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Integrating Technology Adoption Theories into the Construction Management Education: A Pilot Study

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Technology adoption and innovation play important roles in maintaining a competitive advantage for construction companies and are known to have considerable influences on the performance of construction projects. However, the construction industry is very slow in technology adoption because of a wide range of cultural and organizational barriers. More importantly, one of the main barriers that have merely been discussed is the industry readiness for implementing new technologies. To prepare the next generation of professionals to adopt and diffuse new construction technologies, construction education needs to “set the pace” by understanding current and future construction industry challenges and potential technological developments solutions. With the notion that there are disparities of current construction education regarding adopting new construction technologies, this pilot study aimed to examine the undergraduate engineering student learning outcomes through an active and interactive-learning activity about technology adoption theory with the industry professionals. The feedback obtained from students demonstrated that their understandings of new construction technologies, teamwork skills, and intellectual and critical thinking skills were improved through the activity. The results will contribute to a larger-scale study that aims to identify the areas that need improvements and realignments to the construction management curriculum for both academia and practice.

Key Words: Technology Adoption and Diffusion, Construction Management, Construction Education, Learning Outcomes, Industrial Collaborations

Introduction

The construction industry contributes greatly to GDP in the United States, increasing to 690.70 USD Billion in the second quarter of 2021. Over the last decades, the construction industry has undergone major changes. And the shortcoming of current systems has been discussed in the literature (Straub 2017), emphasizing the critical need for enormous technological transformation and embracing new modes of information sharing and communication (Becerik-Gerber et al. 2011). “Technology” in construction refers to machines, tools, modifications to the process to solve day-to-day problems and achieve project goals from design to demolition in a more efficient way (Skibniewski and Zavadskas

2013). While adopting technology and innovation play important roles in maintaining a competitive advantage for construction firms and are known to have considerable effects on overall performance, safety, and efficiency (Sepasgozar et al. 2016, Goodrum and Haas 2004), the construction industry is very slow in technology adoption (Harty 2008, Sepasgozar et al. 2016). Loosemore (2014) argued that the low innovation rate in the construction industry is due to the industry approach toward innovations: innovation in the construction industry is incremental and will be adopted in response to problems rather than being proactive and planned in advance.

The decision to deploy new technologies is affected by many constructs like "intention to use (Bhattacherjee and Hikmet 2007) and "resistance toward use" (Hsieh et al. 2014). In addition, many reasons for this low adoption rate were identified in previous literature: a wide range of cultural and organizational barriers (Mitropoulos and Tatum 2000). These barriers can be exacerbated because of the uniqueness of projects, the dynamic nature of the industry, and, more importantly, the companies' culture and expertise with technologies (e.g., Ozorhon and Oral 2017).

Furthermore, one of the main barriers that have merely been discussed in the literature is the industry readiness for this change and whether the current workforce or future ones are ready to implement these changes (Becerik-Gerber et al., 2011). Since the innovation adoption process is different for various construction technologies (Sepasgozar and Davis 2018), students need to learn how to tailor the adoption approach based on project characteristics, technology type, and customer requirements. Today's engineering graduates also need to know how to work in multidisciplinary teams, promote engineering science and computer skills, and have a broader understanding of social science and economics, so they will be better prepared for adopting and diffusing new technologies in the construction industry.

To better prepare the next generation of workforce and professionals to adopt and diffuse new construction technologies, engineering education must "not keep the pace" with industry and need to "set the pace" by understanding current and future construction industry challenges and potential technological developments solutions. With the notion that there are disparities and insufficiencies of current engineering education regarding adopting new construction technologies, this pilot study aimed to examine the engineering student learning outcomes based on the Associations of American Colleges and Universities (AACU) guidelines through an active-learning activity about technology adoption theory. This pilot study, is a part of a larger study that, in the long-term, will contribute to academia and practice by identifying the areas that need improvements and realignments to the construction engineering and management curriculum.

Background

Adoption and Diffusion of Construction Technologies

In order to incorporate innovations or technologies in the construction industry, there are two primary constructs to be taken care of: (1) adoption, (2) diffusion of the technology. Adoption theories focused on micro-perspective on change by mainly examining individuals' decisions to accept or reject any innovation. However, diffusion theories focused on macro-perspective and how the community adopts, accepts, or rejects any innovation (Straub 2009). In other words, diffusion is a cumulative frequency of individual adoptions (Roger 2010) consisting of five steps: awareness, persuasion, decision, implementation, and confirmation (these steps are further discussed in the methodology section). Therefore, Roger (2010) primarily described the technology spread in the social system (i.e., knowing as a socio-economic viewpoint). Thus, while the adoption is not a single event (e.g., Kale and Arditi 2010), the first step toward it is the knowledge and openness of individuals.

Furthermore, some studies investigated the adoption from a psychological viewpoint based on the technology acceptance model (TAM) developed by Davis et al. (1989). This theory is based on individuals' perceptions of technology/innovation and how this perception eventually affects the use of technology. Davis identified two perceived characteristics about an innovation: perceived ease of use, which is the degree to a person believes that using this system requires minimum efforts, and perceived usefulness, which is the degree a person believes that incorporating that system will enhance his/her job performance. Park and his colleagues (2021) revised and utilized TAM to predict information technology adoption in the construction industry. Later in 2003, Venkatesh and his colleagues proposed the "united theory of acceptance and use of technology" (UTAUT) based on several social cognitive theories and theory of reasoned behavior (by Ajzen 1991). This theory suggested that performance expectancy, effort expectancy (influence by perceived ease of use), and social influence (based on subjective norms from the theory of reasoned behavior) can predict individuals' behavioral intention for using technologies. According to these adoption and diffusion theories, various factors may affect whether an individual (or a company)will decide to adopt a technology.

Previous literature in the area of construction innovation showed that established general adoption theories discussed above are mainly being used in the construction industry. These theories are designed based on knowledge outside of the construction industry, so they lack the construction-specific constructs such as supply factors, demands, skills, and technology costs (e.g., Mitropoulos and Tatum 2000). Very few studies studied the adoption process in construction projects (e.g., Mitropoulos and Tatum 2000; Peansupap and Walker 2005a) and often focused on information systems adoption (3D, 4D, and BIM). In this study, since the focus is on the general aspect of technology adoption, we applied UTAUT to illustrate the key determinants of the technology adoption process.

Methodology

The activity was offered in a junior-level class named Construction Management and Engineering. This course introduces the planning, administration, management, and cost of construction projects and methodologies utilized in executing specified designs. The activity was conducted in three steps: first, the instructor gave a lecture about technology adoption theories and assigned topics to student teams; second, students had one week to do research and prepare presentations; third, students gave presentations to the client from the industry and evaluated the learning outcomes of the activity. Meanwhile, the client evaluated students' presentations to select the technology s/he would like to adopt for her/his company. The details of each step are discussed in the following session.

Description of the Activity

The instructor gave a lecture about Technology Adoption. The lecture consisted of three parts. The first part is about the current situation of technology adoption in the construction industry. As shown in Figure 1 below, the construction industry has the largest difference between expected and actual investments in emerging technologies. The instructor initiated a discussion with students by using

Figure 1. The purpose was to give students opportunities to think about the phenomenon based on their own observations and experience in the industry critically. The instructor also was able to understand students' perceptions of technology adoption in the construction industry.

The instructor summarized students' answers and guided students to the technology adoption theory, which was the second part of the lecture. The emphasis of this part is explanations of cognitive processes and critical determinants of technology adoption. The adoption decision process describes five stages that individuals go through during their evaluation of innovation.

- Stage one is when an individual realizes an innovation.
- Stage two, persuasion, is when an individual accumulates a certain amount of knowledge about the innovation's features to make a personal judgment, which could determine the result will be positive or negative.
- Stage three, decision, has an outcome of an individual's choice to adopt or reject an innovation.
- Stage four, implementation, is when an individual act on his or her decision.
- Stage five, confirmation, an individual re-evaluates whether to continue or discontinue with the innovation adoption (Straub, 2009).

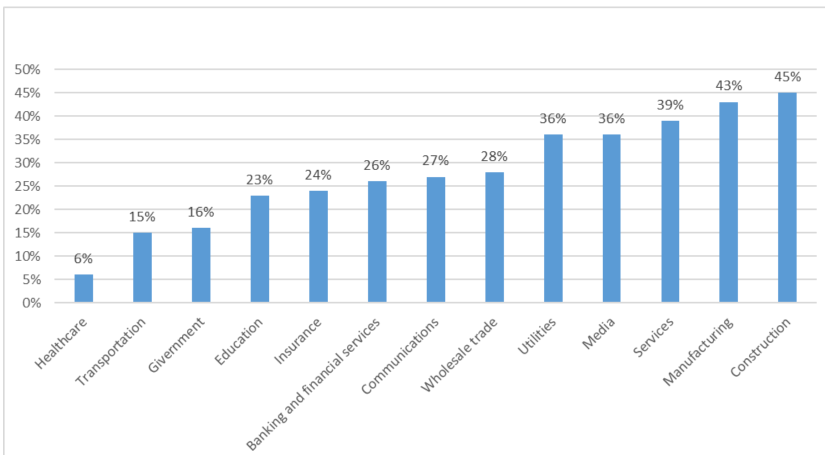

Figure 1. Average Difference between Expected and Actual Investments in Emerging Technology by Industry (adopted from Adam, 2019)

After, the instructor used the model (see Figure 2) to illustrate the key determinants of the technology adoption process. First, performance expectancy is reflected by the degree to which an individual believes that technology will assist them in performing job duties. Second, effort expectancy is reflected by the degree to which an individual perceives a particular technology to be easy to use. Third, social influence means the degree to which an individual feels social influence pressure to use a specific technology. Lastly, facilitating conditions are about the degree to which an individual believes conditions that his or her organization is supporting the change.

The last part of the lecture was the introduction of the client and the assignment of technology for students. In this activity, the instructor invited a project manager from a mid-sized construction contractor as the client, whose company did not adopt any technologies that will be presented by students later. The instructor introduced the basic background information of the client's position and company, such as job descriptions and services of companies. The instructor divided the class into three groups. Each group picked one technology that they would like to study for the presentation. The three technologies are Unmanned Aerial Systems (UAS), Virtual Reality (VR), and Building Information Modeling (BIM). The objective was to convince the client to adopt the technology by applying the technology adoption theories. Students used one week to prepare the presentation. They did research on the technology and its application. They also further studied the company about the ongoing projects and services. On the presentation day, each team gave a 15-20 minutes presentation to the client. The evaluation sheet (See Table 1) for the client was designed based on the key determinants of technology adoption (Im et al., 2011).

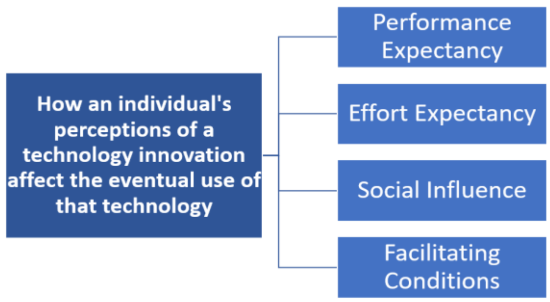

Figure 2. Key determinants of the technology adoption process (Venkatesh et al., 2003).

Table 1. Evaluation Form for the Client

Measurement items (name of the technology):
On a scale from 1 to 7, 1 being “Very Little” and 7 being “Very Much

Performance expectancy	I would find this technology useful in my job	1 2 3 4 5 6 7
	Using this technology enables me to accomplish tasks more quickly	1 2 3 4 5 6 7
	Using this technology increases my productivity	1 2 3 4 5 6 7
Effort expectancy	It would be easy for me to become skillful at using this technology	1 2 3 4 5 6 7
	I would find this technology easy to use	1 2 3 4 5 6 7
	Learning to operate this technology is easy for me	1 2 3 4 5 6 7
Social influence	People who influence my behavior think that I should use this technology	1 2 3 4 5 6 7
	People who are important to me think that I should use this technology	1 2 3 4 5 6 7
	The senior management of my company may be helpful in the use of this technology	1 2 3 4 5 6 7
Facilitating conditions	My company have the resources necessary to use this technology	1 2 3 4 5 6 7
	My company have the knowledge necessary to use this technology	1 2 3 4 5 6 7
	My company intend to use this technology in the next 12 months	1 2 3 4 5 6 7

Assessment

Student surveys were filled out on paper after presentations in class. The student's survey consisted of a series of questions and their evaluations of learning outcomes of this activity. The learning outcomes measured for this activity were created based on the Associations of American Colleges and Universities (AACU) guidelines on important learning outcomes for engineering students (Hood et al., 2019). The learning outcomes of this activity include: 1) enhancing the knowledge of the construction industry; 2) developing intellectual skills (e.g., critical or creative thinking, quantitative reasoning, problem-solving, etc.); 3) developing professional skills (e.g., written or oral communication, teamwork, etc.) 4) enhancing the sense of social responsibility. Each learning outcome was evaluated on a 7-point Likert-type scale, with 1 being "very little" and 7 being "very much." The survey is shown in Table 2.

Table 2. Learning Outcomes Evaluation Survey for Students

Construction Engineering and Management Technology Adoption Activity Evaluation		
No.	On a scale from 1 to 7, 1 being "Very Little" and 7 being "Very Much	
1	This activity helped me develop intellectual and critical thinking skills	1 2 3 4 5 6 7
2	This activity helped me argue effectively.	1 2 3 4 5 6 7
3	My understanding of the construction industry has increased.	1 2 3 4 5 6 7
4	I am capable of locating, evaluating, and using the information in the literature.	1 2 3 4 5 6 7
5	I am confident in my ability to communicate construction management knowledge effectively.	1 2 3 4 5 6 7
6	I understand professional responsibility related to technology adoption in construction.	1 2 3 4 5 6 7
7	Will this activity be helpful for the growth of my career?	1 2 3 4 5 6 7
8	The activity helped me further develop my writing ability.	1 2 3 4 5 6 7
9	The activity improved my verbal communication skills	1 2 3 4 5 6 7
10	The activity increased my ability to collaborate and work in teams.	1 2 3 4 5 6 7

Results

As described earlier, each learning outcome was evaluated on a 7-point Likert-type scale. A total of 12 students filled out the survey in this class. The authors calculate the average evaluation score for each learning outcome (See Figure 3). The score can reflect how the activity addressed a learning outcome. The higher score indicated a learning outcome was addressed better than others in this activity. As shown in Figure 3, first, the overall result is positive because the score of every learning outcome is above 4.00, which is higher than the mean value of 7; second, the learning outcome 4, which is "I am capable of locating, evaluating, and using the information in the literature," has the highest score; the learning outcome 8, "The activity helped me further develop my writing ability," has the lowest score. Learning outcome 3, "My understanding of the construction industry has increased," has the second-highest score, and learning outcome 10, "The activity increased my ability to collaborate and work in teams," has the third-highest score. Most students have heard of technologies mentioned, but they barely know their exact applications in professional fields. During their presentation preparation, they spent the most time searching and studying these technologies regarding their functions, limitation, current market. In this process, they found many case studies related to the application in the construction industry. In the meanwhile, students have limited time and a tight schedule to prepare the presentation, which challenges their teamwork and coordination skills. These reasons may explain why learning outcomes 4, 3, and 10 were ranked in the top three.

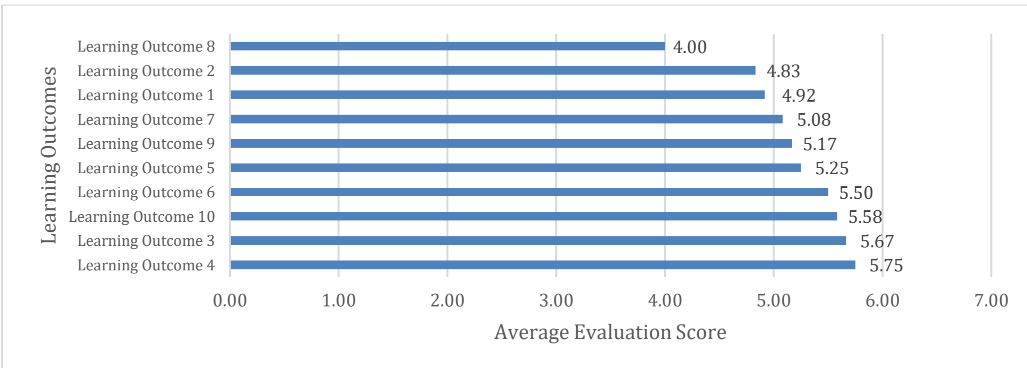

Figure 3. The average scores of learning outcomes evaluated by students

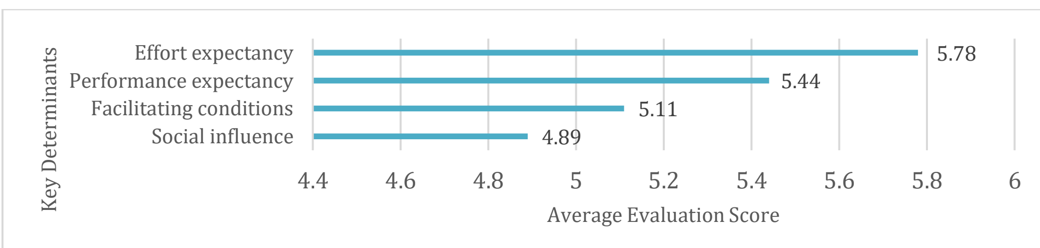

Figure 4. Average scores of key determinants of technology adoptions evaluated by the client

Figure 4 shows the average score for each evaluation item given by the client. The client filled out a paper evaluation form for each group based on how well the presentation addressed each key determinant of the technology adoption process. Each key factor had three evaluation items. Each evaluation item was also evaluated on a 7-point Likert-type scale. As shown in Figure 4, students obtained the highest score in ‘‘Effort Expectancy.", which is about convincing an individual believes that technology will assist them in performing job duties. Among the three sub-evaluation items, students were more successful in demonstrating the easiness of technology operations. Students obtained the lowest score in "Social Influence.", which explains the degree to which an individual feels social influence pressure to use a particular technology, especially the evaluation item related to senior management influence. The overall result is also positive because the score of every learning outcome is above 4.00.

Discussion

The pilot study findings provided insights on the effectiveness of the activity about technology adoption in the construction management class. Students reported that the activity helped them understand the construction industry better and improve their professional skills such as communication and teamwork. During presentation preparations, students were able to study the technologies and came up with a strategy to link the technologies with actual projects. By communicating with clients from the industry, students would gain a practical understanding of technology applications. Instead of focusing only on technical information, students learned to study and understand a subject from multidisciplinary perspectives.

The findings of the pilot study should also be interpreted within its limitations. First, the data were collected from students from only one university in the United States. A much larger nationwide sample of students is needed. Second, only one client was invited to participate in the activity. There could be potential bias related to the perceptions of technology adoptions. Many personal traits such as age, past experience, and educational background could largely influence the degree to which an individual accepts a particular technology. For future study, multiple companies should be invited and generate a discussion panel with students.

Conclusion

Construction technologies have triggered the demands for (civil and construction) engineering graduates who have sufficient knowledge and skills to enhance industry operations through successful identification, adoption, and dissemination of technologies and sensors. This study utilized an active-learning approach to improving undergraduate students' skills and competencies as game-changers in the construction industry. The feedback obtained from students demonstrated that their understandings of new construction technologies, teamwork skills, and intellectual and critical thinking skills were improved through this activity. This pilot study calls for further research to integrate more active learning and problem-based learning activities in the construction management curriculum to ensure future engineering graduates have emerging competencies to foster construction transformations.

References

Adam Rosenthal, “How to Use Technology Adoption Rates to Market Emerging Tech”, https://blog.capterra.com/use-technology-adoption-rates-to-market-emergent-tech/

Becerik-Gerber, B., Gerber, D. J., & Ku, K. (2011). The pace of technological innovation in architecture, engineering, and construction education: integrating recent trends into the curricula. *Journal of Information Technology in Construction*.

Bhattacherjee, A., & Hikmet, N. (2007). Physicians' resistance toward healthcare information technology: a theoretical model and empirical test. *European Journal of Information Systems*, *16*(6), 725-737.

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Management science*, *35*(8), 982-1003.

Goodrum, P. M., & Haas, C. T. (2004). Long-term impact of equipment technology on labor productivity in the US construction industry at the activity level. *Journal of construction engineering and management*, *130*(1), 124-133.

Harty, C. (2008), "*Implementing innovation in construction: contexts, relative boundedness and actor-network theory*", *Construction Management and Economics*, Vol. 26 No. 10, pp. 1029-104

Hood, C. L., Holtzman, D. M., & Abbott, J. I. (2019). Essential learning outcomes (ELOs): Forming a bridge between college and the workplace. *Journal of Higher Education Theory and Practice*, 19(1), 73-79.

Hsieh, P. J., Lai, H. M., & Ye, Y. S. (2014). PATIENTS'ACCEPTANCE AND RESISTANCE TOWARD THE HEALTH CLOUD: AN INTEGRATION OF TECHNOLOGY ACCEPTANCE AND STATUS QUO BIAS PERSPECTIVES.

Im, I., Hong, S., & Kang, M. S. (2011). An international comparison of technology adoption: Testing the UTAUT model. *Information & management*, 48(1), 1-8.

Kale, S., & Arditi, D. (2010). Innovation diffusion modeling in the construction industry. *Journal of construction engineering and management*, *136*(3), 329-340.

Loosemore, M. (2014, April). Innovate or perish? Exploring some of the myths of construction innovation. In *Australasian Journal of Construction Economics and Building-Conference Series* (Vol. 2, No. 2, pp. 44-55).

Mitropoulos, P., & Tatum, C. B. (2000). Forces driving adoption of new information technologies. *Journal of construction engineering and management*, *126*(5), 340-348.

Ozorhon, B., & Oral, K. (2017). Drivers of innovation in construction projects. *Journal of construction engineering and management*, *143*(4), 04016118.

Park, Y., Son, H., & Kim, C. (2012). Investigating the determinants of construction professionals' acceptance of web-based training: An extension of the technology acceptance model. *Automation in construction*, *22*, 377-386.

Rogers, E. M. (2010). *Diffusion of innovations*. Simon and Schuster.

Sepasgozar, S. M., & Davis, S. (2018). Construction technology adoption cube: An investigation on process, factors, barriers, drivers and decision makers using NVivo and AHP analysis. *Buildings*, *8*(6), 74.

Sepasgozar, S. M., Loosemore, M., & Davis, S. R. (2016). Conceptualising information and equipment technology adoption in construction: A critical review of existing research. *Engineering, Construction and Architectural Management.*

Skibniewski, M. J., & Zavadskas, E. K. (2013). Technology development in construction: a continuum from distant past into the future. *Journal of Civil Engineering and Management*, *19*(1), 136-147.

Straub, E. T. (2009). Understanding technology adoption: Theory and future directions for informal learning. *Review of educational research*, 79(2), 625-649.

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS quarterly*, 425-478.