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Understanding Students' perceptions of Construction Technology Utilizing UTAUT Framework

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While technology adoption promises benefits like cost savings, safety improvements, and enhanced collaboration, the construction sector traditionally lags in adopting these innovations, leading to sustained inefficiencies. The emergence of Construction 4.0, aligned with Industry 4.0 principles, integrates emerging technologies to revolutionize design, construction, and asset management. Amidst these advancements, the construction workforce, particularly students in architecture, engineering, and construction (AEC) programs, plays a pivotal role in industry transformation and technology advancement. While digital technologies and construction innovation are widely accepted in construction education, it is unclear how much such acceptance will translate into students' future usage of construction technology when they enter the industry. Utilizing the Unified Theory of Acceptance and Use of Technology (UTAUT) framework, the study aims to predict and understand students' technology adoption, providing valuable insights for enhancing current education on construction technology and preparing the future workforce for industry advancements. This study distributed surveys to AEC students, and 88 valid data were obtained and analyzed. It was found that students' effort expectancy and behavioral intention vary across different educational levels and working experiences. The results emphasized the significance of persistence in incorporating the construction technology curriculum in construction educational programs.

Key Words: Construction 4.0, Construction Technology, Technology Acceptance, UTAUT, Construction Education

Introduction

The construction industry employs millions of people in the United States and is a cornerstone sector for the US economy. However, its productivity is notably lower in comparison to other sectors (Firth et al., 2022; Li et al., 2023). This low productivity is observable in different phases of construction projects such as supply chain, design, build, operation, and end of life. Numerous studies have identified the sectoral benefits of adapting technologies for the construction industry, including cost and time savings, enhanced safety, better time and cost predictability, improved project quality, sustainability, collaboration and communication and industry image (Sawhney et al., 2020). However, the construction industry has traditionally been slower or unsuccessful in adopting new technologies compared to other industries, which results in sustained inefficient performance cost and productivity (Maali et al., 2022). Meanwhile, there are some key challenges the construction sector has been suffering, including workforce shortage of young talent.

In the fourth wave of technological advancement (Industry 4.0), the AEC (Architecture, Engineering, and Construction) community should be ready to embrace and implement emerging technologies in their working environment. Drawing inspiration from the principles of Industry 4.0, Construction 4.0 is crafted through the amalgamation of emerging trends and technologies, offering the potential to revolutionize the way we design, construct, and manage assets within the built environment (Sawhney et al., 2020). The construction industry is at the cusp of this transformation, and the future workforce in the construction industry needs to be prepared for such transformation.

In construction education, digital technologies and construction innovation, such as computer applications in construction management and Building Information Modeling, are widely accepted (Adhikari & Meadati, 2021). Students registering in the AEC educational programs represent the future workforce in the construction industry and are the driving forces of the construction industry advancement. The students in the junior and senior levels have a higher awareness of digital technology in construction education (Adhikari et al. 2020). However, it is unclear how much such awareness will translate into students' future usage of construction technology when they enter the industry. Therefore, understanding their current experiences and perceptions of digital technologies and construction innovation (i.e., construction technologies) becomes the first step in advancing the industry's technological advancement and preparing students for the industry transformation. In this study, construction technologies are categorized into three themes such as Digital and computing technologies, Cyber Physical Systems, and Digital Construction Management Software. The examples of these three themes are:

- Digital and computing technologies: such as Building Information Modeling, 360 reality capture, Virtual and Augmented Reality, Laser scanning, Artificial Intelligence
- Cyber-Physical Systems (CPS), such as robots, drones
- Digital construction management software: such as software for estimating, scheduling, accounting, and project management

This study aims to understand AEC students educational and working experience with construction technology, and their perceptions on it. The unified theory of acceptance and use of technology (UTAUT) is applied in this study as a guiding framework. This model can be used to predict technology adoption, and explain and assess users' technology adoption, which can provide insights into the facilitation and improvement of technology adoption (Dashti & Viljevac-Vasquez, 2020). By understanding the future workforce's perceptions of construction technology with the help of UTAUT, this study can help predict their technology adoption in the future, and provides insight into how much the current education on construction technology would translate into future usage and what aspects of current education can be further improved or strengthened.

Theoretical Background

The unified theory of acceptance and use of technology (UTAUT) is applied in this study as a guiding framework. UTAUT integrated the theory of reasoned action (TRA), the technology acceptance model (TAM), the motivational model (MM), the theory of planned behavior (TPB), the combined TAM-TPB model, the model of PC utilization (MPCU), the IDT and the social cognitive theory (SCT). As an integration of eight dominant theories and models applied for technology or innovation adoption, this theory brought together alternative views on user and innovation exception (Williams et al., 2015). The UTAUT model proposes that four fundamental factors (performance expectancy, effort expectancy, social influence, and facilitating conditions) directly influence behavioral intention and, consequently, actual behavior (Figure 1). Additionally, these factors are subject to moderation by demographic characteristics such as gender, age, and experience (Venkatesh et al., 2003).

UTATU has been widely applied in higher education to evaluate students' perceptions and appearance toward digital innovations and systems, such as handheld devices, early warning systems and online learning programs (Almaiah et al., 2019; Handoko, 2019; Raffaghelli et al., 2022). The AEC sector has also adopted similar models to assess the acceptance and use of various technologies from multiple levels. For instance, Howard et al. (2017) applied the model to investigate Building Information Modeling adoption at the organization and project levels.

This study aims to understand AEC students' perceptions (i.e., performance expectancy, effort expectancy, and intention to use) of construction technologies given their perceived facilitating conditions and social influence, and how students' literacy skills and demographic characteristics affect their perceptions of construction technologies. Demographic characteristics include age, gender, and experience (learning and working experience with construction technologies).

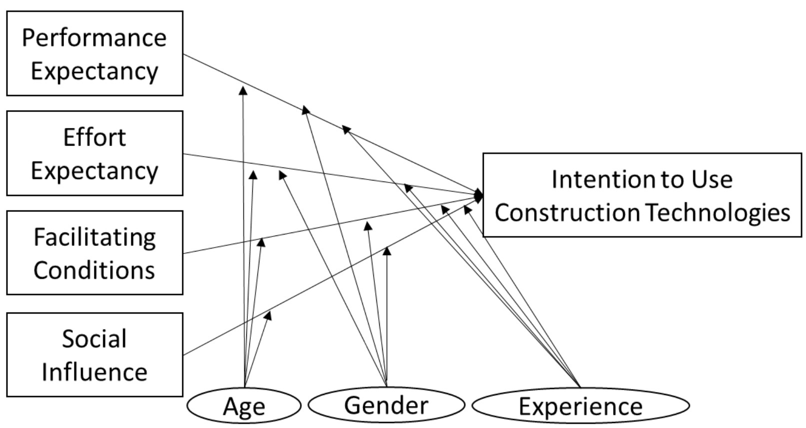

Figure 1. Conceptual model (adopted from Nikou & Aavakare, 2021; Venkatesh et al., 2003)

Research Methodology

Data Collection

This study applies the UTAUT framework to evaluate construction students' perceptions of digital technologies and construction innovation. An online survey was distributed to AEC students at Kennesaw State University using the Qualtrics platform. To gather insights from the students, data collection occurred in Fall 2023, spanning a five-week period. The survey encompassed two sections: the first section involved inquiries about the respondents' demographic characteristics, the second contained items related to the conceptual model constructs, and there were open-text fields where respondents could offer additional insights about their experiences. The demographic questions used in this study include respondents' gender, age, major, year in the major, and their working and learning experiences with construction technologies. In terms of the construct measurement items, participants were instructed to respond on a five-point Likert scale, ranging from one ("Strongly disagree") to five ("Strongly agree"). The questionnaire was subsequently distributed by sending survey invitations to students' email accounts. Proper statistical tests and descriptive analysis were applied to analyze the collected data.

Measures

Performance expectancy: The degree to which a student believes that the use of construction technologies enhances the performance of learning and working activities. This was evaluated by four Likert-scale statements adapted from Venkatesh et al. (2012). An example statement is 'Using construction technology increases my chances of achieving the goals that are important to me'. A higher score indicates the student is more likely to believe that construction technology can enhance their performance.

Effort expectancy refers to the extent of ease associated with students' use of construction technology. This was evaluated by four Likert-scale statements adapted from Venkatesh et al. (2012). An example statement is, 'Learning how to use construction technology is easy for me'. A higher score indicates a higher level of ease associated with construction technology ease.

Intention to Use: refers to the degree to which a student has formulated conscious plans regarding whether to use construction technologies for learning and working purposes. This was evaluated by three Likert-scale statements adapted from Chao (2019). An example statement is 'Assuming I had access to construction technology, I intend to use it (for learning/working purposes).'

Facilitating conditions is defined as the degree to which a student believes that an organizational and technical infrastructure exists to support the use of construction technologies. An example statement is 'I have the resources necessary to learn/use construction technology'. The social influence is the degree to which a student perceives that important others believe they should use construction technologies. An example statement is 'People who influence my behavior think that I should learn/use construction technology.' Statements for both factors were adapted from Venkatesh et al. (2012).

Moreover, student learning experiences with construction technologies, working experiences (with construction technologies), and their perceptions of technology usage in these learning and working activities were also collected to gain more insights into their background information.

Data Analysis and Discussion

Eighty-eight valid data were collected and processed in IBM SPSS. The majority of the students are male (76.14%) within the age range of 18-25 (89.77%). Most of them major in the construction management program (80.90%) in their first (25.84%), second (24.72%) or third (25.84%) year. Given their different ranks in the program, five categories describe their educational experiences with construction technology. More than half of the respondents reported having systematically learned construction technology in a class and used it for schoolwork. The most mentioned construction technology includes software for design (e.g., AutoCAD), construction management (e.g., Bluebeam and Procore) and BIM (e.g., Revit and Navisworks). Around one-third of the students reported having no or some knowledge of construction technology but had no experience using it. The rest of them reported themselves as having systematically learned about construction technology but not used any of it; or conversely, have used construction technology but have not systematically learned about it.

In terms of working experiences, this group of respondents was distinguishably diversified (Figure 2). 10% of the respondents have no working experience, and the other 10% of them have more than 5 years of working experience. 33% of the respondents have 0-6 months of work experience, and around 15% of the respondents have 6- 12 months, 1-2 years, and 2-5 years of work experience, respectively. For the 90% of respondents with work experience in the AEC industry, more than half have not used construction technology during their work. For the respondents who use construction technology, the most frequently mentioned experience is the application of digital construction management software (e.g., Procore, Microsoft Project, Auto CAD, and Bluebeam). This partially aligns with the knowledge and experience students gain in school. This moderate misalignment reflected that the industry has gradually adopted construction technology, while the progress is still behind the research results, where the benefits of BIM have been widely validated.

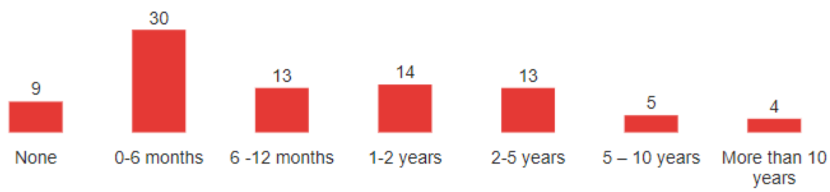

Figure 2: Respondents' work experience in the AEC industry

Analyzing respondents' five UTAUT factors (Table 1), it is observed that students find the use of construction technology somewhat easy (3.7102), they somewhat believe an organizational and technical infrastructure exists to support their use of construction technology (3.8210), and they somewhat perceive their important others believe they should use construction technology (3.6402). Students agree that construction technology can enhance their performance (4.1392) and present moderate intention to use it for learning or working purposes (4.1780).

Table 1: Descriptive Statistics for students' UTATU factors

UTAUT Factors	**Mean**	**Std. Deviation**
Effort Expectancy	3.7102	0.69469
Performance Expectancy	4.1392	0.77298
Social Influence	3.6402	0.82462
Facilitating Conditions	3.8210	0.69785
Behavioral Intention	4.1780	0.77797

These UTAUT factors don't present any difference across different gender or age groups. Interestingly, using descriptive analysis, effort expectancy difference was observed across different lengths of working experience (Figure 3). 10% of respondents who have worked for more than five years have more than average effort expectancy, which indicates a higher perceived ease of construction technology usage. The other 10% with no working experience present less than average effort expectancy, showing a lower perceived ease of construction technology usage.

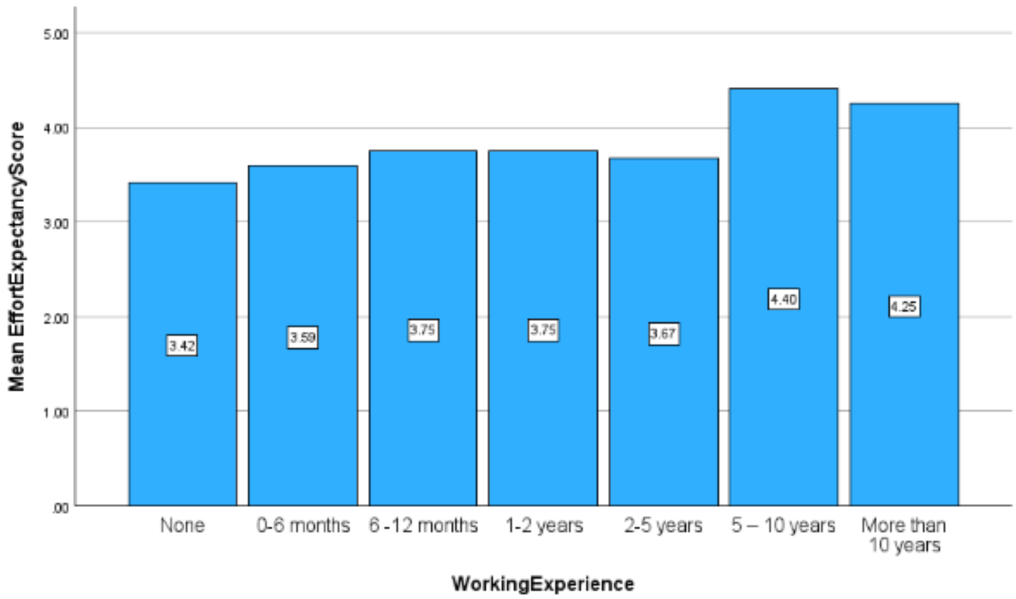

Figure 3: Effort expectancy across different lengths of work experience

In the educational setting, respondents who have systematically learned about construction technology present a higher perceived ease of construction technology usage (Figure 4). These differences may suggest that by systematically gaining knowledge on construction technology, or as the working experience grows, students would be more confident or comfortable in using construction technology (i.e., more likely to find construction technology easy to use).

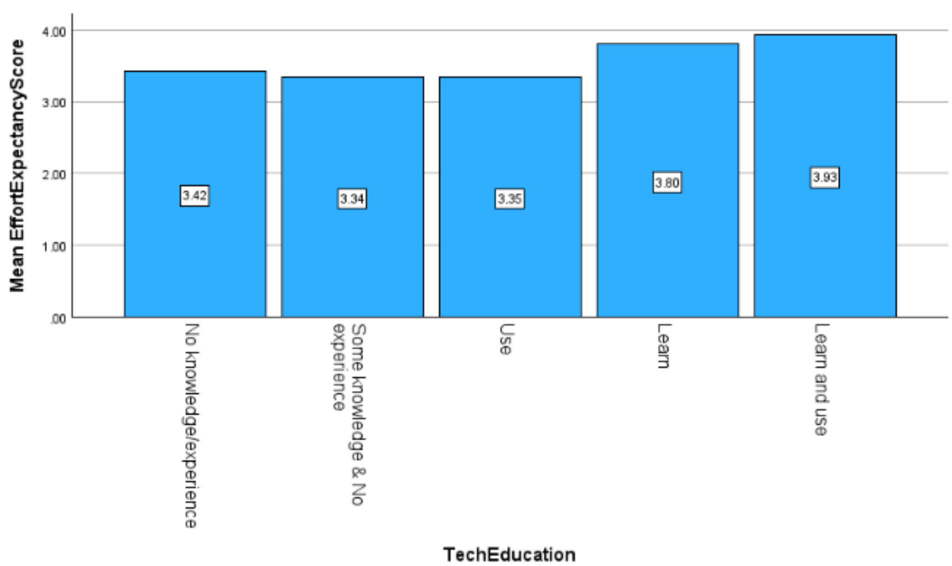

Figure 4: Effort expectancy across different levels of education on construction technology

Furthermore, the behavioral intention across different experiences (educational and working) was investigated in-depth using descriptive analysis and T-tests. In educational settings, respondents were split into two categories based on their reported usage of construction technology (Table 2). It was found that respondents who have systematically learned construction technology in school (4.31) have significantly higher intention to use construction technology compared to those who have not such experience (3.96), based on the T-test results (P value: 0.018). This finding indicated the significant impact of construction technology-related curriculum on students' intention to use it in the future.

Table 2: Descriptive analysis and t-test results of students' behavioral intentions across different educational levels

Systematically learn tech?	N	Behavioral Intention Scores		
		Mean	Std. Deviation	T-test significance
No	34	3.9608	0.91661	0.018
Yes	54	4.3148	0.64887	

Similarly, respondents were split into two categories depending on their construction technology usage (Table 3). The T-test result revealed that respondents who have used construction technology during work present significantly higher intention (4.34) to use it (P value: 0.042) compared to those who don't have this experience (4.05). Therefore, to help improve or reinforce people's intention to use construction technology, it is highly recommended that construction companies expose their employees to it. This effort would also significantly increase employees' construction technology acceptance level, ultimately increasing the companies' competencies in Industry 4.0.

Table 3: Descriptive analysis and t-test results of students' behavioral intentions across different working experiences

Use Tech at Work?	N	Behavioral Intension Intention Scores		
		Mean	Std. Deviation	T-test significance
No	50	4.0533	0.84209	0.042
Yes	38	4.3421	0.65982	

Conclusion

This study aims to comprehend the educational and working experiences of AEC students with construction technology, along with exploring their perceptions of it. Under the framework of UTATU, this study created a survey and distributed it to AEC students at Kennesaw State University. There were valid 88 responses, and their educational experiences with construction technology (construction technology) varied, with over half systematically learning and using construction technology for schoolwork. More than half of those with work experience had not used construction technology at work. The partial misalignment between students learning experiences in school and working experience in the industry suggests that the industry has been slowly embracing construction technology, with progress lagging behind research findings that have extensively affirmed the benefits of construction technology.

Analyzing UTAUT factors, it was found students generally present positive attitudes toward their intention to use construction technology. Given the relatively low UTAUT scores in effort expectancy, social influence, and facilitating conditions, these three directions may be considered to be improved in the future endeavors of promoting technology adoption in construction. Notably, effort expectancy varied based on working experience and education level. Students who systematically learned about construction technology in school demonstrated higher perceived ease of use. Further analysis revealed that students with systematic learning experiences or who have used construction technology for their work had significantly higher intentions to use it. In this study, as students reviewed a whole observation of construction technology, there was a lack of information to identify which types of construction technology play a more significant role than others in affecting students' UTAUT factors. Future studies should investigate how teaching different technologies can affect students' technology acceptance.

For the organizational level, this study emphasized the significance of persistence in incorporating the construction technology curriculum in their construction programs to better prepare students for the industry; such a workforce with higher intention of technology usage will advance the technological transformation in the industry. Moreover, educational institutions should increase students' awareness of existing construction technology resources they have access to improve students' perceived facilitation conditions. At the individual level, it is recommended that students actively involve themselves with construction technology usage during their work in the industry, which will also reinforce their intention to keep using it in the future. Similarly, it is highly recommended that construction companies expose their employees to construction technology, which would significantly increase their construction technology acceptance level, and ultimately increase the companies' competencies. Such reinforcement mechanisms will better prepare the individuals and the companies for the implementation of Construction Industry 4.0.

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