Advantages of Integrating Technology Knowledge into an Undergraduate Curriculum

Nicholas Nam, Lonny Simonian, and Paul Weber

***Abstract*—Advancements in technology have made daily construction tasks both easier and more efficient, and presumably, will continue to do so. California Polytechnic State University, San Luis Obispo, CA, USA (Cal Poly) currently offers a Building Information Modeling (BIM) course, however, it is limited to certain application programs and the extent to which the course is offered for instruction is also limited. This paper is based on the results of a student senior project that explored the opinions of current Cal Poly Construction Management (CM) students on their views to successfully implant additional technology programs, and to which courses these programs could be integrated. Training on an expanding number of varying applications is necessary for internships. An analysis of the survey results indicates a strong consensus for the implementation of additional technology within the existing CM curriculum. The importance of technology within the new generation of builders is imperative to give students the resources they need to succeed in the construction environment.**

***Index Terms*—BIM, curriculum, technology.**

I. Introduction

The construction industry has divergent forms of work and each one is supported by technology. This includes software packages or web services for document control, three-dimensional modeling, scheduling, estimating, site logistics, cost controls, and more. Whether it's preconstruction, construction, or post construction, technology is improving the efficiency in all facets of construction. Diverse generations use varying methods, however, one common aspect among every generation is that the efficiency of construction is vitally important, and anything that assists with improving the efficiency of construction is considered beneficial.

The processes in which these (technology) classes are becoming relevant have been developing at a slow pace [1], and what is taught is soon outdated. Currently, California Polytechnic State University, San Luis Obispo, CA, USA (Cal Poly) has been evaluating technology programs and technology knowledge in their Construction Management (CM) BIM class, CM 280, *Emerging Trends*. This course was once optional, but is now required. There are many benefits to the current BIM course as it gives students the basic knowledge and subject matter introduction to programs that are used in the industry today. It is taught *by* students and is relatable to internships *for* students. One advantage with BIM is it allows an electronic collaboration with others on a specific construction project [2]. However, the current BIM course does not implement this technology into real construction situations, and it can be limited in depth. There are more ways in which these programs should be implemented across the curriculum in lieu of a technical elective.

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A. Introduction of Technology in Industry

The use of technology in construction can be described as a way to view work electronically versus doing the work physically. BIM provides information supporting design, analysis, cost estimating, procurement, detailing construction simulation, and more [3]. Document control programs, such as Procore, offer an application that keeps documents organized, and eases collaboration in the editing of the documents. In the construction industry, where paper documents are frequently distributed, such as via subcontracts, submittals, RFIs, closeout documents, and more, it is important to be able to track these simultaneously. Another type of document control program is Bluebeam. Bluebeam was once a standard document reader, but has expanded its use to include estimating and group editing. Procore and Bluebeam are just two of the programs that are dominant in document control and are drawing interest from students.

BIM has evolved its three-dimensional modeling capabilities as well. Throughout the construction industry, there are many BIM programs, such as Revit, Tekla, Archicad and ProjectWise. When Cal Poly students were asked about their use of programs in a series of survey questions, there were mixed reviews as to which they thought were the most important. The capabilities of these programs are all similar in that they allow you to model in 3D and to perform a quantity take-off from the model. This has become embraced by the industry since it greatly decreases the time to estimate quantities. Take-offs that were previously performed manually through drawings can now be accurately, and collaboratively, performed electronically through these programs. There are other programs that are specific for take-offs and estimating such as the Revit plug-in Assemble or Vico. The Architecture, Engineering, and Construction (AEC) industry tests emerging applications and occasionally new software companies are spawned.

Finally, another type of technology that was reviewed was one that could detect clashes in materials or equipment, also known as clash detection. Clash detection is useful in preconstruction because it helps subcontractors coordinate to eliminate clashes at the jobsite. To resolve these clashes in the preconstruction stage, rather than experiencing the clash physically at the job site, saves a great amount of time and money. Programs we surveyed included BIM 360 Glue and Navisworks. Both of these programs have the capability to import models from programs, such as Archicad, Revit, and

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Tekla, and are able to subdivide them by subcontract trade, align and clash accordingly, facilitating discussions for solutions to problems caused by clashes.

A case study by [4] shows the benefits of clash detection on the Mitchell Interchange project in Milwaukee County, Wisconsin, USA (Table I). This was a three-year, $250M USD project that included four interchanges, 19 new bridges, three tunnels, and more than 40 retaining walls. This table shows the percentage cost reduction by category and the average cost per issue for the project. Some categories were more affected than others, but the overall trend indicates that 3D modeling and clash detection saved money on the project.

TABLE I: ESTIMATED COST IMPACT (IN USD) FROM THE USE OF 3D MODELING ON THE MITCHELL INTERCHANGE PROJECT (PARVE 2007.)

DIN Category	Estimated Percent of Reduction	Total Cost ($ millions)	Average Cost Per Issue
General Structures	30.5%	6.8	$45,674
Roadway/Drainage	25.5%	5.7	85,631
Wet Utilities/Drainage	11.1%	2.4	27,120
Bridges	8.0%	1.8	15,557
Noise Wall	8.0%	1.8	125,909
Retaining Wall	7.7%	1.7	21,818
Earthwork	4.5%	1.0	59,220
Electrical/ITS/FTMS	2.6%	0.6	15,557
Traffic	2.1%	0.5	18,174
Sign Structures	0.1%	0.02	738

B. Challenges of Technology in Industry

Affordability, the pace of software updates and revisions, new applications offered from emerging startups, and sometimes, a steep learning curve, are obstacles to widespread adaptation. Smaller companies can afford, lighter, lower priced software such as Bluebeam. Larger, leading-edge, heavier BIM software, like Revit, supported with a growing number of third party add-ons is rather expensive for small firms that don't have the time and need to leverage its full potential. Adaptation of new applications becomes organically paced during the shakeout phase life cycle. Having a dominant application emerge, such as Excel for spreadsheets, helps narrow down future selection decisions in industry and, hopefully, in education.

C. Benefits of Technology in Industry

Benefits during the preconstruction stage alone include visualization, resolving construction problems, space conflict analysis, and hazard analysis [5].

Exporting quantities from a model to other applications can be fast, tirelessly repeatable, accurate (given an accurate model), and flexible. This reduces management costs and time, adds value, and perhaps can add additional services to the client by leveraging the power of the software. This speed and flexibility is more meaningful with projects or clients that create many change orders. It is anticipated that this trend will continue to expand with IPD and Design Build approaches to project delivery.

Clash detection of major system elements in a model, prior to fabrication and installation, by the principal subcontractors (structural, mechanical, electrical, fire suppression, process piping), reduce change orders and overall project costs and time.

The accuracy of these clash detection programs allow for minute clashes to be found for repairs, maintenance, and renovation [6]. Uncovering these issues before they actually appear could be a deciding factor as to whether a project is completed on time.

Document control technology assists with the coordination of all documents between the architect, contractor, and engineer. This coordination allows ease of mock-up and editing, giving all parties instant feedback. The feedback loop through electronic documentation is more organized than that through paper copies and document tracking can be much more effective.

D. Challenges of Effectively Implementing Technology into Curriculum

There are many challenges within a university to successfully educate students on how to effectively use technology. The Cal Poly CM Department requires students to provide their own laptop for classes, as much software is available at a reduced price (Adobe), or free on a Cal Poly hosted site (MS Office and MS Project) or free software (Revit, AutoCAD, Navisworks, and dozens more) from Autodesk. Software features vary among operating systems. Bluebeam features (Bluebeam Extreme) has limitations on Macs compared to PC's. And students with Macs have to partition their hard drive to run Revit, as Revit is not supported by the Mac OS. Laptops with relatively small hard drives are slow or often crash. Other software, such as P6, is taught in our computer lab due to the large purchase cost students would have to incur.

There is a trend for applications to become cloud based rather than PC based. BIM 360 Glue is a cloud based BIM management tool that allows a Navisworks model to be viewed on a tablet. FormIt 360, a SketchUp alternative, is a 3D application that works on mobile devices and web browsers. It is not OS dependent and can export to Revit.

Time for faculty training on the many existing, continuously developing, and dawning applications is scant given other inclinations of academia. Fundamental introduction and instruction of varying software capabilities is commonly the degree of depth that may be covered, given the demands of student course advising, student club advising, conferences, committee assignments, search committees, research and publishing, documenting of self-performance, and so on. There is little institutional credit for such training

II. METHODOLOGY

The process of conducting the survey included soliciting input from students via a survey on various types of technology related to construction and how these technologies are currently presented in our construction curriculum.

The survey consisted of ten questions and was available to construction management majors and minors. Responses from students in the College of Architecture were not solicited since their coursework principally focuses on other forms of technology.

The survey questions offered students an opportunity to express interest in topics they were interested in learning more about, as well as technology they had already had experience with in the industry. Students were asked how they would like to see technology courses implemented into the curriculum. They were asked how they saw technology in the future.

III. Results

The first survey question asked which of these programs were already in use by students during their internships (Fig. 1). Of the 45 students surveyed, 4 did not respond while the reaminder of responses were scattered amongst several programs. Most of the options that the students had for this question were related to programs that are readily available in the Cal Poly CM computer lab.

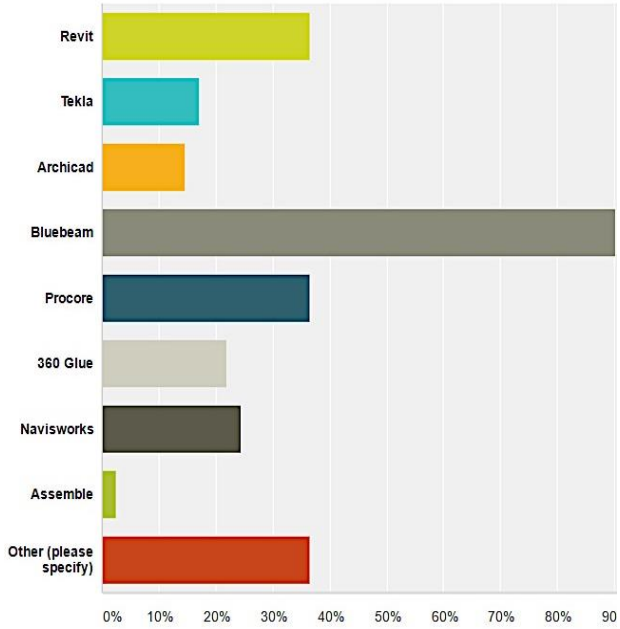


Fig. 1. Responses to survey question - Which of these programs have you used during an internship or job?

Recognizing that all of the options were checked off by students indicates that, during internships, students apply these technologies, howver, to varying degrees.

The next question asked which of these programs would students want to learn more about (Fig. 2). The response to this question was the most surprising. The most predominate response was Bluebeam, which is interesting because most students would say they were already proficient in Bluebeam and had to use the program in previous internships. Knowing there is a program they want to learn more about indicates a lack of Bluebeam education throughout the CM BIM courses offered. It is not known if students discovered more features during their internship while utilizing Bluebeam Extreme on a PC versus ReVu on PC's or tablets.

Another interesting take-away is the amount of desire that students had in Navisworks and Revit. Navisworks has many capabilities, but the program that industry is increasingly using for clash detection is BIM 360 Glue. There is no real education of this program offered in the curriculum currently.

Along with Navisworks, there is interest in learning more about Revit. Revit is one of the most common BIM programs and the lack of education in this is a concern. There should be more time spent using programs such as this because they are seen in industry more so than some of the programs that are being taught. However, in March of this year, the Cal Poly CM Department has been awarded an Autodesk Education Grant program that includes BIM 360 Docs, BIM 360 Glue, BIM 360 Field, and BIM 360 Plan.

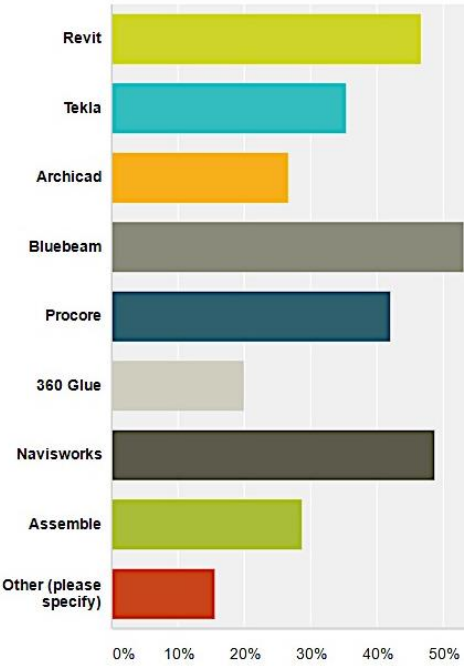
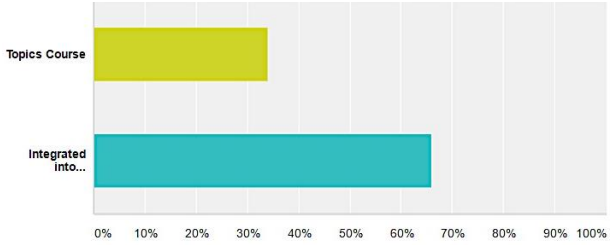


Fig. 2. Responses to survey question - Which of these programs do you want to learn more about in your construction classes?

The final question was how they would like to see the integration of these programs into the curriculum (Fig. 3). By a wide margin, almost 2/3 of students would like to see these programs instructed inside their major labs rather than as technical electives.



Answer Choices	Responses	
Topics Course	34.09%	15
Integrated into construction management labs	65.91%	29
Total		44

Fig. 3. Responses to survey question - Would you rather see a technology topics course, or more programs implemented into construction management labs?

IV. Conclusion

Student responses to this survey indicate they believe technical knowledge education should be integrated within the main construction management labs offered at Cal Poly. The challenge for instructors will be how best to integrate this technical knowledge, and through curriculum mapping, determine the most appropriate lab to present the material.

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