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Assessing Head- Hand- and Heart-Related Competencies through Augmented-Reality

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Abstract

This work in progress paper presents an assessment framework for an authentic learning activity in augmented reality (AR). Constant changes in technical and societal needs require educational programs to constantly rethink the status quo and explore ways to align future professionals' formal education with emerging workforce demands. Such is critical for all professions — including those in the architecture, engineering, and construction (AEC) industry. While many may agree on the need to do this, what is less clear is the scholarly approach required for undertaking such an endeavor. Insights from studies associated with the Preparation for the Professions Program led by the Carnegie Foundation for the Advancement of Teaching offer a framework used for exploring professional preparation across professions is commonly referred to as the Three Apprenticeships—namely, Apprenticeships of the Head, the Hand, and the Heart. Within engineering-related fields, academic preparation for the profession primarily focuses on technical knowledge; but there is a need for more holistic, integrated learning experiences that involve different kinds of knowledge (Head), skills (Hand), and professional judgment (Heart). This study leverages the Three Apprenticeship framework to assess an integrated learning AEC experience in augmented reality (AR) by using real-time data collected from participants. Using the context of a children's playground, participants were asked to redesign an existing play structure to better meet the needs of children, parents, and other stakeholders within the community. A five-metric assessment was developed to operationalize the head, hand, and heart constructs in this context and measure participants' ability to think holistically in an authentic learning experience. These five assessment metrics included cost, time, safety, sustainability, and fun. This paper explores the development of this assessment and shares preliminary findings from the study.

Introduction and Background

With change as a constant force in today's world, educational programs must continuously adapt to ensure students are prepared for the workforce. This remains true in the architecture, engineering, and construction (AEC) industry, a cohort of disciplines responsible for designing and maintaining society's infrastructure. To properly prepare graduates for the demands of this work, educators must carefully consider the needs of today's graduates. Within engineering-related fields, academic preparation for the profession primarily focuses on technical knowledge, leaving little room for other types of competencies within the tightly packed curriculum [1]. Other competencies include ethics, professional judgement, and an understanding of practicality and constructability, all of which have a critical impact on real-world engineering design. Most importantly, students must understand how these competencies fit into the complex nature of design and the difficult choices that often must be made to satisfy design criteria and develop solutions in realistic conditions. Thus, to best prepare graduates for work, engineering education programs must incorporate authentic design experiences into their curricula, providing students with opportunities to think through real-world scenarios using a holistic set of competencies that go beyond technical knowledge alone.

The purpose of this study was to understand how students prioritize design criteria in an authentic engineering problem-solving scenario. The following research question was addressed:

1) How do students' perceptions of design criteria (cost, time, safety, sustainability, and fun) change as a result of an augmented reality engineering design experience?

Theoretical Underpinnings

The research herein leveraged the Three Apprenticeships model from The Carnegie Foundation as a theoretical lens [2]. This framework identifies three forms of competency, referred to as apprenticeships of the head, hand, and heart. In this context, apprenticeship of the head considers the knowledge needed to carry out a particular activity; apprenticeship of the hand focuses on the practical skills necessary to complete the activity; and apprenticeship of the heart concerns the ethical considerations of that activity. Within engineering, the Three Apprenticeships model provides a useful lens through which to investigate how engineers carry out the design process – though engineers rely heavily technical (head) skills, this framework provides additional lenses for understanding how engineers leverage practical skills and ethical thinking through the apprenticeships of the hand and heart, allowing for a more holistic assessment of the design process.

Method

Designed as a sequential explanatory mixed methods study, this project leverages both quantitative and qualitative data to understand what engineers prioritize during the design process. To assess these priorities, an augmented reality scenario was created that allowed participants to demonstrate their thinking relative to apprenticeships of the head, head, and heart in an engineering design context. Participants were asked to redesign an existing playground (Figure 1) to better meet the needs of children, parents, and a local community government. This context was chosen for two reasons: (1) most people have encountered a playground, and thus the context is accessible and readily understood by most participants; (2) playgrounds must meet the standards of multiple stakeholders, many of whom have differing priorities. For example, though parents may prioritize safety in the design of the playground structure, children may prioritize "fun," while the local community government may prioritize a low cost of construction. Such criteria are often at odds with one another, requiring participants to explicitly make choices regarding priorities in the design.

Figure 1 – Playground structure

Data were collected from 38 participants at two large, public universities in the western United States. Participants were asked to take a pre-survey to gauge their initial thoughts about their priorities in the design and note their prior experiences with mixed reality technology. Afterward, each participant was fitted with a Microsoft HoloLens for the experiment. Participants were then asked to redesign the playground structure to better satisfy the needs of the local community. At their disposal was a catalog of materials and resources that could be used for the redesign.

To measure the changes made in the playground design, five assessment metrics were employed. These included cost, time, safety, sustainability, and fun, as illustrated in Figure 2. Each of these metrics was tracked throughout the experiment. Every change made to the playground was associated with a particular cost and time for labor. Safety hazards were counted in accordance with U.S. Consumer Product Safety Commission (USCPSC) guidelines [3]. Each item installed in the playground also had a sustainability value that was derived from the material's environmental product declaration. Finally, fun was measured according to the number of activities available to children using the play structure.

Figure 2 – Assessment metrics

After completing their design, participants were provided with a report indicating their results in each of the five metrics. These metrics were divided into quartiles based on the performance of all participants and illustrated via radar plots, as shown in Figure 3. These radar plots illustrate the difference between participants' original expectations of their priorities within the design and their actual performance based on the activity. A semi-structured interview was then conducted with each participant to understand their thought processes and justifications for their priorities in the experiment. A portion of the interview protocol is included below for reference.

1) Tell me about your overall strategy.
2) In your opinion, what were the most important changes to the playground structure? Why?
3) How did this experiment make you think differently about your priorities in design?

Interview transcripts were analyzed using thematic analysis. The following section will present preliminary findings from this analysis.

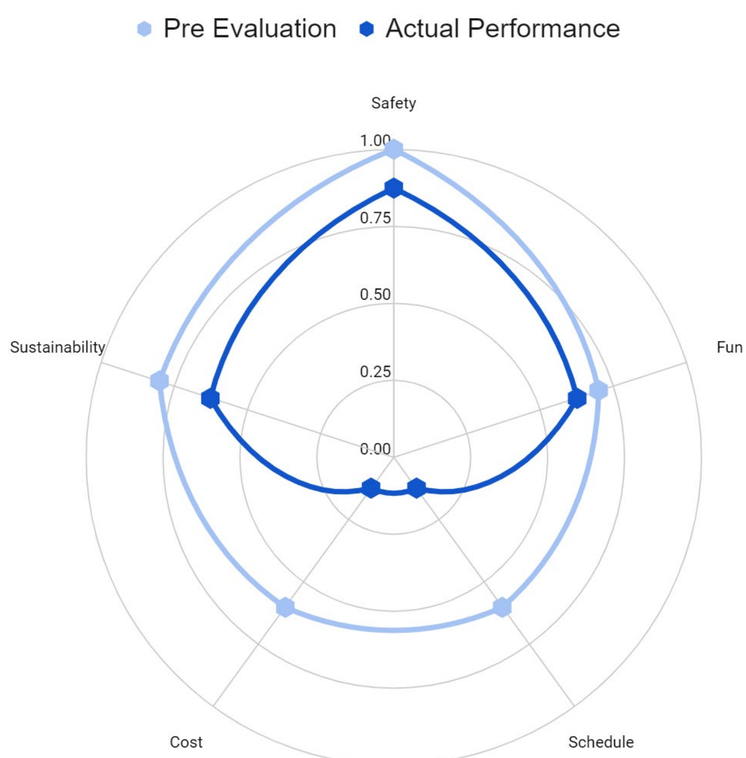

Figure 3 – Radar plot

Preliminary Results

Initial findings suggest that most participants experienced changes between their expectations of their priorities and their actual priorities in the experiment. The radar plot in Figure 3 highlights one such instance. Though the participant predicted that they would prioritize safety but not sacrifice scheduling and project cost, their actual results indicated significant losses with relation to both schedule and cost. Follow-up interviews then allowed participants to share more details about their decisions. In many of these interviews, participants shared the challenges associated with prioritizing these criteria, such as in the following example:

> "I learned that trying to manage cost, design, structure, sustainability, safety, schedule, and stress all at once is quite difficult…working through the challenges to still obtain a result provided some experience with conflict management and problem solving."

In this excerpt, the participant shared the difficulty they experienced while managing the five design criteria used in the study, a task that required conflict management and problem solving. This sentiment was expressed by many students, a finding that perhaps indicates a need for more training with realistic problem-solving scenarios. Participants also shared general comments about the usefulness of AR technology within the construction field:

> "I learned that augmented reality could be quite a good way to understand the project you would take part in. I learned that while there are some issues with the program being new, virtual reality understand is developing quite quickly, and construction companies should move towards working with this kind of technology. This could save a lot of money and time when understanding drawings and understanding processes going through construction and being able to visualize the project before actually starting. This leaves room to minimize mistakes during the construction processes."

More results regarding participants' priorities in engineering design and their perceptions of AR will be developed and disseminated as analysis continues.

Conclusion

There is a clear need within engineering education for more holistic, integrated learning experiences that involve different kinds of knowledge (Head), skills (Hand), and professional judgment (Heart). This work-in-progress study has leveraged the Three Apprenticeship framework to assess an integrated learning AEC experience in augmented reality (AR). Using the context of a children's playground, participants were asked to redesign an existing play structure to better meet the needs of children, parents, and other stakeholders within the community. Preliminary results indicated that many participants experienced changes between their expectations of their priorities and their actual priorities in the experiment. Moving forward, the project team will continue to collect and analyze data to understand how engineering students prioritize design criteria in an authentic engineering problem-solving scenario.

References

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