ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE
Paper ID #36877

Preparing Students for Construction Management Technology Curriculum

Kirk Hochstatter

PhD Candidate in the University of Washington's College of Built Environments, researching shared leadership, integrated project delivery (IPD) and collaborative governance, virtual teams and building information modeling (BIM). Has been teaching in the UW construction management department since 2017, and developed the digital tools in construction management course. Has worked in the construction industry for over 20 years and delivered several projects throughout the San Francisco Bay Area and the Seattle/Puget Sound region.

Alireza Borhani

Lucky Pratama

Bijesh Kumar Gautam

Ahmed Abdel Aziz (Associate Professor)

Hyun Woo Lee (Associate Professor)

Sanaz Saeidi

Carrie S Dossick (Professor and Associate Dean)

Final Paper

Preparing Students for Construction Management Technology Curriculum

Kirk Hochstatter, Alireza Borhani, Lucky Agung Pratama, Bijesh Kumar Gautam, Ahmed Abdel Aziz, Hyun Woo Lee, Sanaz Saeidi, Carrie Sturts Dossick

University of Washington
Seattle, WA

Abstract

Teaching technology in construction engineering and management curriculum has been a topic of education research for some time. The influx of Building Information Modeling has dominated the literature in recent years, while data analytics and visualization have increased importance in the field. Many programs continue to grapple with teaching technology alongside the fundamental concepts of the discipline. To address these challenges, the Construction Management Department at the University of Washington has conducted a holistic review of technology across the curriculum for our undergraduate program. In recent years, we developed a new prerequisite class to better prepare students for learning the technologies across estimating, scheduling, and building information modeling. In this paper, we present this holistic curriculum philosophy and design for technology in our construction management undergraduate program including the preparation class, and three subsequent lab classes in estimating, scheduling, and building information modeling. This paper includes a teaching and learning evaluation to assess the success of this curriculum design, the transfer of learning across the curriculum, and the gaps we need to address in terms of emerging technology trends in data analytics and project management. We will discuss the strategies of preparing students to engage with technology across an undergraduate curriculum and define technology readiness for CM programs.

Introduction

In recent years there has been an increasing interest in technology across the construction industry including data, analytics, visualization, and document management. Information technology is available for almost every aspect of construction management with tools for scheduling work and estimating projects, managing documents, and creating drawings. One of the larger arcs of these changes started with the transition from traditional computer-aided design

(CAD) drawings (i.e., graphical entities such as dots, lines, and curves) and 3D models (i.e., 3D based presentations, renderings, walk-through, etc to enhance model-based visualizations) to the new paradigm: Building Information Modeling (BIM) [1, 2, 3]. These shifts are not only re-shaping the design and construction industry, but also the construction management education (Johnson & Gunderson, 2009). With the growing use of graphic communication on construction projects and the advancements in digital graphic technology, the ability to use applications of digital visualization programs has become one of the important skill sets for construction management students [4]. Furthermore, the move from drawings to data has significantly changed the ways project teams can work and students can learn. For example, the technologies for construction visualization like Building Information Models (BIM) and on-screen takeoff (OST) when used in estimating courses, appear to have a positive influence on the estimating skills of CM students [5]. In another study, users were able to consider significantly more design options from more perspectives with a similar budget and time schedule than was possible using traditional methods [6]. These benefits are only realized however by individuals and teams who know how to leverage these tools in the project organization and team context.

In this paper, we take up the questions about how to prepare our students to engage this technological future of construction. Like mathematics and physics, technical literacy provides students with sets of skills they can bring to more complex subjects in the Construction Engineering and Management (CEM) curriculum. When designing technology curriculum across CEM contexts, educators need to consider transferable skills and knowledge to prepare students to use technology while learning the fundamental concepts. In this paper, we present a curriculum design for teaching technology across a CEM curriculum and evaluate the effectiveness of this curriculum both in terms of knowledge transfer and learning.

Literature Review

In recent years studies such as [7], determined the technical and personal abilities required of young professionals by today's construction industry: today's CEM graduates need to have strong collaboration and teamwork skills; they need to have a broader perspective of the issues that concern their profession such as social, environmental, and economic; and finally, they need to know *how to apply fundamental engineering science and computer skills in practice*. This paper focuses primarily on this last concern. Today's 21st-century architects, engineers, and construction managers must be able to deal with a rapid pace of technological change, a highly interconnected world, and complex problems that require multidisciplinary solutions [8]. Continual advances in computer technology have created a potential for construction education to vastly improve its techniques, processes, and managerial decision-making capabilities. Computing and information technologies improve networking multi-discipline teams, planning construction activities, cost management of the project, visualizing the finished product, reporting the status of the project, and assisting the project transaction and communication

processes [9]. In the context of Construction Management education, how do we prepare our students to engage in these technological practices in addition to the fundamental concepts of construction planning and management?

As BIM has been the focus of technological innovation in recent decades, several universities have developed BIM-integrated curriculums for students of construction engineering and management (CEM), but they represent only a handful of a large number of such programs available worldwide [10, 11], and in addition, there is significant diversity in their content. *A technology education framework for CEM programs is needed to aid educators in establishing coherent and comprehensive curricula, both within existing courses and by introducing new courses.* The curriculum is the foundation of the teaching/ learning process, so when developing a new course it is crucial to adopt a curriculum model that will enable educators to systematically and transparently map out the rationale for the use of particular teaching, learning, and assessment approaches [12, 13].

Context and transfer are important elements of learning. Context can be very helpful for students to understand how to apply basic skills like math or technology applications to complex engineering problems. However, if students are only taught in one context, they may have trouble transferring to other contexts [14]. The challenge for teaching technology across the CEM curriculum is to create knowledge and skill-building opportunities that allow students to transfer this learning to more advanced coursework such as estimating and scheduling classes. Knowledge transfer is one of the main goals of the education evaluation in this paper. Have we set up a technology course series that prepares students to engage technology in advanced subjects such as estimating, scheduling, and Building Information Modeling?

Methods

This research attempts to better understand how the approaches being used by the UW construction management to teach digital technology are supporting the fundamental concepts of construction management. A digital transformation of the technology, that was once used to support construction activities, has shifted the skills required for professionals working in today's industry. While the technical skills required to make this transition to a digital world require a change in programs being taught, the concepts that make up the fundamental approach of managing construction projects still remain. In order to accommodate this shift, the UW has added prerequisite and preparation courses that support the students' skills in estimating, scheduling, and using building information models.

In order to assess the UW's CM department's holistic approach of preparing students to develop these skills, a learning assessment of the prerequisite digital tools course (CM 260), the estimating lab (CM 330), virtual construction (CM 414), and computer applications in construction (CM 422) was developed. This assessment focuses on the technology topics,

associated software programs introduced, the teaching methods used in the CM 260 course, and how that aligned with the background, knowledge, and skills students needed for the upcoming technology classes within the CM department. The data collected from the survey would address which teaching methods have been useful and allow for discussions on where improvements can be made.

The learning assessment was accomplished through a student survey that asks the participants to rate how the CM 260 course prepared them for subsequent technology-focused coursework and careers in the CM industry. We conducted the survey during a lab section and received 51 complete survey responses. By distinguishing between fundamental knowledge and practical skills introduced, the online survey assesses how teaching methods and the students prior background possibly influenced their ability to succeed with the skills introduced in their current course. The responses will be quantified using a Likert scale so that the data can be distributed and examined. Assessment from the data will address the alignment across the curriculum and inform how to prepare and develop the CM 260 course for the students entering that class. The development of the course will discuss teaching methods and technology and what a diversity of learning modalities brings to the classroom.

Technology across the CM Curriculum

CM 260 - Digital Tools

The learning outcomes for the CM 260 Digital Tools course focuses on the understanding and application of digital tools discussed in class. The digital tools that will be applied are selected based on how they support the tasks related to construction budgets, costs, visualization and communication of construction project design, plan reading, collaboration, estimation, construction operations, geographic information systems (GIS), and project management, and the foundations of construction management concepts related to the digital tools are discussed. The students taking this course have limited exposure to construction management and to support the learning outcomes the expectation of the learner is to be prepared for future courses that will focus more specifically on specific technology and construction management concepts.

The CM 260 Digital Tools course was developed to provide an overview of digital tools that are commonly used in the construction industry. Over the course of a 10 week period, students will gain basic knowledge of digital tools, including Excel, Bluebeam, On-Screen Takeoff, SketchUp, AutoCAD, Navisworks, and more if necessary, and serve as a foundation for an advanced curriculum within the University of Washington's Construction Management program. This entry-level course focuses on the fundamentals of digital tools and gives the student the opportunity to use the programs in industry-specific contexts.

The students meet in a digital tools lab for three hours each week where the first half of the class is a lecture that discusses the program being introduced and the second half is dedicated

to working on the weekly assignment. The lecture portion focuses on the application of the tool being used that week, while also offering a host of other digital tools that are used for the same function in the construction industry. Guest lectures have also been used to discuss the topic for the week and also serve as an introduction to the construction industry, networks, and career possibilities. The assignment portion will concentrate on the application of the digital tool that includes a PowerPoint presentation that gives instructions on how to use the program commands to complete the work required, and also allow for the instructor to give 1-on-1 directions for students who prefer more hands-on learning. In addition to the weekly assignments, the students are assessed on classroom participation that requires that they submit a reflection on what was discussed, learned, or their thoughts on the session that day, and a final exam that includes questions that address applications of the digital tools in the class as well as demonstrating simple applications of the program.

CM 330 - Construction Estimating Lab

There are three main learning outcomes for CM 330 Construction Estimating Lab. The first is to create construction project estimates. The second is to analyze construction documents for planning and management of construction processes and the third is to apply information technology to manage the construction process. This is accomplished by focusing on the use of digital tools to perform material and quantity take-offs (QTO) and communicating costs that will be used in the estimation process. The students taking this course have been exposed to the technology being used and it is expected that they will be better prepared to develop estimates being introduced in other classes and in professional settings.

Building off of the knowledge gained in CM 260, students will use Excel, Bluebeam, On-Screen Takeoff (OST), and Sage Estimating to quantify and estimate digital documents. Students will also learn how to use multiple tools together through applications like exporting QTO's, and linking programs that will update estimated files used in Excel. The assignments are based on actual projects and will cover building scopes that include earthwork, underground utilities, concrete, steel, wall framing, exterior & interior finishes, and add-ons like fees, overhead, and applicable taxes. The skills developed in this course will help the students with completing assignments and capstone projects that are assigned in the CM 331 Estimating class that is taken during the same quarter.

CM 414 - Virtual Construction

The learning outcomes for this course are to assess the applications of electronic-based technology to manage the construction process, and to support the creation of written communications and oral presentations appropriate to the construction discipline, construction project cost estimates and schedules, analyze construction documents for planning and management of construction processes, and understand construction quality assurance and control. Ideally, students in this course should have a little experience with digital technologies and will ultimately be able to create, apply, and understand Virtual Design and Construction

(VDC) and Building Information Models (BIM) through projects that mimic real-world industry problems as a team. They also interview professionals from the industry to be able to identify those problems or situations that direct the context of their study that not only strengthens their technical skills in regards to construction procedures but also provides them with a broad perspective of the issues that concern their future work such as social, environmental and economic issues.

This class provides a comprehensive digital project management approach that reflects on emerging technologies and introduces best practices and examples of how VDC and BIM play out on projects' lifecycle. CM 414 is a course on the study of Building Information Models for pre-construction applications that enables students to identify conflicts caused by poor collaboration throughout the design, construction, and operation phases and suggests ways to optimize processes, develop and modify proactive resolutions to reduce RFI's, change orders and re-work. The course is divided into four main modules (i.e., 3D Coordination / Clash Detection / Digital Fabrication; 4D modeling; Model-Based Estimating; and, BIM Execution Planning) and the learning outcomes are established for these smaller units that map onto the larger course-level outcome -- apply electronic-based technology to manage the construction process. CM 414 also briefly touches on the common project delivery methods and discusses the fundamentals of BIM execution planning requirements and the necessary documentation for implementing BIM in projects. The course is concluded by students showcasing all their learning through a BIM portfolio in the format of a project-specific BIM proposal.

CM 422 - Computer Applications in Construction

The required learning outcomes for this course are mastery in using planning and control software for the management of projects, and how to update the time and cost of projects using actual data. The students taking this course are very likely to have not been introduced to the Primavera P6 software but may have been exposed to construction schedules and software like Microsoft Project in previous courses and/or professional experience.

Prior to CM 422, students were introduced in another course, CM 411 Project Planning & Control, to the concepts and principles of the critical path method (CPM) for planning and scheduling construction projects, time management, resource management, and performance measurement using earned value analysis. Building from these concepts and principles, students in CM422 will then learn how they are applied and utilized in the software applications of Oracle Primavera and Microsoft Project. Learning is done through a hands-on step-by-step approach. Students will learn basic applications by creating projects, adding activities and relationships, generating and assigning activity codes, developing work breakdown structures, and defining and assigning resources and costs. Example projects and case studies are utilized to help students develop and generate the deliverables used in the AEC industry, such as traditional construction schedules, specialized Gantt Chart schedules (grouped, sorted, and filtered based on activity codes - responsibilities, WBS, etc.), activity network diagrams, resource usage profiles and

spreadsheets, resource leveling charts, cost profiles, and tables, and cash flow diagrams and spreadsheets. Students will also learn how to update the time and cost of a project and how this is used to generate updated schedules that show the variances between the planned and actual project progress and generate earned value analysis reports and charts. With that, students also get to know and develop plans and schedules for repetitive types of work.

Learning Assessment and Discussion

The survey was conducted in order to identify how the CM 260 course prepared students to leverage digital technologies, subsequent technology-focused coursework, and in their careers in the construction industry. The survey was developed to specifically distinguish between the technology-related fundamental knowledge (e.g. tech.-based project scheduling, estimating, and management) and practical skills (e.g. effective use of construction software applications). The first part of the survey results (as shown in table 1) show that the students believe that the CM260 has moderately prepared them for most conceptual topics except for project scheduling and project management, for which students responded with "slightly prepared". The "slightly prepared" could be due to the lack of background knowledge (e.g. construction workflows and the sequence of construction activities courses that these students would learn after CM 260) among the students for learning the more complicated topics such as construction project scheduling and management. However, it is possible that the students that took the survey most likely took their CM 260 course in the 2019-20 academic year and during the COVID pandemic, when classes went remote. Microsoft Project & scheduling was not taught due to student access constraints and replaced with On-Screen Takeoff (OST) with plan-reading and quantity take-offs (QTO).

1. How well did CM260 prepare you for learning with technology on the following topics (N=51)							
	Not at all	Slightly prepared	Moderately prepared	Mostly prepared	Fully Prepared	Mean	StDev
Budgets & Workbooks	22.2%	13.9%	36.1%	22.2%	5.6%	2.8	1.20
Finance and Formulas	19.4%	22.2%	22.2%	27.8%	8.3%	2.8	1.28
Building Design/Schematic Design	8.6%	17.1%	31.4%	34.3%	8.6%	3.2	1.10
BIM and Digital Twin	16.7%	27.8%	25.0%	16.7%	13.9%	2.8	1.30
Plan Reading	16.7%	27.8%	19.4%	30.6%	5.6%	2.8	1.21
Estimating/ Takeoffs	22.2%	27.8%	5.6%	36.1%	8.3%	2.8	1.37
Project Scheduling	26.5%	32.4%	17.6%	17.6%	5.9%	2.4	1.24
Project Management	28.6%	34.3%	22.9%	8.6%	5.7%	2.3	1.15

In the table, the mean values were presented in the scale of 1 to 5 (while 1 equals "not at all" and 5 equals "fully prepared"). Also, the standard deviation was calculated to better interpret the responses' distribution. Accordingly, the students' responses were divided regarding the topics of BIM/digital twin as well as cost estimating and financing. In terms of learning the software applications, the survey analysis showed that CM260 has mostly prepared students for

using Excel and Bluebeam, slightly to moderately prepared them for using Sketchup, Revit, and On-screen takeoff, and slightly prepared them for using Microsoft Project. This result aligns with the course developers' intention of putting more emphasis on the basic software tools compared to more advanced ones (like Revit) that are included in the CM curriculum advanced courses. Overall, the outcome of the CM260 evaluation is consistent with the instructors' expectations for this course.

Methods of teaching technology is another topic investigated through the survey. The CM 260 instructors used multiple methods for teaching and learning evaluation and in the second part of the survey, we asked the students about the effectiveness of those methods for teaching the intended knowledge and skills. Table 2 summarizes the results of this part of the survey. In general, different teaching methods were used throughout the course to leverage different learning modalities. In this regard, software tutorials (along with the software homework assignment) seem to be the most effective methods for learning both concepts and practical skills. This finding confirms the benefits of flipped classrooms model for teaching technology reported by previous research studies [15]. In this model, students encounter conceptual information outside the classroom or in a lecture session. Then in a lab/software tutorial session students work on an exercise with limited scopes to reduce ambiguity and direct students' attention to the important aspects of the intended technology.

2. How well did CM260 prepare you for using the following software applications							
	Not at all	Slightly prepared	Moderately prepared	Mostly prepared	Fully Prepared	Mean	StDev
Excel	2.8%	16.7%	19.4%	22.2%	38.9%	3.8	1.22
Sketchup	12.1%	27.3%	27.3%	24.2%	9.1%	2.9	1.18
Revit	11.8%	29.4%	41.2%	11.8%	5.9%	2.7	1.03
Bluebeam	5.7%	11.4%	20.0%	22.9%	40.0%	3.8	1.26
On-Screen Takeoff	31.4%	22.9%	17.1%	17.1%	11.4%	2.5	1.40
Microsoft Project	28.6%	28.6%	25.7%	17.1%	0.0%	2.3	1.08
Navisworks	32.3%	32.3%	19.4%	9.7%	6.5%	2.3	1.21

In the case of CM 260, during the software tutorial sessions the student's had the chance to actively engage in learning a software application through following a step-by-step guideline and asking questions. Also, the course instructor used the tutorial example to further contextualize the concepts taught in the previous lecture sessions. The survey result shows that this active learning approach can be an ideal method for teaching technology.

3. Which of the following help you learn concepts like design, estimating and scheduling?								
	Not at all	Slightly	Moderately	Mostly	Fully	Don't know	Mean	StDev
Software Homework assignment	1.9%	15.4%	26.9%	48.1%	5.8%	1.9%	3.4	0.90
Faculty Lecture	3.8%	21.2%	25.0%	38.5%	9.6%	1.9%	3.3	1.04
Guest Speaker	11.5%	26.9%	38.5%	17.3%	0.0%	5.8%	2.7	0.93

Software tutorial	1.9%	1.9%	11.5%	40.4%	42.3%	1.9%	4.2	0.88
Course reflections	40.4%	26.9%	21.2%	5.8%	0.0%	5.8%	1.9	0.95
External learning materials (reading)	23.1%	40.4%	25.0%	5.8%	1.9%	3.8%	2.2	0.95
External learning materials (video)	15.4%	17.3%	32.7%	17.3%	13.5%	3.8%	3.0	1.26

Regarding external learning materials, “reading materials” are slightly and “video materials” are moderately helpful for gaining both knowledge and skills. However, opinions are relatively scattered, which might be related to two broader pedagogical subjects. First, the CM260 students were anticipated to use the external learning materials as a supplemental source for self-learning and students tend to have different performance and pace in self-learning. Second, it is possible that some students had limited access to digital devices outside the class which is needed for using reading/video materials. This result helped us to address the currently emerging discussion in academia about the inequality in access to educational resources and the COVID pandemic has shed more light on this issue since many educational institutions have limited access to digital equipment on their campuses.

Finally, the guest speaker presentations and course reflection were shown to be the least effective methods (the result for the course reflection is expected since teaching knowledge/skill isn't the main goal for this activity). We realized that using guest speakers (mostly industry professionals) could be challenging for teaching technology due to the rapid changes in the emerging technologies’ knowledge and practices. In some cases, we observed that a guest speaker may either provide a too general overview of multiple emerging technologies or provide an in-depth discussion about implementing a specific technology solution. In both scenarios, the inconsistency between the provided information and students’ background/contextual knowledge would have a negative impact on the students’ learning experience. Therefore, in-advance coordination between the course instructor and the guest speaker is required to prepare a well-balanced and consistent lecture content.

4. Which of the following help you learn software skills like creating formulas in excel, conducting quantity take off in Bluebeam, or creating models in sketch up?								
	Not at all	Slightly	Moderately	Mostly	Fully	Don't know	Mean	StDev
Software Homework assignment	1.9%	15.4%	26.9%	36.5%	19.2%	0.0%	3.6	1.04
Faculty Lecture	15.4%	13.5%	40.4%	23.1%	7.7%	0.0%	2.9	1.14
Guest Speaker	30.8%	30.8%	26.9%	9.6%	0.0%	1.9%	2.2	0.99
Software tutorial	0.0%	3.8%	19.2%	42.3%	34.6%	0.0%	4.1	0.84
Course reflections	48.1%	30.8%	13.5%	5.8%	0.0%	1.9%	1.8	0.91
External learning materials	28.8%	26.9%	21.2%	15.4%	3.8%	3.8%	2.4	1.19

The last part of the survey was created to investigate the logical connection between the CM 260 as a preparation course and more advanced technology-related courses. In this regard, we asked the students about the ways they learned certain background knowledge/skills (topics

shown in table 3). Based on the survey CM 260 was most successful in teaching emerging technologies (both options of existing technologies and technology uses for design/construction), followed by working with spreadsheets and understanding database/data hierarchy (which is related to the previous topic). Also, students reported that Internships help them mostly in learning reading and interpreting digital drawings and the basics of construction activities. Although this result is in alignment with the general goal for internships in a construction company, it shows that more internship opportunities can be provided in specialized areas (e.g. estimating, scheduling, and VDC). Additionally, working with spreadsheets is the only topic in the given survey question that students learned in high school. This information is helpful because having an accurate assessment of students' background knowledge is required for developing proper content for a preparation course.

5. How did you learn about the following background knowledge/skill topics?						
	High School	Course CM260	Other CM Courses	Internship	Other	Didn't learn this topic
Working with spreadsheets	26.5%	15.7%	21.6%	26.5%	9.8%	0.0%
Basics of construction materials	2.3%	11.4%	48.9%	28.4%	9.1%	0.0%
Basics of construction activities	1.1%	13.3%	45.6%	30.0%	10.0%	0.0%
Understanding of database and data hierarchy	4.1%	14.9%	39.2%	25.7%	6.8%	9.5%
Reading and interpreting digital drawings	1.2%	13.6%	43.2%	37.0%	4.9%	0.0%
Basics of construction estimating	0.0%	13.8%	53.8%	28.8%	3.8%	0.0%
Basics of construction scheduling	0.0%	9.5%	60.8%	23.0%	6.8%	0.0%
Understanding of emerging technologies: existing software/hardware	4.5%	23.9%	44.3%	21.6%	4.5%	1.1%
Understanding of emerging technologies: technology uses for design and construction	0.0%	23.5%	45.9%	24.7%	5.9%	0.0%

To better connect the technology sequence courses, we examined how the CM260 prepared students to achieve the course CM414 (Virtual Construction) learning objectives. Students reported that they had mostly possessed the background knowledge/skills needed to use digital tools for 3D coordination. For all other topics, responses were equally divided into "slightly" and "mostly" prepared which refers to teaching effectiveness of digital technology as well as construction-specific subjects (e.g. estimating and project management). It also refers to students' various expectations from a preparation course which indicates the importance of effective communications between faculty/advisors and students regarding clearly discussing the curriculum structure and the sequence of relevant courses. The survey's results helped us to make alignment between the topics in the preparation course and those in the more advanced courses. In this case, we made a comparison between the content of the CM260 course and the learning objectives of the courses in the technology sequence to make sure students obtain all required knowledge and skills. We also use the survey tool to maintain alignment across the

curriculum by addressing new topics to be included in the sequential courses as technology evolves over time.

6. In the CM414 virtual construction, you learned about the following topics. Based on your experience in that class, do you think that you possessed the background knowledge/skills needed for learning the following topics?						
	Not at all	Slightly	Mostly	Fully	Mean	StDev
Use digital tools for 3D coordination	3.9%	23.5%	58.8%	13.7%	2.8	0.71
Use digital tools for 4D modeling	3.9%	37.3%	52.9%	5.9%	2.6	0.67
Use digital tools for model-based takeoff/estimating	5.9%	43.1%	39.2%	11.8%	2.6	0.78
Working with BIM execution plans	9.8%	41.2%	41.2%	7.8%	2.5	0.78
Use BIM for project management	4.0%	42.0%	48.0%	6.0%	2.6	0.67

Conclusion

This research sought out to better understand how the approaches being used in the UW construction management department supported the digital transformation of technology that has shifted the skills required for professionals, while maintaining the fundamental concepts of construction management. This was supported by the CM 260 Digital Tools course that was developed to help students prepare for these shifts. The responses from the survey show that the students were moderately prepared for most of the conceptual topics with some exceptions that could be explained by shifts in access to technology caused by the COVID pandemic. CM 260 mostly and moderately prepared students to use Excel, Bluebeam, Sketchup, Revit, and On-Screen Takeoff, which was consistent with the instructor's expectations of this course. Students reported that they mostly possessed the background knowledge and skills needed for 3D coordination introduced in more advanced courses, which shows that there is alignment as a preparation course. As for the teaching methods used in CM 260, there is evidence to suggest that the software tutorials and related assignments are the most effective methods for learning concepts and practical skills, and the active learning approaches can be ideal methods for teaching technology.

References

[1] Computer Integrated Construction Research Group, "BIM Project Execution Planning Guide V2.1." The Pennsylvania State University, University Park, PA, USA, [online document], 2011. Available: http://bim.psu.edu/Project/resources/default.aspx [Accessed: December 15, 2021]

[2] B, Succar, "BIM ThinkSpace episode 24: Understanding Model Uses," BIM Think Space, 2015. [Online]. Available: http://www.bimthinkspace.com/ [Accessed: December 15, 2021]

[3] A.C. Badrinath, Y.T., Chang & S.H. Hsieh, "A review of tertiary BIM education for advanced engineering communication with visualization," *Visualization in Engineering*, vol. 4, no. 1, Oct., pp. 1-17, 2016

[4] J. Liu, and M. F. Hein. "Visualizing construction: a course in digital graphics for construction management students." In Sulbaran, T. and Cummings, G., Proceedings of the 43rd Annual Conference of Associated Schools of Construction (ASC), University of Southern Mississippi, Northern Arizona University, Flagstaff, Arizona, USA, pp. 12-14. 2007.

[5] C. Hunt, C. (2005, March). eArchitect: Revit Finally Comes of Age. [Building Design]. March 2005. Available: http://global.factiva.com/en/arch/print_results.asp, [Accessed Dec. 15, 2021]

[6] T. Harmann, and M. Fischer, "Applications of BIM and hurdles for widespread adoption of BIM." 2007 AISC-ACCL eConstruction Roundtable Event Rep., Stanford Univ., Stanford, CA., 2008

[7] B. T. Johnson, and D. W. Gunderson, "Educating students concerning recent trends in AEC: A survey of ASC member programs." Associated Schools of Construction: Proc., 45th Annual Conf., Univ. of Florida, Gainesville, FL, 2009.

[8] B. Becerik-Gerber, K. Ku, and F. Jazizadeh, "BIM-enabled virtual and collaborative construction engineering and management." J. Prof. Issues Eng. Educ. Pract., vol. 138, no. 3, pg. 234–245, 2012

[9] A. Jaafari, K. K. Manivong, and M. Chaaya. 2001. "VIRCON: Interactive System for Teaching Construction Management." *Journal of Construction Engineering and Management, vol.* 127 no. 1, pg 66–75, 2001. doi: 10.1061/(ASCE)0733-9364(2001)127:1(66).

[10] M. B. Barison, and E.T. Santos, "BIM teaching strategies: An overview of the current approaches." Proc., of the Int. Conf. Computing in Civil and Building Engineering, W. Tizani, ed., Nottingham University Press, Nottingham, UK, 577–584, 2010.

[11] B. Becerik-Gerber, D. J. Gerber, and K. Kihong, "The Pace of Technological Innovation in Architecture, Engineering, and Construction Education: Integrating Recent Trends into the Curricula." *Journal of Information Technology in Construction (ITcon), vol.* 16, no. 24 (February 22, 2011): 411–32.

[12] G. O'Neill, "Overview of curriculum models." 2010, Available: http://www.ucd.ie/teaching%3, [Accessed Dec. 15, 2021]

[13] Y.H. Ahn, C.S. Cho, & N. Lee, Building information modeling: Systematic course development for undergraduate construction students. Journal of professional issues in engineering education and practice, vol. 139, no.4, pg. 290-300, 2013.

[14] National Research Council, How People Learn: Brain, Mind, Experience, and School: Expanded Edition. Washington, DC: The National Academies Press, 2000. https://doi.org/10.17226/9853.

[15] C. Monson, H. Homayouni, C.S. Dossick and A. Anderson, "Improving the Understanding of BIM Concepts Through a Flipped Learning Lab Environment: A Work in Progress" Proceedings of the 122nd ASEE Annual Conference and Exposition, June 14-17, 2015 Seattle, WA