two groups of students, where the first group recorded their results on a 2D worksheet the other group used AR [26]. The task the students were given were aimed at resembling a typical carpentry task that one might encounter on a construction site, and the results showed that even though the students who had to use 2D design finished faster than their peers, their design was more prone to errors and did not meet the required dimensional details. In contrast, their AR colleagues had fewer errors and saw the exercise as an opportunity to develop hands-on skills [26].

Design Focus in Engineering

Because engineering design is a critical component to engineering as a whole, it is important to consider how AR may provide opportunities for students to learn design. Engineering education prior to World War II was primarily focused on design; practical manufacturing was seen as an integral part of the design process, and engineering students were instructed in the technical skills that technicians in the many engineering areas utilize daily, such as designing and drafting [27]. Since, the curriculum has evolved tremendously, however research has shown that professional engineers still may encounter new issues that they were not faced with while in school [2]. Educators must carefully consider the needs of today's graduates in order to properly prepare students for the demands of this work. Academic preparation for the profession in engineering-related fields primarily focuses on technical knowledge, leaving little room for other types of competencies within the tightly packed curriculum [28]. To respond to these challenges, incorporating augmented reality in an authentic learning activity has potential to help understand how young engineers view the real world and make informed decisions that they may be required to make in the workplace [2], [3].

More specifically, one of the core competencies required for engineers is ability to design a system, component, or process to meet desired needs within realistic constraints [29]; however, this process is less straightforward than it may seem. Engineering students are expected to consider a myriad of factors when designing and not only focus on the technical aspects of their solution. These factors must be prioritized and may include time, cost, accessibility, and many others.

AR has been used in the industry extensively [30], but it is not discussed herein as this paper is more interested on how AR can be used to prepare engineering students for industry during the undergraduate curriculum. To understand how students set priorities in engineering design, Cynthia et al., 2008 [31] used a mixed methods approach to examine how engineering students use their design skills to solve real-world problems. They found that engineering students are more likely to think like professionals in their senior year compared to freshmen students, who approach design issues based on their introductory courses. The senior students also prioritized metrics such as budget and safety, leading them to conclude that capstone students are able to focus on an holistic design solution compared to the first-year students, whose focus was based on getting the project done faster [31]. Another study by Zheng et al., 2018 [32] involved assisting students in engineering design process. The study revealed that the students' priorities in engineering design were based on teamwork with their peers and not just on the technical aspects behind the project. Instead, the students prioritized collaboration and took into account ideas from other team members [32]. Studies like these illustrate the potential for research to better understand how students make priorities within the design process, an important skillset for success in the engineering industry.

AR technology has the potential of enhancing engineering design and building the development process for young engineers. AR can revolutionize the engineering design process by making it faster, more efficient, more safety conscious, and more precise. With AR, students can easily visualize their designs before they are built in a real-world experiment because they can make accurate conclusions from 3D prototypes [33]. This can reduce issues that are being caused by not having enough foresight of the engineering development process ahead of implementation.

Future Work

Allowing students to experience and master situations that reflect real life is the core goal of authentic learning. According to some academics, emerging technologies are particularly adept at supporting inquiry-based learning environments by developing "genuine" science learning environments and, perhaps more significantly, by involving students in scientific inquiry [34]. The capacity of augmented reality (AR) technology to engage students and create a setting for genuine scientific inquiry and discovery should be taken into consideration [35], [36], [37].

While so many other fields such as chemistry, medicine, physics etc. have experienced how augmented reality (as seen in the literature review of this paper) has assisted in improving authentic learning for students, engineering is yet to fully explore this technology; hence, the study that this paper is a part of will attempt to understand how the use of an augmented reality device (Hololens) can assist students in learning how to set priorities in real-world engineering design.

The intention of using AR in this study is to enable students to discuss how authentic learning experiences can prepare them for industry. As a result, integrating AR technology into engineering education can have an impact on academic performance in the short term while simultaneously giving engineering students the skills they need to succeed in the labor market in a more complex industry over the long term [38].

To answer the research questions of the upcoming larger study, the advancement of teaching framework on professional preparation across professions known as the “three apprenticeships model” will be used as a guiding theoretical lens. To explore the research purpose, 10 civil engineering undergraduate students from a university in the Midwest will be assessed on their knowledge via an authentic learning activity to redesign a children’s playground using augmented reality based on five assessment metrices (cost, fun, sustainability, time, and safety). Feedback will be gathered through semi-structured interviews and analyzed through thematic analysis.

Conclusion

This literature review has revealed that AR has not been fully explored in engineering. Though it has been used in biomedical, thermal, electromagnetic, civil and mechanical engineering fields, AR still has untapped potential as a means for authentic learning in engineering education. In particular, AR has budding potential in civil and construction engineering education, more of which will be explored in the coming full version of this study. This authentic learning research will aim to understand how working in an AR space will prepare students to set priorities in engineering design using real-world scenarios. The full paper will provide full insight into how the AR activity is useful in preparing civil engineering students for real-world practice. In the meantime, more work is needed to fully understand how AR can be leveraged to create more authentic learning experiences in engineering education.

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