

The Integration of BIM in the Undergraduate Curriculum: an analysis of undergraduate courses

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The purpose of this study is to investigate the existence and prevalence of undergraduate courses devoted to the study of building information modeling (BIM) and to discover the constraints on these programs. A survey was mailed to all members of the Associated Schools of Construction which offer four-year undergraduate programs. The survey asked about AutoCAD and BIM and whether they are offered as stand-alone courses or as part of other courses; which elements of BIM are offered; and what barriers could be identified to offering BIM in the curriculum. Fewer than 1% responded that BIM is taught as a stand-alone course, while 9% said BIM is addressed as part of existing courses. The most significant obstacles to including BIM at the undergraduate level are the already-existing requirements for graduation, the absence of room in the curriculum for additional elective courses and the lack of reference materials and established curricula.

Key Words: Building Information Modeling, Construction Education, Integrated Project Delivery, Technology Education

Introduction

The days of the straight edge and protractor are over. Computer-aided drafting (AutoCAD) was for a time the most sophisticated modeling technique available to construction managers. It is now giving way to the more complex technology of building information management (BIM).

Progressively more complicated project management tools produce fresh opportunities for construction project managers. Construction managers are striving to improve their project development and operational management through the use of increasingly sophisticated technology. One new tool, BIM, is being used ever more frequently in private industry and in U.S. government projects as a method of integrated project delivery. In 2008 the American Institute of Architects (AIA) issued its first contracts which specifically refer to BIM.

Incorporation of BIM technology in undergraduate curricula is taking place more slowly. The new project management tools, like BIM, are challenging for undergraduate construction management education. The standard of non-integrated, stand-alone courses no longer meets the needs of students who will be employed in the construction industry. Long-established courses take students through benchmarks, semester after semester, often without integrating new developments in technology or introducing new methods of project delivery. Students' post-university employment increasingly depends upon their ability to integrate all facets of the curriculum and to comprehend more than the design-bid-build model – or even the more recent design-build model – of project management.

A review of recent studies and university websites, admittedly incomplete, reveals that some undergraduate programs are making the leap to incorporate BIM in their curricula. For example, Auburn University introduced BIM by way of a one-week tutorial, followed by a semester-long introductory course (Taylor, Liu and Hein, 2008). The New Jersey Institute of Technology introduced BIM “several years ago in various upper-level studios....we now offer a BIM class and use it as the main tool in a design studio.” (Rudesill, 2007)

This study is an attempt to quantify what undergraduate programs have done, if anything, to incorporate BIM in their curricula. The paper describes the status of BIM in the curricula of undergraduate programs in construction management. The survey was conducted in Winter 2008. The survey was administered to determine the extent to which BIM is integrated in American universities' undergraduate construction management programs.

Definition

What is BIM? BIM represents a migration in the architectural design field from two dimensions to three dimensions by creating intelligent, multi-dimensional building models. (Reddy, 2007) Through BIM, designers can enhance their computer projections to incorporate actual materials. BIM shows a building at every aspect of its development and illustrates construction, design and materials in detail. The embedding capacities of BIM make it a dynamic platform and allow multiple groups in different locations to work on projects. (Thomson and Miner, 2007)

About 25 years ago, AutoCAD pushed designers into a new era of computer-assisted design and modeling. Undergraduate programs were then developed to teach AutoCAD. BIM represents a new generation of virtual models, already widely accepted in industry. Instead of one-dimensional drawings or 2-D AutoCAD files, BIM's multi-dimensional approach allows the building team to see how the pieces of their project fit together in real time. (McFarlane, 2008) BIM is both simple and revolutionary. If every piece of data required to design and construct a project is entered and developed within a single online system, a structure can be built first in the virtual world. BIM creates 3-D models and adds fourth and fifth dimensions of scheduling and cost. The model's output produces all the documentation which would otherwise be created in isolation and duplication. (Thomson and Miner, 2007). A subcontractor's miscalculation can be caught and corrected easily, before construction actually begins.

BIM uses information-rich databases to characterize virtually all relevant aspects of a structure. Parametric modeling is the basis for BIM processes, and the parametric model is data-rich. A parametric modeling system is generated from a relational database containing information regarding attributes of a structure's elements and the relationships among them. The model can be used to generate space calculations, energy efficiency analyses, structural details and traditional design documents.

Parametric modeling does not inherently require object oriented technologies. Sometimes called "intelligent objects," object oriented designs use software objects that encapsulate information concerning each element within the software object rather than the database. Provided they conform to a common specification, objects can be created by third parties, as well as the model design, and can appropriately interact within the model. The objects communicate with each other and with the model itself and adapt to information received from other objects. (Ashcraft, 2007)

BIM has also been called "a disruptive technology" (Eastman, Teicholz, Sack and Liston, 2008) because it will transform many aspects of the architecture, engineering and construction industries. Eastman, et.al. write that BIM invites strategic re-thinking of processes and production to achieve results which are better ("more knowledge about the building earlier in the life cycle regarding cost, energy use, organizational performance, and 3-D visualization by all members of the project team"), faster ("ability to use construction and fabrication knowledge during design, ability for greater use of off-site fabrication, ability to use product information earlier in design and in procurement planning") and cheaper ("much better coordination of project team using the model as source of decision-making and planning, faster procurement, greater use of fabricated components from global sources, fewer owner changes because of better understanding of the building and how it will function for its users, and fewer errors, omissions and claims"). (Eastman, Teicholz, Sack and Liston, 2008)

Methodology

Participants

The colleges and universities which are members of the Associated Schools of Construction (ASC) were surveyed for this study. Though many ASC members have graduate programs, this study is concerned only with programs which are offered to undergraduates. At the time of the survey, there were 119 institutions on the ASC website which offered undergraduate programs in construction management, construction science, building science or construction engineering. Our survey was mailed to each institution. Responses were received from 45 institutions, about 38 % of the total.

Questionnaire

The questionnaire which was developed for this study requested quantitative and qualitative information from the respondents. The first section asked for demographic information about the institution.

The second section concerned the curriculum at each institution. The survey asked if AutoCAD and BIM are taught as stand-alone courses. It also asked separate questions about the incorporation of elements of AutoCAD and BIM in other courses. In addition, it asked respondents to specify which vendors' software applications they use in their curricula.

The third section asked questions about the usefulness of existing technology courses and about obstacles to changing curricula and developing new courses. This section asked (1) Do you believe the technology education offered in your program adequately prepares your students for jobs in the construction industry? (2) Do you believe the use of BIM in the marketplace will continue to increase? (3) What are the most significant obstacles to offering BIM in your undergraduate curriculum?

The final portion of the questionnaire concerned accreditation. The question referred both to the American Council for Construction Education (ACCE) and the Accreditation Board for Engineering and Technology (ABET). The survey question appeared to provoke confusion and the information received from respondents was inconsistent. In this paper none of the data regarding accreditation was used.

A portion of the survey is in Appendix A.

Data Analysis

Our analysis includes only descriptive statistics and no comparative statistics. No other statistical analysis was completed.

Results

Respondents reported that 6.5% teach AutoCAD as a stand-alone course. At institutions where AutoCAD is not taught separately, it is incorporated in other courses according to 88.9% of respondents. Only one institution (fewer than 1% of respondents) reported that its program offers BIM as a stand-alone course. BIM is incorporated in other courses in 9% of programs. Of the 45 institutions which responded to our survey, only 23 specified at least one software program which is used in their construction management department. A plurality cited Autodesk Revit. Other applications include Graphisoft ArchiCAD, Bentley Architecture and VectorWorks ARCHITECT.

Our survey of undergraduate education shows that about 62% of our participants say that BIM education is not adequate. Coupled with our survey data which show that 75% of participants believe the use of BIM in

the marketplace will increase in the next five years, and the empirical data which show that construction companies are increasingly reliant upon BIM, there are strong signs that the BIM curriculum needs to be enhanced at the undergraduate level.

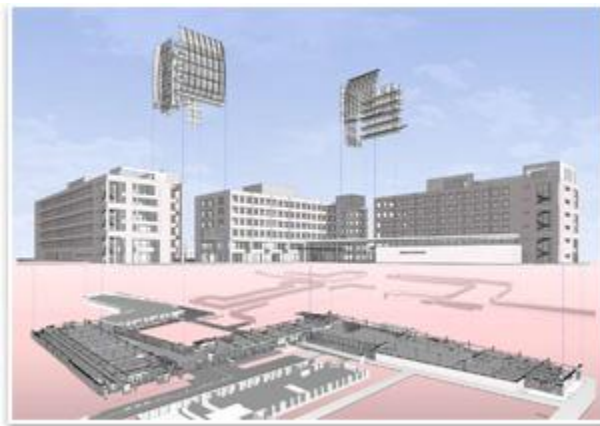
Participants in our survey were asked to identify factors at their institutions which they perceived to be obstacles to providing BIM education at the undergraduate level. The survey mentioned four barriers and also invited respondents to identify others. Of the four barriers which were cited in the survey, the most common response was that there was no room for new courses in the existing curriculum (82%). Respondents also cited the limited number of courses (requirements and electives) which students can take if they are going to graduate in eight semesters (66.7%), the faculty time and resources required to develop a new course (86.7%) and the lack of textbooks and other educational resources for students (53.3%).

The survey respondents also volunteered that they identified these barriers to incorporating BIM in their curricula: complexity of BIM, students' lack of interest or willingness to explore new technology, lack of support from faculty colleagues and/or administrators, unwillingness to change curriculum to add BIM when BIM itself may be supplanted by another technology program in a few years, and uncertainty about which BIM platform (Revit, Bentley or something else) will become dominant. Finally, about 10% of our survey respondents volunteered that, at their respective institutions, they anticipate that the most practical way to offer BIM to their students would be to incorporate it into an upper level independent project.

Discussion

Innovation in the construction industry is driven by demands for cost savings and increasingly quick project completion. Software developers have responded by creating new systems of project management. Designers now think beyond two-dimensional blueprints to multi-dimensional models.

One of the drivers of the movement to BIM implementation is the US General Services Administration (GSA), the largest builder-owner of federal projects in the United States. (Khemlani, 2007) The GSA has mandated the use of BIM not only for its immediate benefits of meeting schedules and controlling construction costs, but also for the long-term benefits of controlling building operating costs and limiting energy use. (Khemlani, 2007) The GSA's requirement will certainly have the effect of compelling construction management practitioners to incorporate BIM among their design services. The GSA has announced that the adoption of BIM is not being driven exclusively by cost savings. In addition, it has said that BIM has other benefits, including its ability to explore different engineering systems, perform energy analysis for LEED certification, derive specifications automatically and eventually eliminate paper-based processes.



The federal government is building its new 4.7 million-square-foot Food and Drug Administration headquarters in Maryland (pictured above) on a BIM platform. Over a period of eleven years, 20 structures

will be built. In December 2007 the project won an honorable mention award from the American Institute of Architects in the “Design/Delivery Process Innovation Using BIM.”

Architectural, engineering and construction firms are also moving quickly to adopt BIM as an industry standard. A recent study by AECbytes (Khemlani, 2007) revealed that architectural, engineering and construction firms want to be able to “produce construction documents so another drafting application need not be used.” Firms want “scalable solutions to support...large projects...they also want automated setup...and coordination, reducing traditional CAD management tasks...[They want] all the capabilities of CAD [including the powerful documentation and visualization capabilities and] they want the fully automated change management and coordination [of BIM]. In short, they want to the best of both worlds – all the capabilities of CAD that they have [used] over the last few decades, as well as all the new capabilities that BIM applications have the potential to provide.”

Conclusion

Drafters huddled over drawing tables are an image from the past. Today new structures are being designed by architects and engineers who are well versed in the requirements of a myriad of software programs, BIM among them. The professional architecture and engineering community is embracing new technology quickly, incorporating new opportunities to streamline the design process and to save time and money. The academic community moves more deliberately and thoughtfully to incorporate new technology and to offer new courses.

While government and private sector entities use BIM for new construction, university programs have been much slower to incorporate the technology. Even the development of curriculum has not been left to the universities. In April 2008 the Associated General Contractors of America (AGC), a trade association, issued a Request for Proposal, “Project to Create a Building Information Curriculum for the Associated General Contractors of America.” The AGC will hire with curriculum developers to create an instructor-led Building Information Modeling (BIM) curriculum for use by the AGC chapters.

BIM is currently being addressed in only about 10 % of undergraduate programs. That is a sobering statistic in light of the expectations of industry practitioners. The future is even less encouraging when one considers how long it takes for a university to develop new courses and to integrate them into the curriculum. As the pressures increase both to control costs and save time, it is inevitable that our construction management students will move into a world which demands that they are adept at using tools like BIM.

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Appendix A

Sample of Survey

Section 2

1. Is AutoCAD taught as a stand-alone course for undergraduates at your institution? Y N
2. If not, are elements of AutoCAD incorporated in other courses? Y N
3. Is BIM taught as a stand-alone course for undergraduates at your institution? Y N
4. If not, are elements of BIM incorporated in other courses? Y N
5. Which vendors' software applications are used in your curricula? Please list all applications.

Section 3

1. Do you believe the technology education offered in your program adequately prepares your students for jobs in the construction industry? Y N
2. Do you believe the use of BIM in the marketplace will continue to increase? Y N
3. What are the most significant obstacles to offering BIM in your undergraduate curriculum? Please underline any or all which apply to your institution: no room for new courses in existing curriculum, limited number of courses students can take and still graduate in eight semesters, faculty time and resources required to develop new courses, lack of BIM textbooks and other educational resources. In addition, please specify any other obstacles which you can identify at your institution which you think are obstacles to offering a BIM course to undergraduates.