Building Information Modeling in Today's University Undergraduate Curriculum

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Abstract

Building Information Modeling (BIM) is a process that has been gaining traction in the architect, engineer and construction (AEC) industry. BIM allows combining a virtual model with all aspects of a project, from design to construction and operations. The model provides the ability to extract quantities for estimating, to define work elements for scheduling, to simulate environments for sustainability and to model work processes for facilities management. BIM is a tool that is aiding the AEC industry's shift to a more collaborative construction process .

The shortage of experienced personnel in the AEC industry conversant with BIM leads to an expectation that architecture, engineering and construction management graduates must be better prepared to enter the workforce. Because of this expected shortage of qualified personnel, research was undertaken at Arizona State University with FIATECH to understand how academia can support the construction industry as BIM becomes a major design / contractor tool.

Through surveys and face to face meetings, current educational programs were reviewed and recommendations developed to assist universities with curriculum development. The recommendations include methodologies of teaching the core concepts to understand the process of building by using a combined lab/lecture class allowing a hands-on learning process. Another recommendation to keep schools aligned with industry is to use industry professionals in the classroom to give presentations on BIM usage in the industry with examples to help illustrate skills needed by students so they can be successful. To help guide further curriculum development utilizing BIM, techniques used for BIM implementation in one class or throughout several courses are reviewed. Overall, the research explored the industry expectations and current educational approaches for the use and development of BIM in the classroom.

Keywords

Building Information Modeling, Construction Education, Workforce, Training, BIM, Construction Curriculum.

1. INTRODUCTION

The construction industry is experiencing a shortage of qualified personnel. One of the reasons is the lack of communication regarding core technology competencies needed for new graduates (Cleveland 2008). New forms of collaborative software, such as Building Information Modeling (BIM), are being introduced into the construction industry. This software is a key tool to aid in better collaboration between the design and construction

teams, helping drive new project delivery methods (Eastman et. al. 2008). These project de-delivery methodologies, such as Construction Management at Risk (CMAR) and Integrated Project Delivery (IPD), are designed to provide faster delivery time in the overall design and construction process resulting in projects with shorter installation times and more efficient construction. These more collaborative methods reduce design/ coordination errors as changes can be made earlier before the cost of a potential change grows significantly (Konchar & Sanvido 1998).

To gain a better understanding of the industry's current requirement with new technologies available, a survey was conducted to understand what the construction industry expects from a new graduate. After completing an industry survey, a second survey was conducted with academic institutions to provide insight into what schools are teaching students. A site visit was also conducted to an academic institution to obtain a more in depth view of their teaching style, techniques, and concepts. From this, recommendations were developed to better match industry expectations with technology implementation in a university setting, focusing on Building Information Modeling.

2. BACKGROUND

A shortage of qualified workers is possible in the near future in the construction industry. Despite the economic downturn, with a corresponding slowdown of construction work, the shortage of skilled and experienced workers in the industry is growing. As noted by the Chartered Institute of Building's (CIOB) third annual skills survey, 77% of the respondents indicated that there is a skills shortage in construction despite the economic downturn and 78% feel that the loss of skills in the industry will hurt the recovery when the economy improves (CIOB 2009). According to information from the US Department of Commerce regarding construction industry labor productivity as seen in Figure 1, the U.S. construction industry productivity dropped when compared to non-farm productivity over a period of 40 years (Teicholz, 2004).

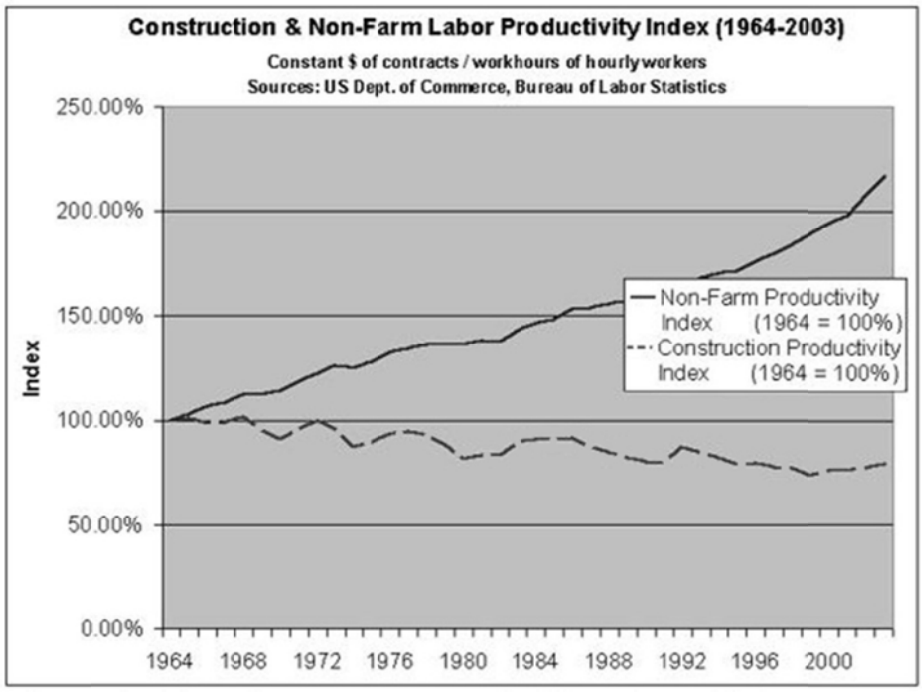

Figure 1: Construction Productivity Index vs. Non-Farm Productivity Index (Teicholz, 2004)

Since technology can be used to improve productivity, this research focused on seeking ways to improve the skill level of new college hires through the introduction and use of newer technologies, primarily Building Information Modeling (BIM). The 2008 BIM Smart Market Report published by McGraw Hill Construction notes that greater productivity, along with improved communications, are being seen by experienced BIM users. This tool will also support the integrated project delivery (IPD) methodology which has been shown to help streamline the design and construction process by reducing rework through sharing the information throughout the entire lifecycle (Jones 2009). Educating the incoming workforce with the skills and knowledge of how to implement this technology into the industry will help better prepare new hires for the construction industry. In addition to educating the current workforce, this will create a broader knowledge base for implementation into today's fast paced construction project.

In 2007, the 8th Annual FMI/ Construction Management Association of America (CMAA) survey of owners focused on the current usage of BIM. The survey showed that 35% of the respondents had used BIM technology for one or more years. Three quarters of the owners who had used BIM would recommend it to others for use on similar projects (FMI/CMMA, 2007).

The BIM Smart Market Report (2008) by McGraw Hill Construction is a report on BIM's current uses across the Architecture Engineering Construction Owners (AECO) industry and expected use in the near future. The 2008 report indicated that overall the rate of BIM usage is increasing in both design and construction companies, with the construction industry forecast to see the biggest increase of BIM usage in 2009. The report also stated that BIM would be most useful in the construction industry when compared to its use by Architects or Engineers because of its potential for construction cost savings (McGraw Hill Construction, 2008).

3. LITERATURE REVIEW

Since the use of BIM in the construction industry has increased and the advantages are being seen from its use, academic institutions are developing curriculum to help meet the industry demand. Some schools teach BIM throughout the entire curriculum and some place it within one course. The techniques used for instruction also vary depending on what each school determines best fits their approach. Most curriculums have been developed in the last three to five years because of the recent increase in usage of BIM. It should be noted, schools accredited under the ACCE for construction curriculum or ABET for engineering curriculum programs must follow the requirements developed for the school to remain or gain accreditation.

Auburn University, in a paper titled "Integration of Building Information Modeling (BIM) into an ACCE Accredited Construction Management Curriculum" (Taylor, Lui, & Hein, 2008), describes two introductory courses that outline the fundamentals of software use geared toward the construction industry. The original software based course included setting up estimates and project timelines in Microsoft Excel and Visio and 3D Modeling utilizing Google Sketchup and AutoCAD applications. BIM software use included Autodesk's Revit Architecture with VICO Constructor introduced later on a test basis with students in the course. Another course using BIM was also developed as an introductory elective course. In the development of this course, Auburn determined that learning how to model is not a key skill for a contractor, but rather it is important how to utilize existing 3D models for construction analysis and to determine construction efficiencies. Topics covered in this course included the development of Architectural, Structural and MEP (Mechanical,

Electrical, and Plumbing) models, development of a site plan, templates for estimating, pro-project scheduling, and knowledge of animation and presentation issues. A requirement was also added to include BIM in a Senior Capstone project. From the Auburn experience, it was determined that it was important to implement BIM throughout several courses in the curriculum because it does not fit into one course sufficiently or effectively. Since several core competencies need to be covered. Overall students were using available software to develop an understanding of the concepts behind the technology and the construction process (Taylor, Lui, & Hein, 2008).

For an engineering based curriculum, Worcester Polytechnic Institute (WPI) developed courses utilizing BIM for Civil and Environmental Engineering. Parametric modeling software was introduced during a one week basic module in 2003 utilizing Autodesk's Revit software. This one week session was developed in WPI's CE1030 class (Civil Engineering and Beginning of Computation) based on the "essentials of the dynamics of groups in civil engineering, the essentials of engineering, workmanship to prepare presentations and written reports and in the use of the computer". The course was developed so students could understand the "communication of the design, visualization and coordination of tasks of construction." Utilizing an existing 3D model, the basic aspects of how software can assist in design coordination, quantity take offs, and collaboration was demonstrated. Each semester after the completion of the class, a survey is taken to gauge the student's impression of BIM with the majority indicating BIM is a useful tool that helps facilitate the work group (Baeza Pereyra & Salazar, 2008).

4. METHOD

To understand the industry's status in relation to core construction technology competencies, a survey was sent to industry stakeholders. The survey consisted of 32 questions, seeking information regarding each company's use of BIM, the expectations of the workforce in regards to BIM, and where BIM is going in the future. The questions were based partially on input from industry professionals, and developed with a knowledge base focused around the construction industry. The survey was available through the FIATECH website from September to October 2008. The 77 respondents were located across the US and included some international locations. Respondents represented Engineering Construction (EC) firms (47%) and combined Architecture Engineering and Construction (AEC) firms (25%). The companies are located in the US, Canada, Europe and the Middle East. The majority of the companies (66%) are large companies, with over 5000 personnel and gross revenues of over $1 billion annually.

After completion and analysis of the industry survey, another survey was developed to determine the current state of BIM implementation in the curriculum at academic institutions. The survey was focused on construction education programs, but also included architectural and engineering schools. The survey was sent to members of the Associate Schools of Construction (ASC), the American Council of Construction Education (ACCE), buildingSmart alliance™, and FIATECH. The survey was available from January 2009 to March 2009 yielding a 40% response rate with 59 respondents to the survey; a good cross-section in location, size, and discipline of school was achieved. The survey design helped focus the respondents on answering the questions yielding important information. The respondents also had the opportunity to add comments to some questions to provide additional information where elements were missing through the survey.

5. RESULTS

5.1 Industry Survey

From the respondents to the survey, 56% indicated that they use Building Information Modeling (BIM) software. Of those who indicated that they do not currently use BIM in their company, 46% plan on using BIM in the future. This would indicate that approximately 77% of companies ultimately foresee using BIM in the future. With several different vendors of BIM software for the AEC industry, the majority of the respondents use Bentley products (85%) with approximately half of the respondents (48%) utilizing Autodesk products. Respondents also indicated they use other software including Archicad, AVEVA, and VICO (see Figure 2). Most companies use BIM for design, concept development, and construction documents. Fewer companies use BIM for scheduling, estimating, and the procurement process (see Figure 3). This seems to indicate companies during the pre-construction and construction phases are not using BIM to its full potential. Utilizing BIM in all phases of the project lifecycle could save time in coordination and clash detection identifying and correcting errors before it reaches the field thus saving time and money in the project overall.

The research objective was to understand the knowledge base expected for new hires to suggest educational curricula that will support the industry expectation. As indicated from the survey, industry expects new hires to have a grasp on skill knowledge (95%) rather than knowledge pertaining to a particular software program (5%). As indicated in Figure 4, the majority of companies (70%) expect new hires to have a working knowledge of 2D line drawings for use as construction documents, more than the ability to develop and work with conceptual modeling (56%).

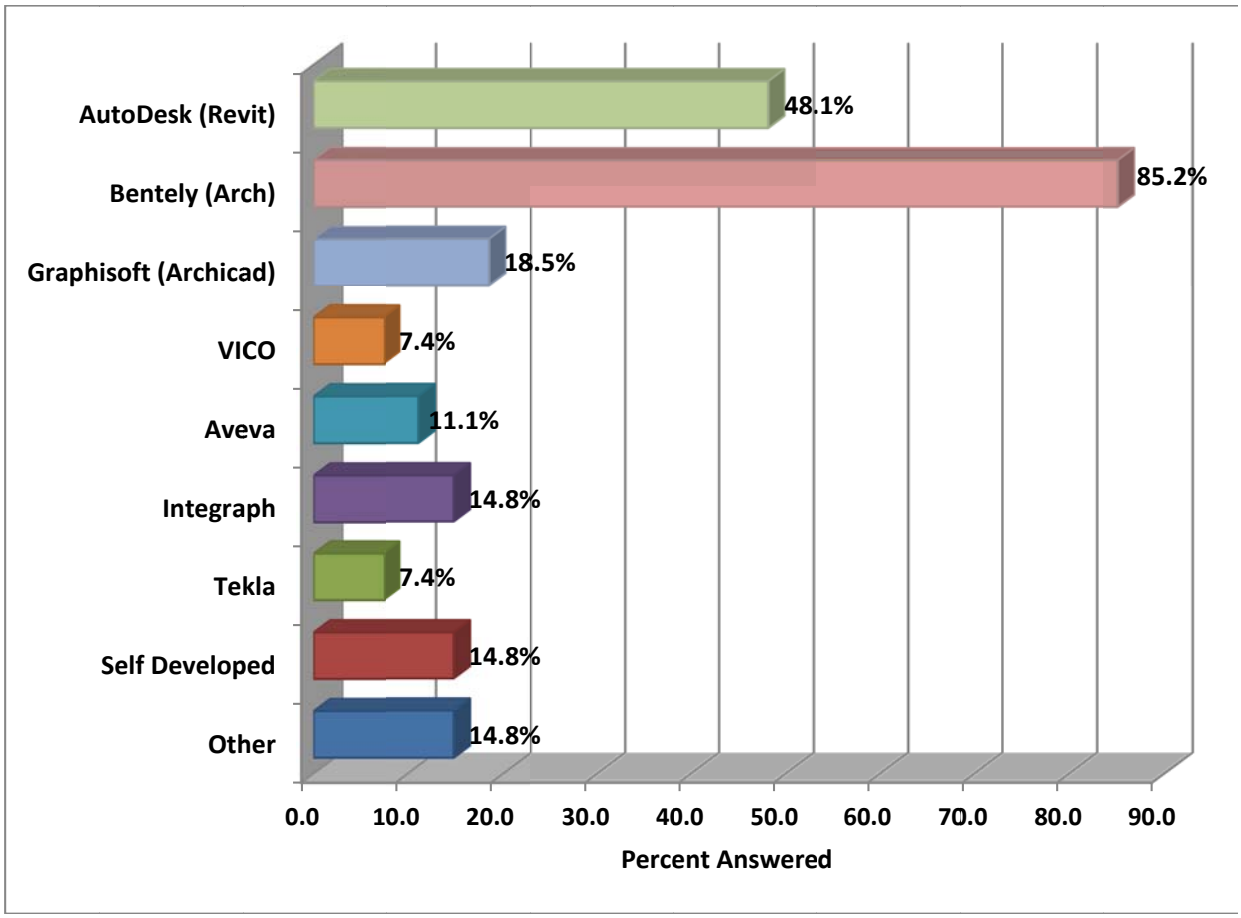

Figure 2: Building Information Modeling Software used by Industry

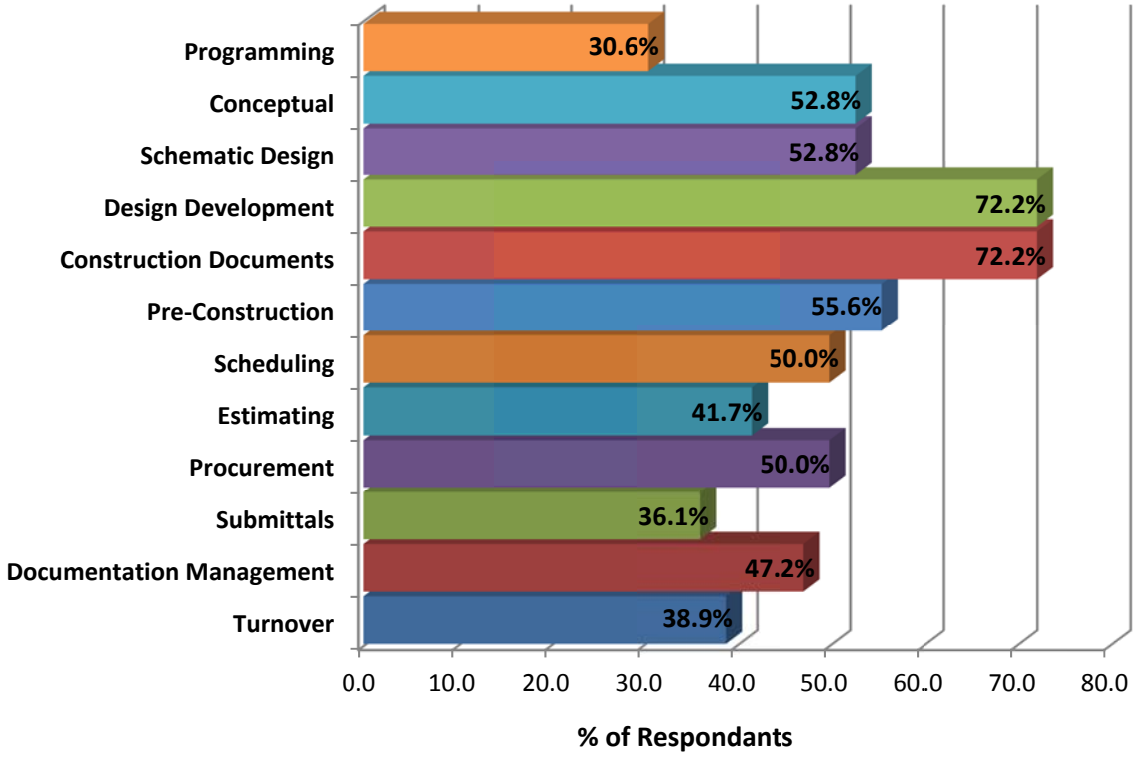

Figure 3: Industry's Use of BIM

BIM has several dimensions of use. These include adding cost or schedule to objects and attaching and implementing details regarding materials within the project model while utilizing various software. Half of the respondents from the survey indicated they tie a schedule to the 3D model allowing them to review what should be constructed at any particular time. The model's construction sequence can be simulated in a virtual environment using software such as Navisworks. Navisworks can be a very important tool to utilize because it provides a methodology to simulate a construction process virtually and allows for visualization of a proposed construction sequence. The majority of survey respondents (74%) indicated they did not currently use Navisworks.

The development of scheduling models and estimating models are key components to BIM in the pre-construction and construction process (Gao & Fisher 2008). From the industry survey, currently half of those who use BIM tie schedules to 3D models and less than half (approximately 40%) extract quantities from 3D models. Approximately half of those who are using BIM software currently are using it for 3D coordination, which would indicate not using BIM to its full potential.

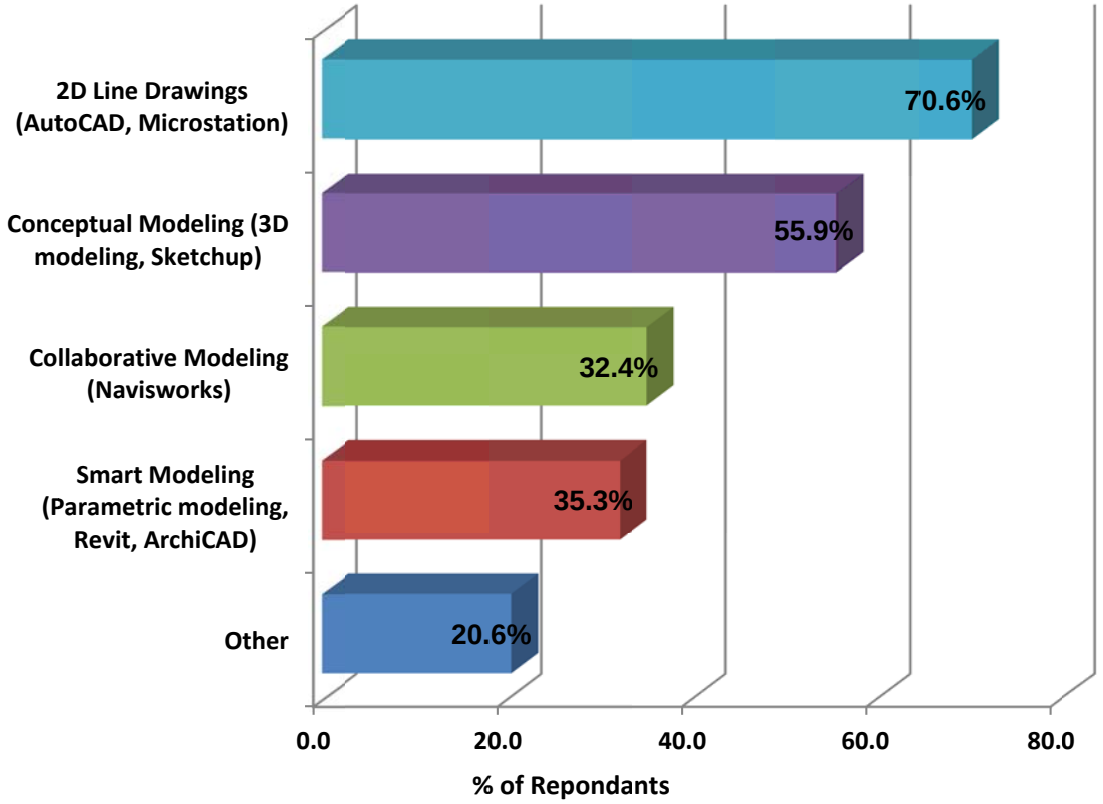

Figure 4: Industry's Expectation of New Hire Knowledge

5.2 Academic Survey

The results from the academic survey show that 58% of respondents were from construction specific curriculum, with 85% having an element of construction education in their curriculum. Overall 70% of the schools indicated they currently integrate BIM into their curriculum. For those that currently do not use BIM, 88% plan on implementing it, suggesting that 97% of all respondents will have BIM in the curriculum in the near future. Within the 70% of institutions that are currently using BIM, several noted that they are just starting to develop their curriculum.

From Figure 5, most schools offer a single course where BIM is taught. From the survey results, the longer BIM has been offered as part of the curriculum, more courses have been implemented. Most of these classes are taught by tenure track faculty with approximately one quarter of the schools using a faculty associate from industry or guest lecturers to teach the class. As seen in Figure 6, BIM is primarily taught in Design, Project Management, and Estimating courses. From the survey the classes are mainly taught using a combination of lab and lecture.

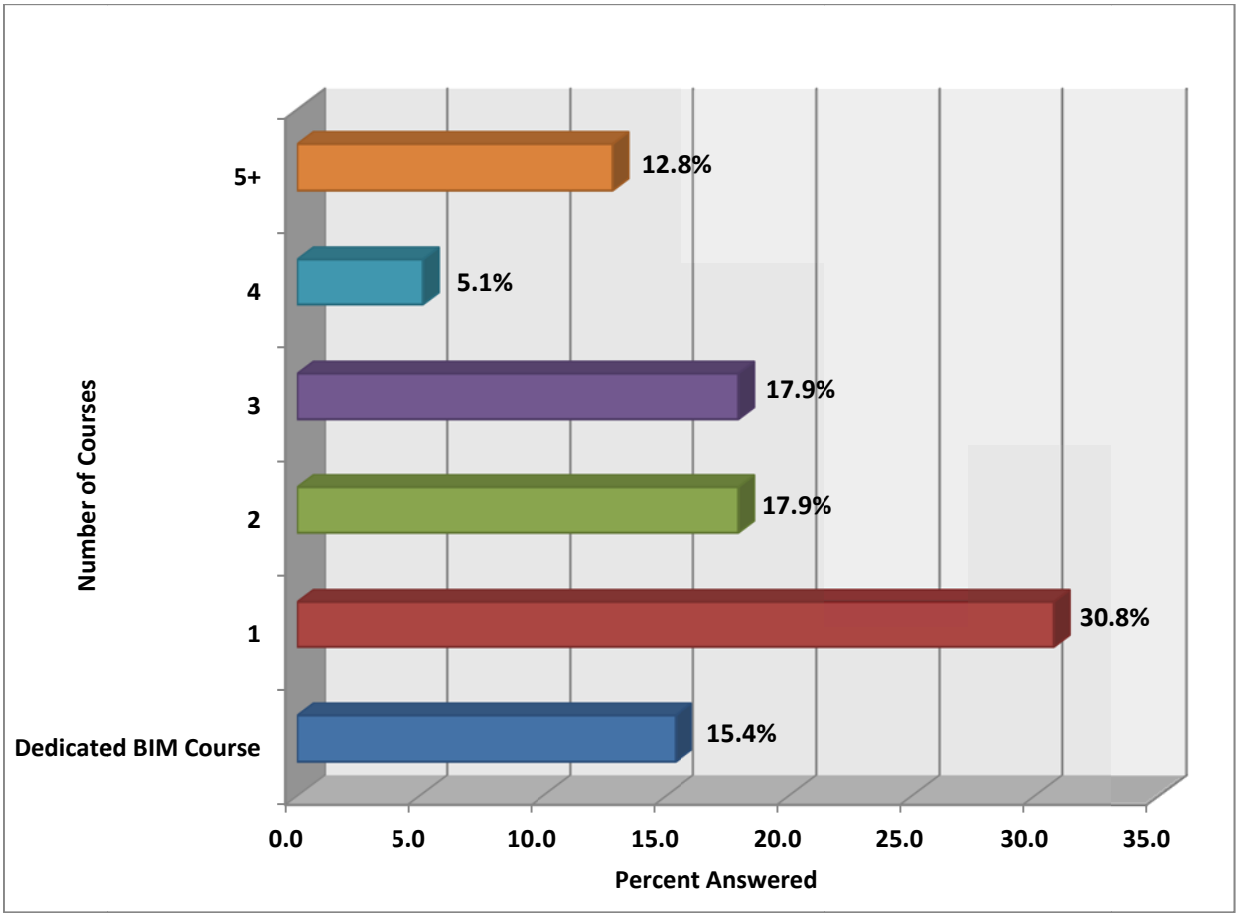

Figure 5: Number of Courses offered Implementing BIM

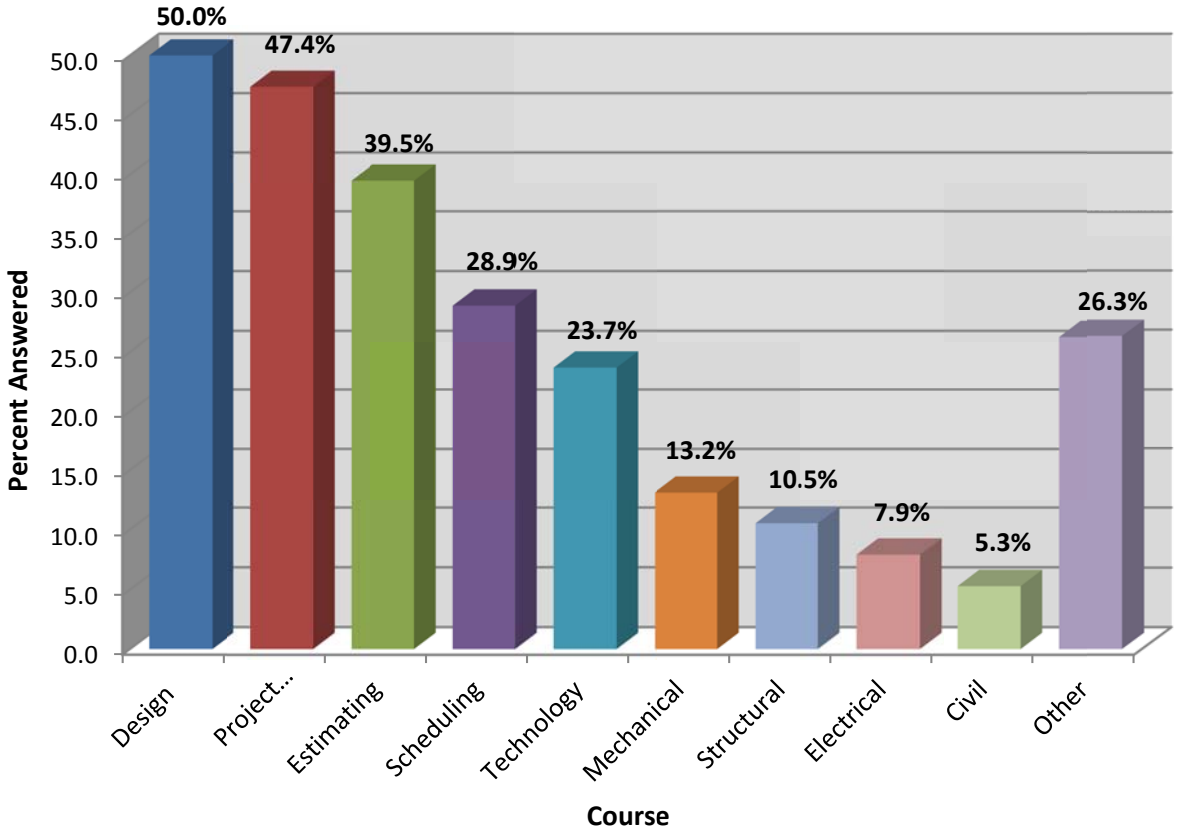

Figure 6: Courses Implementing BIM

With the industry indicated importance of tying estimates, schedules and information to a 3D parametric model, it appears from the survey only a few schools are implementing these techniques into their curriculum. The schools which responded use BIM for 3D coordination purposes (82%), while only half (46%) tie schedules to models, and even fewer (35%) tie estimates to the models. Very few schools are teaching energy simulation or operations and maintenance activities within the models.

5.3 Two Curriculum Examples:

In reviewing several examples of current curriculum which implement BIM into both ABET and ACCE accredited curriculums, basically two approaches have been taken. The first approach is to integrate it into one or two courses. The second approach is to implement BIM in several courses throughout the curriculum. There are advantages and disadvantages to both methodologies.

In the first approach, the students are introduced to basic and key concepts in the use of BIM software. Guest lecturers include industry professionals from various phases of the construction process such as a General Contractor, Sub Contractor, Pre Construction, Legal, and Facility Operation and Maintenance. This provides the students a better understanding of how BIM affects the facility through the life cycle. This is taught within one senior level class in a construction based curriculum.

Key skills taught in this senior level class include Logistics & Site Layout, 3D Coordination, scheduling simulations, and quantity take-offs. The course is structured to first show the students the current methods of developing construction documents helping them understand how 2D drawings are used in project development. By illustrating the basic workings of the drawing software, the students learn how designers compile their drawings, using single lines, layers and line types. This focuses the students on why drawings are not always coordinated, not on the software and then allows a building of skill in the 3D environment

The second approach studied integrates BIM throughout a 5 year Architectural Engineering (AE) curriculum. The objective of this program is to mix Building Information Modeling throughout the curriculum. Here, the traditional Construction Management classes, such as estimating, scheduling and project management, are not offered as standalone classes and BIM is treated much the same. These topics and tools are taught through a variety of classes that are focused around Architectural, Structural, Mechanical, Plumbing and Electrical design elements. The models are created in BIM software and the information is a key component in helping produce estimates, schedules and constructability reviews. The models are an avenue for communicating and teaching the traditional subjects, helping the students visually understand the complexity of performing task such as scheduling and quantity take-offs. BIM is being treated as a core tool required for understanding complex problems and the more proficient students have great success in implementing it into all of their classes. The knowledge of the tools is continuously applied through the program culminating in a Senior Project that demonstrates the expertise of each core skill.

6. CONCLUSIONS

The integration of BIM into the classroom can be accomplished through stand-alone courses or throughout the program, adding the concepts and tools in several courses. The surveys taken and the literature reviewed indicate that schools are moving in this direction, with over 97% indicating that BIM will be a part of the curriculum.

Utilizing BIM as a problem based learning tool is a benefit to students and industry, but in order for it to be a true success, industry and academia must form a strong partnership. Academia should work to integrate BIM into multiple courses with qualified instructors. They also must be dedicated to ensuring students grasp the skills. Industry must be willing to invest

in academia taking the time to visit the classroom and discuss current trends and scenarios. Industry could share generic models that can be utilized in a BIM curriculum providing students with current and applicable material to implement the skills they have learned. Without this partnership it will be difficult for academia to prepare students for the challenges the students will face in the workforce.

To prepare the construction industry to be in a position to negate the effect of a shortage of qualified personnel, industry and academia must work together to train and educate the next generation workforce to take their position. Productivity increases for construction will be needed to ensure that capital projects are continued to be provided in a cost effective manner to meet the needs of owners. Building Information Modeling (BIM) is proving to be a technology that will have an impact on the delivery process of the architectural, engineering and construction community. This research explored the needs of industry related to the skills desired for new hires and how educational institutions can help. The industry is moving toward the implementation of BIM as part of a more collaborative delivery process and the educational process needs to seek ways to implement BIM into the Construction Management curricula.

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