WIP: Teaching of emerging technology in construction workforce development programs

Luke Buscemi
School of Construction Management Technology
Purdue University
West Lafayette, USA
lbuscemi@purdue.edu

Luciana Debs
School of Construction Management Technology
Purdue University
West Lafayette, USA
ldecresc@purdue.edu

Mark Zimpfer
School of Construction Management Technology
Purdue University
West Lafayette, USA
mzimpfer@purdue.edu

***Abstract*— (WIP) Construction is currently facing a moment of change with the rise of the so-called Construction 4.0, which represents the adaptation of the construction industry to the use of digitalization and automation. Even though the transition to a largely digitalized and automated construction industry might be distant, it is important for construction professionals to understand the possible effect of these changes to the workforce. To this point, the present study provides an initial understanding of how job-readiness, pre-apprenticeship and apprenticeship programs within a midwestern state of the United States include digital literacy skills and construction-specific technology in their curricula using a survey approach. Our initial findings represent the responses from three programs and suggest that little hands-on activities using new technology are included in the curricula, and the students from these programs found learning about technology only slightly useful. Complementing our findings with information from other trades programs in the United States, we also note the importance of partnering with construction companies and technology manufacturers to advance technology training in trades education. Further research recommendations include gathering more participant input using alternate approaches, given our low response rate; understanding the role of technology companies and manufacturers in the training of construction trades workers; and surveying construction undergraduate programs about their efforts in preparing their students to handle human capital through as construction transitions to its 4.0 version.**

Keywords—Digital Literacy, Workforce Training, Construction Engineering, Lifelong Learning, Construction 4.0

I. INTRODUCTION (*HEADING 1*)

In the past decade, construction industry employment predictions forecasted an increase of roughly 1.3 million workers from 2012-2022 - a 21.4% increase [1]. A decade later and under the impact of the COVID-19 pandemic, the revised estimates still point to a growth outlook of 7% between 2020 and 2030 [2]. Furthermore, even with layoffs due to the pandemic, 52% of firms surveyed by Associated General Contractors (AGC) were having issues with filling some or all of their craft labor positions and 40% expect to recall or hire new employees [3]. While this looks to be a sign of hope for one of many industries attempting to recover from the COVID-19 pandemic, another challenge poses a major threat to the advancement of the construction labor force – equipping all of the new, and existing, employees with the skills and knowledge to utilize and understand new technologies.

In fact, the rise in the use of technology has been disrupting the construction industry for several years now. Previous researchers call this moment the Construction 4.0, which represents the adaptation of this industry to the use of digitalization and automation [4]. Even though the transition to a largely digitalized and automated construction industry might be distant, it is important to understand the effect of these changes in the workforce. Previous research has mentioned that disruptions to the workforce will occur and it is possible that job availability and roles will change [4].

A recent study by the Seattle Jobs Initiative analyzed how likely a trade occupation within construction was to be impacted by automation [5]. The method for predicting the impact on a construction occupation included estimating the probability of being able to automate the occupation's tasks and assessing if a technology exists to perform those tasks. The findings were that for most occupations, except for electricians and front-line supervisors, which had minimal change, there was a high probability of being automated and a high exposure to automation technology [5]. The Seattle study highlights the importance of understanding this changing landscape within construction industry - specifically for the construction trades. For example, to safely and adequately use exoskeleton technology on construction job-sites, workers would need to be trained into using the technology [6].

Therefore, as construction companies continue to incorporate and implement advanced technology into the construction trades, it is becoming increasingly apparent that digital literacy skills are essential for workers to keep up with the growing demands of technology and to prepare them for new job requirements [7]. Additionally, according to a report published by McKinsey, the lack of workers and increasing labor costs are key driving factors pushing construction companies to adopt new technologies [8]. Furthermore, the report outlines six technologies that have the potential to bridge the gap between labor demand and supply: modular construction, drones, BIM, 3-D printing, robotics and automation, and interactive technologies (AR, VR, MR). These technologies play a major role in addressing productivity issues related to construction practices and the labor shortage. With the

rise in application of these and other transformative technologies set to expand, the role of the construction worker will change [4]. This was also highlighted by previous research focused on improving training of construction workers, combined with the increase in automation as a way to reduce the workforce shortage experienced in the construction industry [9]. Beyond trade training implications, this also impacts construction engineering and management undergraduate programs (here referred to as construction programs), given that construction professionals may be project leaders in this time of change.

With the roles of construction workers evolving due to changes in methods of construction and advancements in technology, the new skill sets that construction workers must possess are poised to change drastically. With construction demand still on the rise, ABC reports that 430,000 more craft workers must be hired in 2021 to compensate for demand [10], and, companies looking to hire workers will be limited by a lack of qualified workers. These issues directly affect the context in which graduates of undergraduate construction programs work.

To remedy the lack of skill and knowledge, the construction industry must invest, and continue to invest, in educating its workforce [9]. This not only include educating workers on the technology of today and the near future, but setting an educational foundation that allows the knowledge requirement and skills of future technologies to be easily and readily adopted, as well as transferable to workers in the future through lifelong learning. In fact, one of the major benefits for lifelong learning is helping people deal with changes, including technological changes [11]. It is evident that the construction industry has already begun, and will continue to, adopt and use new technologies. However, as companies advance their use of technology, there is a clear cause for concern in the lack of workers that are equipped with the skills to operate them. Despite the importance of this new context, there is a lack of studies informing how construction trades' training programs incorporate technology into their curriculum, and how they are preparing their students for the future of construction.

To address this gap, this work-in-progress presents findings of a survey about the use of technology and the inclusion of digital literacy skills on job readiness, pre-apprenticeship, and apprenticeship programs. At this exploratory stage, we reviewed the programs within the state of Indiana, in the United States, as a pilot case. We were guided by the following research question (RQ):

RQ: How are trade-oriented training programs adapting to emerging construction technology?

The significance of our results is threefold. First, to raise the discussion about digital literacy skills and technology use in construction trades' education; second is to guide future research in this area; and third is to discuss the implications of trades' training for undergraduate education in construction. The latter assumes that graduates of construction programs will likely take part on the transformation towards a 4.0 industry, including dealing with the technological, labor and ethical implications of this transformation.

II. Methodology

In this pilot study, we have used a survey approach to collect data from construction trades training programs within the state of Indiana. To do so, we first collected contact information on construction trades training programs available in the state by conducting online searches. Due to the diversity of trades working in construction, we have delimited our survey to training related to carpenters, electricians, operators, plumbers/pipefitters and ironworkers. Eighteen programs that had job readiness, pre-apprenticeship and apprenticeship program in one of the aforementioned construction trades in Indiana were identified.

Programs were contacted through email and/or phone and asked to complete an online (Qualtrics) survey about their training program during December 2021 and February 2022. The survey contained 26 questions and was divided into three blocks. The first block included ten questions about the organization and training program (or programs) offered, including typical student demographics. The second block included questions about the use of technology in the curriculum, including questions about specific technology, digital skills and potential barriers to the inclusion of more technology in the training curriculum. Finally, the third block provided a space for respondents to add more thoughts about the topic. Closed and open-ended questions were utilized.

Results include an overview of the respondents, including type of programs and basic program characteristics, and typical student population. Then, descriptive statistics, namely frequencies, are reported for the questions specific to technology use in the programs. Answers for the open-ended questions were themed and frequencies are reported in the results section.

III. Survey Results

In this work-in-progress, we present preliminary results from our survey. First, we present aggregated demographic results from the respondent programs, and then we describe their use of technology and inclusion of digital literacy skills in their programs.

A. Programs' Demographics

Of the eighteen targeted programs, we have received three responses (response rate = 16.67%). This is much less than anticipated and indicates that perhaps a different approach (or additional approaches) could be helpful, such as mailed-in surveys or interviews.

Of the three responses received, two were related to ironworker training programs and one was a carpentry related training program. These programs varied in size (in regards to the number students moving through the program per year) ranging from a low of 45 graduates on average per year to 800 graduates per year. Additionally, a majority of the students were from age groups 18-24 years old (with a minimum of 31% and a maximum of 41%) and 25-34 years old (with a minimum of 41% and a maximum of 45%), with these two brackets representing the largest percentage of students in all three responding programs.

The program with the longest duration of training time was 816 classroom hours and 5200 on the job learning hours, while

the other two programs were shorter with 1225 hours and 240 hours each. The cost to students of each program was as low as zero and as high as $400. Two of the programs utilize a fixed training center and an online component of teaching, while the other does not provide training online. An overwhelming majority of students from all three programs are high school graduates (minimum of 70% to a maximum of 90%), followed by college graduates (minimum of 8% to a maximum of 30%). In terms of gender, male students are majority (with a minimum of 93% to a maximum of 96%), followed by females (minimum of 4% and a maximum of 5%), and non-binary, third gender or other (minimum of 0% and a maximum of 2%).

B. Use of Technology

All three respondents provided varying techniques they use to teach students about emerging technologies. One program mentioned reaching out to industry contractors to see what technology is being utilized in the field and what they are exploring. This comes in the form of semi-regular meetings with contractors along with committees that represent labor and education to discuss technologies and provide feedback. Moreover, this program also works with technology manufacturers to provide product specific training to students. The other two programs mentioned that their national training department keeps their curriculum up to date or utilized their learning management system (LMS) software to provide students with information on emerging technologies. Two of the three programs felt they provide a moderate amount of information related to emerging technology, while the other program perceived it as 'a little'.

Not all three programs provided information about the teaching of eight highlighted technologies, which included augmented (AR), virtual (VR) and mixed reality (MR), 3D scanners, photogrammetry, drones and similar unmanned aerial systems, 3D printing, robotics, sensors for digital twins and Building Information Modeling (BIM). One program indicated discussing digital twins and BIM, with a practical demonstration on BIM (without student manipulation); one program clearly mentioned not teaching AR, VR or MR and only discussing drones and similar technology; one indicated discussing AR, VR and MR and clearly not teaching 3D scanners. Of the four technology concepts mentioned in the survey (data analytics, internet of things or digital twin, blockchain and offsite construction), only one program mentioned discussing offsite construction and its implications. Not all respondents answered provided input for all items.

Apprenticeship programs are offered by all three programs and two programs listed that technology is utilized in the field half of the time, while the other listed 'sometimes'. Of five digital literacy skills options provided (Email, word processing, spreadsheet usage, management of professional social media profile), two programs listed email and word processing as being taught a 'moderate amount' and one listed 'a little'. Additionally, one program indicated they taught 'a little' of social media profile management and one program indicated they did not teach spreadsheet software at all. Not all three programs included the answers for all options, which provided unclear results for the researchers.

All three respondents listed that student perceptions within the program found that learning about emerging technologies was 'slightly useful'. Six options and an additional open space were given to participants to describe barriers to incorporating more technology into the training using a five-point Likert-type question. Four barriers were mentioned by one respondent each as moderate impacting in the decision on this topic – space limitations, lack of interest, lack of knowledge to teach, and lack of perceived industry value; cost was mentioned as having a lot of impact; and limited time was considered as having less than moderate impact in incorporating more technology in training of all three respondents. Of those, cost was a significant barrier to one program. And all respondents listed some form of further learning opportunities related to the role of technology in their trade from online resources to specialized courses or workshops.

C. Discussion on Initial Findings

Our partial data suggests that most emerging technology is only discussed, with little interaction by students. Previous research has indicated the benefits of hands-on learning for construction trades education [12]. However, the lack of clear response also requires further research to explore the reasons for this, especially if this could point to a lack of knowledge about the included technology and technological concepts.

Another important finding was that one program held meetings with contractors that work with other parties that represent labor and education. This is a great way for the training programs to gain insight into the technology trends happening within the construction industry. The contractors are the companies that utilize the students graduating from the training programs, and to have their feedback and understanding of what is going on within the industry is invaluable when it comes to structuring the training curriculum. In fact, Industry Advisory Boards (IAB) are required of construction programs accredited by the American Council for Construction Education (ACCE), as well as those accredited by the Engineering Technology programs accredited by the Accreditation Board for Engineering and Technology (ABET) [13-14]. The IAB is a committee made up of several construction company representatives, most of which frequently hire graduates of the program. The council plays a major role in providing insight, feedback, and up to date trends from the industry to the program's faculty so they can structure their curriculum in the most effective manner for their students. Previous research on the role of IABs in the process of continuous improvement in undergraduate construction management education (for examples, see [15-17]).

D. Comparison with Other Trade Training Programs

Owing to the low response rate on our survey, we complement our discussion by researching other existing trades' training programs and their use of technology to compare our findings with what currently exists. An internet search for publicly available information was performed by one of the lead authors, and little information about the topic was found. This might not mean that trades are not including technology in their programs, however, if they are, there is little information available. Four construction trade training programs were identified as having published information about their use of technology:

- Ironworkers Union (IU) [18];

- Finishing Trades Institute [18];
- International Union of Operating Engineers (IUOE) [19];
- Electrical Training Alliance [20];
- Southeast Wisconsin Carpentry Training Center [21].

Of those four, three of them involve partnerships between training programs and technology companies.

In the past years, the iron workers union (IU) began to adopt certain technologies in their training, such as a collaborative virtual reality training environment, which allows the training of multiple users in the same space, and virtual welders [18]. IU's personnel in charge of the apprenticeship and training department stated, "When the virtual welder first hit the market, it was expensive and you got a lot of people hesitant to utilize the opportunity," he says. "Over time I've seen people start to realize the benefits of using it…" Moreover, he now estimates that almost one third of American IU chapters are using virtual welders in training [18]. One of the major advantages of the virtual training is cost savings, given that training with actual welding activities is not economical [18].

Another program that has been incorporating technology with training is the International Union of Operating Engineers (IUOE). IUOE has partnered with Built Robotics, a vehicular automation company that develops software and hardware to automate construction equipment. This move comes as a push to equip the roughly 400,000 IUOE members with the skills and knowledge to operate and manage robotic equipment, as well as work alongside autonomous vehicles [19].

Another partnership, between the Electrical Training Alliance and Mosaic Learning, has allowed the Local 26 training center in Washington D.C., the ability to provide students and instructors to collaborate in a virtual reality setting. The president of Mosaic Learning said that in the past they had hoped that showing students PowerPoint slides and some other things would be sufficient enough for students to pick up on the basic level learning objectives, but now with the virtual element they can interact with student who retain the information better and are more interested [20].

Another training program, the Southeast Wisconsin Carpentry Training Center, has partnered with Lincoln Electric, to provide a virtual learning aspect to their curriculum, specifically for welding activities. While many people don't think of welding as something that falls under the responsibility of a carpenter, form systems and pile driving are just two examples of carpenters utilizing welding in their craft. The virtual welder connects to an overhead display which allows the whole class to visualize what is going on within the virtual welding booth, and allows the instructor to explain what is going on to the class in real time [21].

While these experiences are helpful and encouraging, we note that the initiatives seem isolated and, when existing, information about them is scattered, and lack a long-term evaluation of its effects to workers and industry. Academic literature for the development of virtual welding training exists since early 2000 (for example, see [22]) to nowadays (for example, see [23]) and provide useful examples, benefits and challenges of such technology. Still, a holistic view about digital literacy and lifelong learning in the construction trades is lacking.

E. Implications for Undergraduate Construction Education

It is in this transformative context that many construction graduates will spend their professional lives. Previous research has recognized that a key factor in this transformation is actually training the workers [24]. Some of this training will be given in training programs, and other training might be provided by companies in which construction graduates will work. Therefore, construction professionals need to assess the readiness of their crews in order to deploy newer technologies, recommending additional training, if necessary.

Furthermore, the incoming of millennials and Gen Z construction employees, the retirement of digital 'immigrants' and the need to adapt to remote work have pushed been raised on technology are pushing the industry to higher levels of technology [25]. With a familiar background in the use of technology and equipping them with the right managerial and leadership skills in their undergraduate pursuits, undergraduate students may serve as ambassadors for ensuring that the technology gap closes within the construction industry. To this end, it is important that construction undergraduate programs prepare their students to be able to identify disruptive construction technology and to understand the transformational aspects of construction 4.0, including the importance of digital literacy and lifelong learning for all stakeholders in the construction industry.

F. Next Steps and Recommendations

While the three responses we have received provided important details, we would have liked to have gathered input from more trade training programs and more complete input for the ones that replied. More information would allow us to better reflect on the state of the construction trades training programs as a whole. Future initiatives that are similar in scope should consider utilizing interviews to collect initial feedback and help respondents who might not be familiar with the technology or concept.

Our results suggest two main findings: (1) training of construction trades still lack hands-on learning when teaching about several forms of technologies, and (2) partnerships with industry representatives is helpful in providing feedback and insight into the curriculum related to technology. Moreover, our results prompt questions about how (and even if) emerging technology should be included on vocational training such as the ones surveyed; or should technology learning be offered 'as-needed', so programs can focus on current industry practices?

Based on our preliminary results, we suggest additional efforts in recruiting training programs, perhaps using alternative research methods such as interviews. Furthermore, other research suggestions include looking at the relationship between training programs and technology companies or manufacturers, and how those relationships could benefit training programs; how construction undergraduate programs are equipping their students to deal with the technology gap; and how construction undergraduate programs are preparing graduates to handle human capital, specifically construction trades workers, during the transition to construction 4.0.

REFERENCES

[1] Emily Richards and Dave Terkanian (2013). "Occupational employment projections to 2022," Monthly Labor Review, U.S. Bureau of Labor Statistics, https://doi.org/10.21916/mlr.2013.41

[2] Bureau of Labor Statistics, U.S. Department of Labor, Occupational Outlook Handbook, Construction Laborers and Helpers, at https://www.bls.gov/ooh/construction-and-extraction/construction-laborers-and-helpers.htm (visited April 09, 2022).

[3] Associated General Contractors of America (AGC) & Autodesk Construction Cloud (2020). 2020 Workforce Survey Results. Retrieved April 15, from: https://www.agc.org/sites/default/files/Files/Communications/2020_Workforce_Survey_National.pdf

[4] García de Soto, B., Agustí-Juan, I., Joss, S., & Hunhevicz, J. (2019). Implications of Construction 4.0 to the workforce and organizational structures. International Journal of Construction Management, 1-13.

[5] Carson, K. Digitalization & Automation in the Constructions Trades (2020). Retrieved Oct. 10, from https://outlook.seattle.gov/Documents/Departments/economicDevelopment/workforce/NetworkEconomy_Construction_24Aug2020.pdf

[6] Kim, S., Moore, A., Srinivasan, D., Akanmu, A., Barr, A., Harris-Adamson, C., ... & Nussbaum, M. A. (2019). Potential of exoskeleton technologies to enhance safety, health, and performance in construction: Industry perspectives and future research directions. IISE Transactions on Occupational Ergonomics and Human Factors, 7(3-4), 185-191.

[7] Cao, Q., & Wang (2021), H. Research on Digital Transformation of Construction Industry. In ICCREM 2021 (pp. 398-405).

[8] Arora, N., Batra, G., Santhanam, N., Varanasi, S., Teulieres, M. & Wong, T. (2020). Construction and Building Technology – poised for a breakthrough? McKinsey & Company. Retrieved Oct. 20, from https://www.mckinsey.com/~/media/mckinsey/industries/advanced%20electronics/our%20insights/construction%20and%20building%20technology%20poised%20for%20a%20breakthrough/construction-and-building-technology-poised-for-a-breakthrough-vf.pdf

[9] Ho, P. H. (2016). Labour and skill shortages in Hong Kong's construction industry. Engineering, Construction and Architectural Management.

[10] Associated Builders and Contractors (ABC) (2021). Construction Spending and Employment: History and Forecast Terms and Sources(webpage). Retrieved Nov 12, 2021, from: https://www.abc.org/Portals/1/News%20Releases/explainer-2021.pdf?ver=2021-03-23-162431-727

[11] Laal, M., & Salamati, P. (2012). Lifelong learning; why do we need it?. Procedia-Social and Behavioral Sciences, 31, 399-403.

[12] Dickinson, J. K., Woodard, P., Canas, R., Ahamed, S., & Lockston, D. (2011). Game-based trench safety education: development and lessons learned. Journal of Information Technology in Construction (ITcon), 16(8), 119-134.

[13] Accreditation Board for Engineering and Technology (ABET) (2020), 2021 - 2022 criteria for accrediting engeneering programs. https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2021-2022/

[14] American Council fro Construction Education (ACCE) (2020) Document 103 – Standards and Criteria for the Accreditation of Construction Education Programs. Retrieved from: https://683b8d30-e51d-49ba-9440-a5669f44051b.usrfiles.com/ugd/683b8d_2714ae361f2f41e9b7eb7c7dcb69a160.pdf

[15] Clevenger, C. M., Abdallah, M., & Wu, W. (2017). Advisory board feedback on construction education learning outcomes. In Proceedings of the Associated Schools of Construction 53rd Annual International Conference, Seattle, Washington.

[16] Lee, N., Ponton, R., Jeffreys, A. W., & Cohn, R. (2011). Analysis of industry trends for improving undergraduate curriculum in construction management education. In ASC Proceedings of the 47th Annual International Conference, Omaha, NE.

[17] Emmer, M. J., & Ghanem, A. A. (2013). Influence of Industry Advisory Boards on Construction Management Programs' Curriculum and Content. In Proceedings of 49th ASC Annual International Conference, San Luis Obispo, CA, USA, April 9 (Vol. 13).

[18] Cho, Aileen. (2018). Construction Unions Warming Up to Virtual Reality Training (webpage) 22 March 2018. Retrieved Jan 23, 2022, from: https://www.enr.com/articles/44207-construction-unions-warming-up-to-virtual-reality-training

[19] Construction Equipment (2020). Built Robotics Partners with Union for Robotics Training (webpage) 19 March 2020. Retrieved Jan 28, 2022, from: https://www.constructionequipment.com/built-robotics-partners-union-robotics-training

[20] International Brotherhood of Electrical Workers (2016). Simulating Reality: Apprentice Training Moves Into Virtual Realm, Takes Notice of TV Show (webpage). 27 May 2016. Retrieved Jan 28, 2022, from: https://www.ibew.org/media-center/Articles/16Daily/1605/160527_ApprenticeTraining

[21] Lincoln Electric (2013). Carpenters Union Incorporates Virtual Reality Welding (webpage). March 2013. Retrieved Jan 28, 2022, from: https://www.lincolnelectric.com/assets/US/EN/literature/mc12130.pdf

[22] Kobayashi, K., Ishigame, S., & Kato, H. (2003). Skill training system of manual arc welding. In Entertainment Computing (pp. 389-396). Springer, Boston, MA.

[23] Chan, V. S., Haron, H. N. H., Isham, M. I. B. M., & Mohamed, F. B. (2022). VR and AR virtual welding for psychomotor skills: a systematic review. Multimedia Tools and Applications, 1-35.

[24] Adepoju, O. (2022). Reskilling for Construction 4.0. In: Re-skilling Human Resources for Construction 4.0. Springer Tracts in Civil Engineering . Springer, Cham. https://doi.org/10.1007/978-3-030-85973-2_9

[25] Wilkinson, P. (2022). Communicating in the Construction Industry. In: Bolpagni, M., Gavina, R., Ribeiro, D. (eds) Industry 4.0 for the Built Environment. Structural Integrity, vol 20. Springer, Cham. https://doi.org/10.1007/978-3-030-82430-3_26