Board 92: Using Mixed Reality and the Three Apprenticeships Framework to Design Head-, Hand- and Heart-focused Learning Experiences for Civil Engineering Students

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Dr. Jeremi London is an Assistant Professor in the Engineering Education Department at Virginia Polytechnic Institute and State University. London is a mixed methods researcher with interests in research impact, cyberlearning, and instructional change in STEM Education. Prior to being a faculty member, London worked at the National Science Foundation, GE Healthcare, and Anheuser-Busch. She earned B.S. and M.S. degrees in Industrial Engineering, and a Ph.D. in Engineering Education from Purdue University.

Dr. Steven K Ayer, Arizona State University

Steven Ayer runs the Emerging Technologies Building Information Modeling Lab at Arizona State University. His research group explores new and emerging electronic technologies, including augmented reality, virtual reality, and other emerging tools. Ayer's group aims to study how these tools may improve the way that building projects are delivered. This research group has an array of different projects and technologies that it explores, but all studies revolve around the single motivation that technology should empower human users. Therefore, most of the studies conducted by Ayer's team aim to focus on human performance rather than technological innovation. His team has explored the use of technology for: students gaining "cyberlearning" experiences related to construction management and engineering; architects aiming to improve the quality of their design concepts; construction managers interested in improving field communication of BIM content; and facility managers interested in better leveraging model information to deliver more maintainable built spaces. Ayer's work has been funded by federal and industrial sources, which has enabled his team to collect data that offers both scientific and practical contributions. Up to date information about Dr. Ayer and his team can be found at www.ETBIMLab.com.

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Wei Wu, PhD, LEED AP, GGP, CM-BIM, A.M. ASCE, is an Assistant Professor in the Department of Construction Management in Lyles College of Engineering at California State University, Fresno. He received his Bachelor of Engineering in Built Environment and Equipment Engineering from Hunan University in China in 2004, Master of Science in Environmental Change and Management from University of Oxford in the UK in 2005, and Doctor of Philosophy in Design, Construction and Planning from University of Florida in 2010. Currently, Dr. Wu teaches courses in Construction Graphics, Design Build, BIM for Construction. Dr. Wu's research interests include building information modeling, construction graphics and visualization, green building and sustainable construction, workforce development, cyberlearning and educational technology, construction and engineering education. Dr. Wu has published more than 40 articles and conference proceedings in these areas. Dr. Wu's research has been funded by regional and federal agencies including a recent National Science Foundation (NSF) grant on investigating Mixed Reality (MR) for career-specific competency cultivation among construction management and engineering students.

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Christina K. Lam is a Ph.D. student in Counseling Psychology at Arizona State University. She has previously earned her B.S. in Psychology and M.A. in Counseling Psychology. Her previous research has examined Asian American ethnic identity formation, racial/ethnic and gender differences in financial stress, and the integration of a three apprenticeships framework in engineering. Her current research emphasizes a health belief approach to examine the likelihood of mental health help-seeking behaviors among Asian Americans.

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Abstract

While the building industry has a major impact on the US economy, it is one that is often criticized for poor productivity and waste resulted from interoperability. Additionally, the impending labor shortage requires that this is industry becomes one that can do more with less in order to remain effective. As part of preparing civil engineering students for careers in this industry and to design/build infrastructure that is responsive to changing societal needs, educators have aimed to replicate the processes associated with real-world projects through design/build educational activities (like the Department of Energy's (DOE) Solar Decathlon, Sacramento Municipal Utility District's (SMUD) Tiny House Competition, and DOE's Challenge Home Competition) as part of helping students situate civil engineering concepts in an authentic learning environment. Unfortunately, not all universities have the financial resources necessary to fund these types of hands-on projects. Thankfully, technology has the potential to mitigate some of these inequities. This paper presents an update on a three-year NSF-funded project that aims to: ***develop mixed reality*** (MR) technology aimed at sufficiently replicating physical design and construction learning environments to ***enable access*** to students at institutions without sufficient resources; and ***assess the impact*** of a MR-facilitated cyberlearning environment on cognitive-, affective-, and skill-based learning that occurs during traditional (in-person) design and construction activities. Human Centered Design principles and the tenets of the Carnegie Foundation's Three Apprenticeships Model (i.e., learning related to "Head", "Hand", and "Heart") inform the design, development, and assessments in this project. Highlights from the first year and future plans will be discussed.

Introduction

The objective of this research is to: ***develop*** mixed reality (MR) technology aimed at sufficiently replicating physical design and construction learning environments to ***enable access*** to students at institutions without sufficient resources; and ***assess the impact*** of a MR facilitated cyberlearning environment on promoting cognitive-, affective-, and skill-based learning that occurs during traditional (in-persona) design and construction activities.

The building industry has a major impact on the US economy and accounts for: $1 trillion in annual spending (Huesman, Holland, Langley, 2015); 40% of the nation's primary energy use (U.S. Department of Energy, 2011); and 9 million jobs (Dong et al., 2014). Despite its massive impact, the industry has been criticized for poor productivity compared with other industries and also billions of dollars in annual waste due to the lack of interoperability (Gallaher et al., 2004).

Furthermore, the industry has been approaching a “labor cliff,” meaning there are not enough new individuals entering the industry to offset the vacancies left by an aging, retiring workforce (Sulak Brown, Goodrum, Taylor, 2015). To remain effective, this critical industry will need to do better with less.

In order to encourage and prepare students for a career in this industry, educators have often aimed to replicate real-world project processes through physical design/build educational activities in events like the Department of Energy’s (DOE) Solar Decathlon, Sacramento Municipal Utility District’s (SMUD) Tiny House Competition, and DOE’s Challenge Home Competition, among others. These learning experiences help situate learning concepts within a specific project context and provide an authentic environment for learning. Unfortunately, not all universities have the financial resources necessary to fund this type of hands-on project. Thankfully, technology –like augmented reality—have the potential to help mitigate this inequity.

To prepare students with the skills to shift the building industry to do better with less, educators need a better way to prepare more students with fewer resources. This research will take a critical first step toward this ambitious challenge and explore a fundamental question: ***Can MR technology enable educators to simulate physical design and construction activities at low costs to enable students at all institutions to gain exposure to these types of hands-on learning environments?***

In order to address this overarching research question, this research uses an iterative development approach according to two guiding frameworks: Human Centered Design principles (Maguire, 2001) and Shulman’s Three Apprenticeships Model (i.e. learning related to “Head”, “Hand”, and “Heart”) (Carnegie Foundation for the Advancement of Teaching, 2009; Shulman, 2005a, 2005b). In short, HCD principles facilitate an approach for designing computing tools for human users whose needs may not be fully understood by the developers. On the other hand, the Three Apprenticeships model is a theoretical framework for designing learning experiences that integrate different forms of knowledge and professional judgement.

In order to achieve these project objectives and address the overarching question, the research team will use current generation Mixed (or “Augmented”) Reality (MR / AR) technology (i.e. a Microsoft HoloLens®) to understand the extent to which this mode of education may allow students to demonstrate knowledge and judgement similar to that which is gained through physical design and construction learning environments. The research will involve several phases of work aimed at specifically exploring MR-enabled learning experiences related to: Heart (Year 1); Head and Hand (Year 2); and Head, Heart, and Hand (Year 3).

Highlights from Year 1

This project is an ongoing collaborative effort among researchers in departments of civil engineering and/or construction management (at Arizona State University (ASU) and California State University-Fresno), and engineering education (at Virginia Tech). This project began in Fall 2017. During the first year, the research team achieved several objectives:

1. Development of MR and Virtual Reality (VR) prototypes of Fresno State's SMUD Tiny House Models. (See Figure 1)
2. Collected video data from more than 40 design/build experts and novices/students navigating the augmented environments to explore the extent to which they can identify Heart-related design concerns that would need to be modified to make the tiny house more handicap accessible.
3. Conducted expert focus group with current industry practitioners to understand decision-making processes related to designing buildings for occupants with needs different from themselves.
4. Designed and collected survey data to understand differences in design/build experts' and novices' opinions about which heart-related values should be prioritized in undergraduate civil engineering education.
5. Interviewed 12 students who were involved with SMUD Tiny House Competition at Fresno State to document the learning reported by students completing physical design and construction learning experiences; this will serve as a baseline for future assessments.
6. Submitted/presented three conference papers ([redacted]) and have three journal manuscripts under review

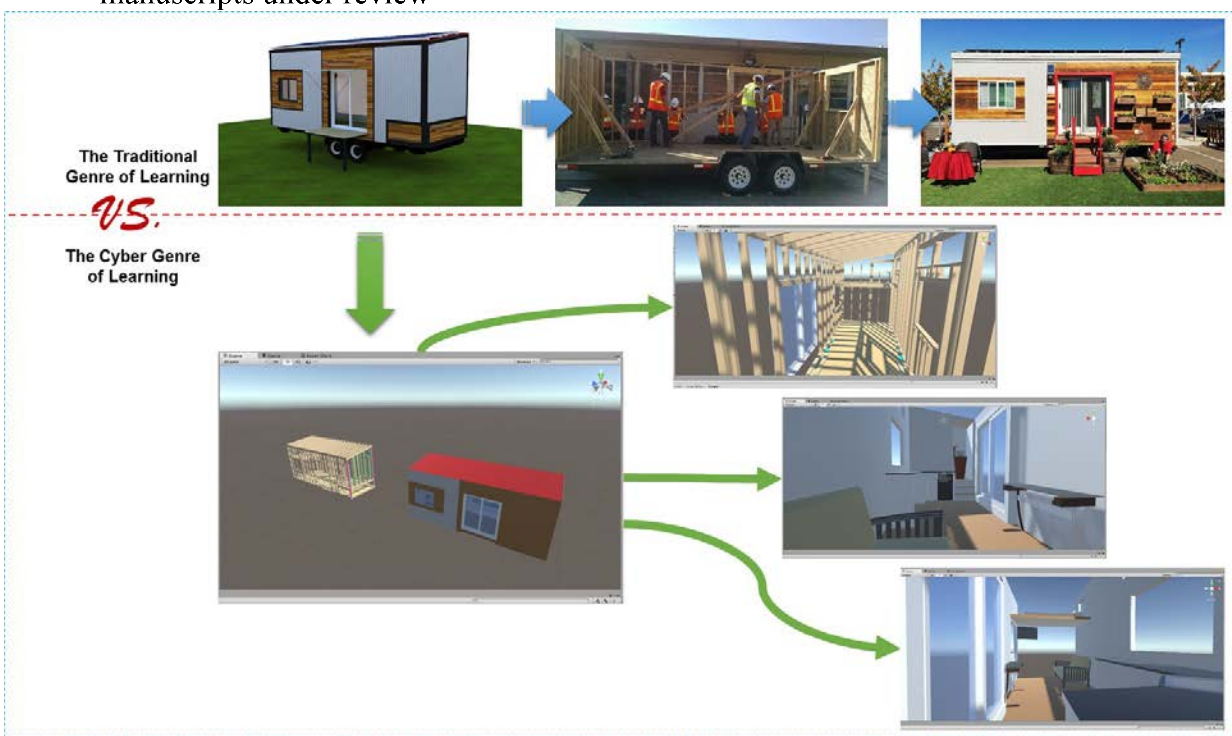

Figure 1. Comparison between physical tiny house design and construction activity (at the top) and the BIM-based components that will be used for the MR activity.

Overview of Plans for Years 2 and 3

In the next two years, the research team is planning several key phases. The phases include:

Year 2: Develop MR experience for supporting learning related to Head and Hand apprenticeships. This experience will involve students using MR to virtually build a small wood structure at ASU. The results will be compared to the performance of students at Fresno State who physically build the same wood structure. The team will design and implement assessments to see if the design comprehension (Head) and construction sequencing (Hand) behaviors are observed in both physical and virtual groups.

Year 3: Develop MR experiences for supporting learning related Head, Heart, and Hand apprenticeships. Based on the findings from years 1 and 2, the team intends to challenge students to complete a MR design and construction activity and consider attributes related to all three apprenticeships. The current plan is to have students assess design and construction considerations for a space designed for small children, to make them consider both intellectual and practical considerations required for this space, while also assessing the needs of building users different from themselves.

Anticipated Outcomes

The researchers hope to continue to find results that offer empirical validation to demonstrate how immersive MR experiences may be designed to enable novices to demonstrate learning behaviors that effectively mimic those observed by both experts, and other novices who completed physical design and construction learning activities. If the team is successful, the findings will help to guide future researchers, educators, and practitioners on how to develop these MR experiences to be able to educate and train novice individuals better than the current approaches, while also using fewer resources than have been traditionally required for physical design and construction learning experiences.

Additional Information and Resources

- Fresno State's SMUD Tiny House Competition Webpage
- Local News Story About This Research at Fresno State

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