The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
ASEE
Paper ID #43922

Redefining Assessment: Implementing an XR Framework for Accreditation in Construction Education

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Abstract

Many higher education institutions use different teaching methods to provide construction education that meets the accreditation requirements. In the United States, most construction management schools receive accreditation through either the American Council of Construction Education (ACCE) or the Accreditation Board of Engineering and Technology (ABET). The paper proposes using an Extended Reality (XR) preliminary framework for active learning that satisfies ACCE Student Learning Outcomes (SLOs) for all construction courses. The framework establishes consistent teaching pedagogies to meet learning outcome requirements. Assessing students effectively during the pandemic, particularly in virtual classes, remains challenging. However, the XR framework can be deployed to students of any modality, thus solving this problem. The paper identifies construction courses where the XR framework can be included as in-class activities to promote knowledge retention and lays out modules of XR activities. The paper provides an overview of how students can understand the fundamentals of utilizing advanced tools in their classroom, which helps them graduate career ready. Overall, with this innovative XR framework, higher education institutions can provide an immersive and effective learning experience while meeting the stringent requirements of accrediting bodies.

Keywords: XR framework, Construction technology, Student learning outcomes, construction accreditation

Introduction

Construction Management (CM) is a popular and well-established degree program offered by numerous institutions in the United States and other parts of the world. According to data from NCES, around 100 higher education institutions in the United States offer construction management degrees [1]. To maintain the quality of education in this field, each accreditation body has established several student learning outcomes (SLOs). According to the ACCE database, 72 bachelor's degrees in construction management programs are accredited by their program [2]. Additionally, there are 15 associate degrees and five master's degrees accredited by the ACCE as of 2022. Similarly, ABET data shows that 20 construction management degree programs in the United States are accredited by ABET at various levels [3].

The CM curricula in most U.S. universities adopt pedagogical approaches with lectures, labs, and projects. This helps them in evaluating students through various assessment tools. In addition, students complete their undergraduate degree with an average of 130-140 credit hours with the addition of one or two mandatory co-ops or internships during their course of study. While this is not the same for all CM programs, the authors focused on one of the universities in the New England region to establish this research. These mandatory work experiences help the students to gain a practical understanding of how subject matter is applied to real-world projects while at the same time achieving specified metrics for assessment through the organized learning outcomes from the accreditation bodies.

According to the ACCE, there are 17 learning outcomes that students must achieve through various courses offered in the construction management program. These courses typically provide lecture content, hands-on labs, and software integration in their course makeup. The learning outcomes from the ACCE include understanding the foundations of estimation, scheduling, and project management for the construction of built projects through concepts, digital tools, and hands-on laboratories.

During the pandemic, most higher education institutions faced challenges in achieving proper measurement and benchmarking against the assessment due to the quick adoption of hybrid learning environments [4]. This research aimed to evaluate and develop an extended reality (XR) framework that could directly measure ACCE-related SLOs (Student Learning Outcomes) using a bachelor's and master's ACCE accredited Construction Management program based in the New England region. However, the authors had to exclude the ABET evaluation due to time constraints and a lack of data from the selected university. They plan to include it as a future expansion of this research, with collaborative opportunities from other universities.

The goal of the paper is to create a framework for XR (extended reality) that can be utilized by educators in AEC (architecture, engineering, and construction) institutions to implement XR-based activities. These activities can assist in evaluating the student learning outcomes (SLOs) necessary for ACCE accreditation. The XR-SLO framework will provide educators with a consistent methodology for gathering ACCE data. However, the paper does not concentrate on assessment analysis. Rather, it focuses on developing a preliminary framework for XR-based assessment of SLOs. The authors plan to collect assessment data, analyze it, and establish assessment criteria as part of their future work.

Research Motivation

Several researchers have introduced and implemented VR and AR into construction education [5]. Integrating technology in education has always enhanced students' productivity and learning strategies. There are two primary reasons for this research: 1) to introduce technological innovations in the classroom that not only showcase fancy, state-of-the-art equipment but also help students achieve their SLOs by engaging with technological innovations that are quickly becoming best practices within the industry, and 2) to provide an alternative pedagogical approach for educators to use XR framework, which in turn enables the expansion of educational models to cater to both traditional and non-traditional student populations. These XR learning modules are particularly beneficial for non-traditional students who are part-time learners and engage in asynchronous or synchronous online learning since they can access any XR module virtually through the learning management system.

Technological Trends in the Construction Industry

In recent years, computing and digital technology advancements have piqued the interest of construction companies looking to improve their projects. Using new equipment, software, and tools can positively impact construction projects by increasing productivity, improving safety rates, and increasing the success rate of winning construction projects and bids. Interestingly, even Artificial Intelligence (AI) has made its way into the construction industry, with tools like

ChatGPT being utilized to realign project schedules and improve overall project efficiency . Researchers have used ChatGPT to explore integration with digital twins for healthcare, writing manuscripts, and adapting classroom education to achieve student learning outcomes [18]-[20]. It is worth noting that tools such as ChatGPT, which have emerged recently as AI-powered assistants, are still in the process of gathering data to establish their reliability. On the other hand, other AI tools show great promise for the construction industry. These AI tools have demonstrated their ability to analyze large amounts of data, identify patterns, and provide valuable insights that can help improve construction processes. Furthermore, they can be used to optimize project management, reduce costs, and enhance safety on construction sites.

With a value of $960 billion, the construction industry faces challenges such as labor shortage, safety concerns, and slow adoption of automation [18], [21]. The recent trends in automation and robotics offer hope for industries to overcome challenges [21]. The utilization of these technologies in the healthcare industry is not fully realized compared to other industries such as mechanical, retail, and food [22]. It is acknowledged that the opening of the major roadblock for the construction industry relates to practical challenges related to physical, on-site construction processes and related changing field conditions and the lack of curriculum knowledge based on the computing side of the construction industry to relate to these changing parameters. According to Boston Dynamics, the pioneer in developing construction-specific robots, there are few case studies of utilizing their flagship robot, Spot, in national and international construction projects [23], [24]. Although upfront costs may be a barrier, the industry believes implementing new technology will benefit traditional workforce development and productivity.

VDC in Construction

The construction industry has been lagging in adapting to visualization technologies to enhance productivity in standard projects. However, things are changing, and in the last decade, there has been a significant increase in the utilization of computerized visualization technologies in construction. This technological advancement has led to the development of a Virtual Design and Construction (VDC) division within many construction companies, which focuses on the integration of technology and tools into traditional construction projects. The introduction of VDC has created new opportunities in the industry, such as careers in VDC specialization, Building Information Modeling (BIM) coordination, technology integration management, and project control specialization. While these jobs are believed to be primarily associated with architectural majors, construction management graduates are preferred due to their extensive knowledge of means and methods, estimating, scheduling, and project management.

Technology in Construction Education

There are several studies on implementing advanced computing in construction and civil engineering education [25]-[32]. Educators utilize a lot of different technologies in education, trying to provide the foundations for the students in their curriculum, which helps them during their career on technology adoption [19], [23], [33]-[35]. However, many institutions still utilize these technologies on a small scale because of budget and infrastructure constraints within standard institutions [38]. According to the study [39], 18.9 % of college students have video gaming disorders, which is alarming. The paper discusses students' interest in game-based education and technological advancements like XR. It aims to use this interest to improve knowledge transfer and retention and equip students with skills to bridge the gap between industry and academia. This will help save the industry time, money, and resources in training and deploying employees for the VDC side of construction. The paper also suggests incorporating new technologies like XR can improve construction productivity.

The paper uses ACCE accreditation to demonstrate how the XR framework can be integrated into an XR-based curriculum to meet the accreditation requirements and benchmarks. It details an XR framework that can be implemented by CM institutions that follow ACCE accreditation as part of their student learning outcomes and program objectives.

XR in Construction Education

Extended Reality (XR) technologies, such as virtual reality (VR), augmented reality (AR), and mixed reality (MR), can provide significant benefits in the field of construction education. They help improve understanding of AEC subdisciplines, enhance the visualization of complex concepts, and increase student engagement and self-efficacy [6]. XR is particularly useful for safety training and risk management, with VR being the most used tool [7]. Integrating deep learning and XR technologies in construction engineering and management presents further opportunities for research [8]. The use of XR technologies in the AEC industry, particularly in converting BIM models to VR, AR, and MR, has been explored [9]. According to [10], students can quickly gain experience by developing and critiquing construction schedules in a full-scale virtual environment. XR has been used in various aspects of construction education to improve students' knowledge retention.

Research Objectives

To develop XR-based active learning pedagogy for the construction curriculum, the authors propose the following objectives:

1. Identify the ACCE SLOs mapped with the major construction management courses.
2. Develop a preliminary XR-SLO framework that serves as a foundation to include XR-based learning modules to assess ACCE accreditation in a construction management curriculum.

Research Methodology

The research methodology for this paper involves mapping ACCE SLOs with proposed XR modules, developing an XR implementation framework, and assessing student's performance using a preliminary XR module. Figure 1 illustrates the research study methodology.

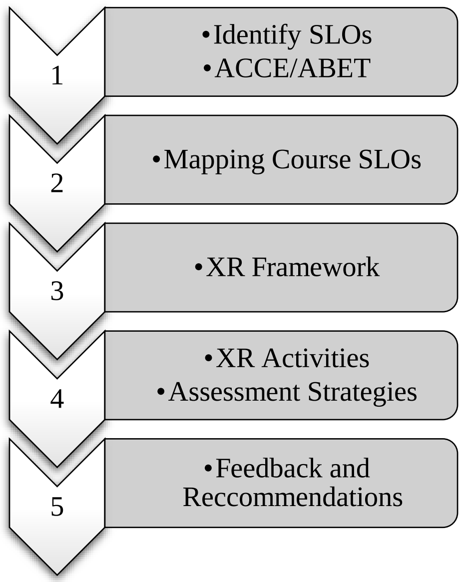

Figure 1: Research Study Methodology

1. Identifying ACCE Course SLOs

ACCE has developed a comprehensive set of twenty learning outcomes for undergraduate students in the field of construction management. These learning outcomes aim to establish a standard content delivery and assessment procedure that ensures that students receive a well-rounded education in construction management.

To implement these learning outcomes, ACCE has created a sample framework that maps the outcomes to specific courses in a sample curriculum. The framework, represented in Figure 2, provides a detailed breakdown of the direct and indirect learning outcomes assessment across different courses. This ensures that each student receives a thorough and structured education covering all aspects of the discipline and regularly monitoring and assessing their progress.

2. Mapping Course SLOs

It is essential to map the ACCE SLOs with the courses to assess students and understand their performance threshold metrics. Figure 2 provides a sample framework utilized in one of the construction management programs of study. Figure 2 shows that the academic unit utilized 19 different courses to collect direct and indirect assessment data from the students who enrolled in those courses.

STUDENT LEARNING OUTCOME MATRIX	CONNM 1000 Intro to CM	CONNM 1200 Building Construction	CONNM 1500 Construction Graphics	CONNM 1600 Heavy Const Equipment	CONNM 2000 Construction Surveying	CONNM 2100 Statics and Strength of Matls	CONNM 2200 Estimating	CONNM 2500 Building Systems	CONNM 2600 Wood and Steel Analysis	CONNM 3000 Material Testing and QC	CONNM 3100 Const Project Management	CONNM 3201 Const Project Scheduling	CONNM 3500 Advanced Estimating	CONNM 3600 Concrete Analysis	CONNM 4000 Const Project Controls	CONNM 4100 Const Business and Finance	CONNM 4200 Const Safety and Risk Mgmt	CONNM 4600 Construction Law	CONNM 5500 CM Senior Project	Senior Exit Survey	Senior Project Panelist Survey
1. Create written communications appropriate to the construction discipline.									I/D											I	
2. Create oral presentations appropriate to the construction discipline.																			I/D	I	I
3. Create a construction project safety plan.																	I/D			I	
4. Create construction project cost estimates.													I/D							I	I
5. Create construction project schedules.												I/D								I	I
6. Analyze professional decisions based on ethical principles.							I/D													I	
7. Analyze construction documents for planning and management of construction processes.											I/D									I	I
8. Analyze methods, materials, and equipment used to construct projects.				I/D																I	I
9. Apply construction management skills as a member of a multi-disciplinary team.																			I/D	I	
10. Apply electronic-based technology to manage the construction process.															I/D					I	I
11. Apply basic surveying techniques for construction layout and control.					I/D															I	
12. Understand different methods of project delivery and the roles and responsibilities of all constituencies involved in the design and construction process.											I/D									I	
13. Understand construction risk management.																	I/D			I	I
14. Understand construction accounting and cost control.																I/D				I	
15. Understand construction quality assurance and control.										I/D										I	I
16. Understand construction project control processes.															I/D					I	I
17. Understand the legal implications of contract, common, and regulatory law to manage a construction project.											I/D									I	
18. Understand the basic principles of sustainable construction.	I/D																			I	I
19. Understand the basic principles of structural behavior.									I/D					I/D						I	
20. Understand the basic principles of mechanical, electrical, and piping systems.								I/D												I	

Figure 2 Sample ACCE SLO Framework

Note: ACCE recently changed their number of SLOs from 20 to 17.

In addition, the indirect assessment data is collected using a senior exit survey and senior capstone panelist survey. These panelists are the industry judges who grade the senior project presentation and evaluate students' learning experiences.

3. XR Implementation framework

The paper aims to develop a preliminary extended (XR) implementation framework that can be utilized in any construction management program to include XR-based activities in classroom education. Extended reality is a terminology that includes both physical and digital reality. XR can be a standalone virtual reality module, a standalone virtual reality module, or a blend of both VR and AR. As discussed earlier, several studies utilize immersive technologies in education and in the construction industry [11], [12], [13], [14], [15], [16], [17]. The authors of this paper aim to focus specifically on construction management and ACCE SLO mapping for the XR framework. During this process, it is important to identify the right courses to develop these XR frameworks since the framework is integrated with the XR activities and assessment through the activities.

4. Develop XR based activities

The authors have developed an innovative and engaging VR-based activity to enhance the learning experience of students studying SLO 7. This activity enables students to immerse themselves in a virtual construction site experience using VR goggles. The virtual site visit is accessed through a link that takes students through several views of a 360-degree image of the construction site, embedded with multiple-choice questions that test their knowledge. This virtual site visit is exclusively available for students enrolled in the Introduction to Construction Management and Construction Graphics courses. The VR-based activity is designed to provide students with a comprehensive construction site experience, giving them a better understanding of the real-life challenges associated with construction management. Figure 3 provides an example of what students can expect to see in the VR site visit.

Figure 3 Example views of VR site visit with multiple choice questions embedded.

5. XR-SLO Framework

Table 1 explains the XR-SLO framework, which includes the ACCE SLOs, courses associated with the SLOs, proposed XR activity, Assessment tools, and software/tools that can be utilized to develop these XR activities.

Table 1 XR-SLO Framework for the Undergraduate ACCE SLOs

ACCE SLO Numbers	CM Courses	Possible XR Activities/Modules	Assessment tool	Software/Tools
1	Wood and Steel Analysis	Develop a VR-based virtual presentation to	Record the presentation and	VR hardware and Mic

		analyze the structural steel.	grade them based on the rubrics	
2	Senior Capstone Project	Develop site logistics using immersive VR tools	Assess the student final presentation based on the VR site logistics developed	Thing link/VR goggles
3	Construction Safety and Risk Management	Utilize 3M safety VR modules	Assess student performance and safety decisions in the VR modules	3M Safety VR modules
4	Advanced Estimating	Visualizing the AR structural members utilizing measuring tools and estimating quantity take-offs	Assess students based on their answers on the quantity take-offs	AR Hardware, HoloLens, Revit Models
5	Construction Project Scheduling	Develop an AR Synchro model and let students identify the issues in Construction sequencing	Assess how many issues that the students can identify within the timeframe provided	HoloLens, Synchro, Revit Models
6	Estimating	Provide games in VR that students make ethical decisions to move to the next level	Assess how many levels the students can reach	Unity/ Unreal Engine
7	Construction Project Management	Develop VR site visits and provide 2D plans	Assess the data from the VR Quiz embedded	Thing link, 360 Images of the construction site
8	Heavy Construction Equipment	Develop VR games on selecting the right heavy equipment based on the needs of a construction project	Assess the number of right and wrong answers and develop a performance index	Unity/Unreal engine
9	Senior Capstone Project	Utilize Mozilla education hubs and engage students in teamwork	Assess the interaction of students in the team environment	Mozilla VR Education Hubs

10	Construction Project Controls	Introduce VR-based clash detection using Navisworks	Assess the number of clashes that the student can identify	Autodesk Navisworks, VR platforms
11	Construction Surveying	Develop XR survey labs for building layouts	Assess the lab report developed by the students	XR Deploying platforms and Unity
12	Construction Project Management	Utilize Autodesk Collaborate and HoloLens to manage projects in AR	Assess the student's performance	Autodesk BIM Collaborate and AR platforms
13	Construction Safety and Risk Management	Utilize 3M safety VR modules	Include questions on risk assessment and assess student performance	3M VR Modules and Learning Management Systems
14	Construction Business and Finance	Visualizing the AR structural members utilizing measuring tools to estimate cost and quantity take-offs, and using Assemble systems	Assess the student answers on the cost	Assemble, HoloLens
15	Material Testing and Quality Control	Develop an XR lab that can provide thermal images on the exterior face of the building to determine the energy leaks and floor flatness	Assess the students based on a quiz on the same XR lab	HoloLens, Thermal Imaging Camera, Unity
16	Construction Project Controls	Develop an AR walkthrough using Matterport and provide information on the AR module	Assess the students on the information added to the AR Module	Matterport Scans, HoloLens
17	Construction Project Management	Provide a VR-based gaming scenario on legal aspects	Identify the chosen options on VR	Unity, Unreal, VR Hardware
18	Introduction to Construction Management	Develop an immersive LEED logistics of LEED building in VR	Assess the students on the quiz embedded in the VR	Thing link, LEED credits, VR Hardware
19	Concrete Analysis	Develop a VR beam/column stability analysis model that fails on overloads	Assess the students on their right calculation that will keep the	Unity, Unreal, VR Hardware

			beam/column stable on VR	
20	Building Systems	Integrate Navisworks with VR add-in and allow students to identify the clash detection in VR and document it in Procore	Assess the number of clashes created and grade students based on their performance	Navisworks, VR Hardware, integrating apps/add-ins

Evaluation Mechanism

Table 1 contains a comprehensive overview of the XR-SLO framework, which is designed to facilitate immersive and engaging learning experiences using extended reality (XR) technologies. This table provides detailed information about the available XR modules and activities, as well as the various assessment tools that can be used to evaluate these modules. Additionally, the table outlines the software and tools that are necessary to create these modules, ensuring that educators have all the resources they need to implement XR technology in their classrooms.

One of the key benefits of using XR technology in education is the ability to assess student learning in new and innovative ways. As such, Table 1 also provides insights into the various assessment strategies that can be employed to evaluate XR modules. These assessment tools can be integrated into the development process of the XR module, or they can be administered as surveys, quizzes, or assignments through a learning management system (LMS). Overall, the primary objective of this work-in-progress paper is to establish a comprehensive XR framework that includes detailed evaluation mechanisms and data-driven results. This framework can serve as a valuable resource for educators who are looking to implement XR technology in their classrooms, and it can help to ensure that students receive the best possible learning experiences using immersive and engaging XR modules.

Discussions and Future Work

The paper being discussed in this context presents a preliminary framework that aims to assess student knowledge retention in relation to the required Student Learning Outcomes (SLOs) for ACCE accreditation standards. The framework intends to expand the integration of XR-based modules throughout the Construction Management Curriculum of the sample program. The primary objective of this framework is to foster the adoption of cutting-edge pedagogy and methodologies for knowledge transfer and retention assessment. The authors believe that using XR-based learning modules will significantly enhance students' educational experience. XR technologies provide multiple modalities of course deployment and enable access to non-traditional student populations. This, in turn, creates opportunities for a larger subset of students to pursue a degree in construction management. Such an increase in potential graduates will help to meet industry demand for skill sets that are in high demand.

The proposed framework is intended to expand the integration of XR-based modules throughout the Construction Management Curriculum. The authors will evaluate student feedback on using these XR modules, which will be used to improve the learning experience. The feedback will assist the authors in refining the XR-SLO framework, making it more effective and applicable to future students. Overall, this framework is designed to enhance student learning outcomes and promote the adoption of modern pedagogy and methodologies for knowledge transfer and retention assessment. The authors hope the proposed framework will be useful for others seeking to improve their curricula and enhance student learning.

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