From BIM to Collaboration:A Proposed Integrated Construction curriculum

Miss Arundhati Ghosh, Arizona State University
Kristen Parrish PhD, Arizona State University

Kristen Parrish is an Assistant Professor in the School of Sustainability and the Built Environment at Arizona State University (ASU). Kristen's work focuses on integrating energy efficiency measures into building design, construction, and operations processes. Specifically, she is interested in novel design processes that financially and technically facilitate energy-efficient buildings. Her work also explores how principles of lean manufacturing facilitate energy-efficiency in the commercial building industry. Another research interest of Kristen's is engineering education, where she explores how project- and experience-based learning foster better understanding of engineering and management principles. Prior to joining ASU, Kristen was at the Lawrence Berkeley National Laboratory (LBNL) as a Postdoctoral Fellow (2009-11) and then a Scientific Engineering Associate (2011-2012) in the Building Technologies and Urban Systems Department. She worked in the Commercial Buildings group, developing energy efficiency programs and researching technical and non-technical barriers to energy efficiency in the buildings industry. She has a background in collaborative design and integrated project delivery. She holds a BS and MS in Civil Engineering from the University of Michigan and a PhD in Civil Engineering Systems from University of California Berkeley.

Dr. Allan Dee Chasey, Del E Webb School of Construction, Arizona State University

Dr. Allan D. Chasey is the Program Chair for the Del E. Webb School of Construction at Arizona State University and the Sundt Professor of Alternative Delivery and Sustainable Development. He received a Ph.D. from Virginia Tech, a Master of Science in Engineering Management from the Air Force Institute of Technology, and a BS in Civil Engineering from Arizona State University. He is Director of CREATE, Construction Research and Education for Advanced Technology Environments, a research consortium of companies representing the Advanced Technology design and construction industry.

Dr Chasey is a registered Professional Civil Engineer in Arizona and a member of the American Society of Civil Engineers (ASCE), the Association for the Advancement of Cost Engineering (AACE), the Institute of Environmental Sciences and Technology (IEST), International Society of Pharmaceutical Engineers (ISPE), and the Semiconductor Environmental, Safety, and Health Association (SESHA). He is also a LEED AP B+C.

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Abstract

Adopting Building Information Modeling (BIM) Education as an essential component of Construction Management is challenging due to inconsistencies arising from various skill levels, conceptual understanding of processes and existing methods of teaching. However, competence in BIM opens new avenues for research and in most cases improves the marketability of students as they prepare for careers in construction and engineering. A BIM environment assures collaboration through participation. While the benefits are significant, the hurdles faced in successfully implementing the BIM concepts and processes are several. The technology being new, students are often misled by an incomplete understanding of the subject--understanding BIM as an acronym for 3D design, rather than appreciating BIM as a process of sharing and simulating information. Teaching BIM as a process versus a single software package is a common issue that may be effectively addressed through a stepped progression of smaller packets of information spread in different courses throughout the curriculum, so called 'vertical integration.' Vertical integration of curriculum supports a comprehensive understanding of a subject and the means and methods that form its core. Further, vertical integration of curriculum helps students retain knowledge from year to year as repeated exposure to a subject, like BIM, allows students to build upon their previous knowledge. Often, vertical integration results in students understanding subjects holistically rather than as a series of individual isolated topics. Only when a certain level of understanding and knowledge retention is achieved can a BIM based collaborative environment become fruitful.

This paper addresses the hurdles faced by Arizona State University in the implementation of BIM in a Construction Management curriculum. It further discusses the ongoing efforts of developing a vertically integrated BIM curriculum through a three pronged approach - teaching the tool, teaching the concept of BIM as a process, while promoting collaboration. We also explore a set of learning objectives that could be used for evaluating the effectiveness of the vertical integration approach.

Introduction

Construction Management (CM) education is a holistic field within academia typically distinct from architectural and engineering curriculums, primarily focused on teaching the 'business of managing the construction process with the changing technology of the industry' (1). Building Information Modeling (BIM) is one such technology popular amongst the Architecture-Engineering and Construction (AEC) industries that makes use of the embedded intelligence in digital design and construction data to inform the construction management process. The industry has embraced BIM as a technological, cultural and philosophical concept, reaping benefits such as time and money savings through reduced rework, enhanced understanding of a project through visualization and collaboration etc., promoting efficiency in the management processes (6). While the industry has championed its use, academia has found several hurdles in implementing BIM in curriculum successfully. Several reasons may explain this, such as conflicting ideologies of teaching BIM as a graphical software application versus teaching the core concepts behind it (5), inconsistencies in learning arising from existing skill levels of students and the traditional methods of teaching resisting inclusion of new technologies (4). A working knowledge of BIM requires the development of the skill to run the application and also understanding how the concepts can be applied beyond the use of the software in isolation. Retaining the skill of operating the software is necessary to advance to more complex applications of BIM in CM. Retaining knowledge of an application is difficult if not practiced; attributing to reasons such as break in flow of BIM use because of certain subjects taught in isolation, course overload from other important subjects and shortage of time.

For promoting BIM education, three common approaches are popular – (1) offer BIM as an elective or a workshop, (2) make it an advanced degree program, or (3) restructure the existing curriculum to include BIM (3). To combat the hurdles mentioned above while considering the realities of the programs already in place, this paper will discuss a fourth approach of integrating BIM with the existing CM curriculum (building on the restructuring concept presented above). CM programs accredited by the American Council for Construction Education (ACCE) do not have any specific requirement for a BIM class but they do have a category for 'Computer Applications' as a part of most construction curriculum subjects such as - Construction Documents, Estimating, Scheduling, Project Management and/or Materials and Methods (12). While the authors support the notion of integrating BIM not only vertically, but also horizontally across courses and departments, their current efforts focus on integrating BIM within the ACCE accreditation requirements. When they have a working model for a vertically integrated BIM curriculum within CM, they will work with other departments to cross list these courses and expand the curriculum horizontally to capture the multi-disciplinary collaborative BIM experience.

This paper addresses the concepts of –
(a) Integrating BIM through a *stepped progression* of smaller packets of information spread over different courses throughout the curriculum and
(b) *Vertically integrating* students from different years for class projects to impress the concept of learning BIM as a continuing process. This approach will engage students from each level as appropriate for their experience and will provide relevant experience for the learning objectives for each class level and course content (e.g., demonstrate knowledge in the first-year courses, evaluate alternatives in third-year courses). The paper will describe an 'Implementation Method' and a 'Proposed Evaluation Plan' for Arizona State University, establishing learning objectives and performance metrics to assess the learning outcomes.

Background

Including BIM in the CM curriculum at ASU was based on factors such as - the full course load, maintaining accreditation criteria and tailoring the objectives to the purpose of construction management rather than architecture or engineering design (2). After conducting relevant surveys and research, ASU in Fall 2008 started offering a 'BIM Lab' adjunct to the senior level 'Project Management' core course. In the beginning all computer work had to be done outside of the class period. This approach was met with skepticism and an overall lack of excitement from the students, as there was very little interaction while solving problems. Also because of the difficulties faced in learning a new software the students were not habitual with, they would most often get stuck and focus only on completing the required deliverable. After a few other iterations ranging from monthly guest lectures to basic tutorials, it was decided to include the 'BIM Lab' as an adjunct single credit offering in addition to the mainstream Project Management lecture (7). Since Spring 2011, the curriculum for the lab has been modified to include more collaborative group assignments using Case Based Scenarios based on real construction projects. Also in Spring 2011, BIM was integrated with the sophomore level 'Working Drawings' core course and also offered as an elective at the junior level 'Introduction to BIM'. 'Working Drawings Analysis' (CON244) is a lecture that 'covers an overview of construction drawings and how they are organized, recognizing the various building components, the different construction methods and the various components of major systems as represented on working drawings' (4). Along with understanding concepts on paper drawings, students spend a maximum of 8 hours exploring digital construction documents in a BIM authoring tool such as Revit Architecture®. 'Introduction to BIM' (CON394) is offered as an elective for those students who want to further their skills in using BIM tools. This exercise was the beginning of a stepped progression of BIM Education at ASU (Table 1).

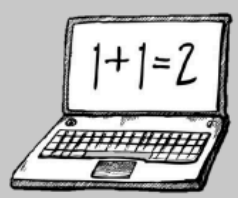
CON224 'Working Drawings Analysis' Units: 3 credits	**CON394** 'Introduction to BIM' Units: 1 credit	**CON453 (capstone)** 'Project Management I' Units: 3 credits
Objective: Overview of **construction drawings** and how they are organized, recognizing various building components, construction methods and the components of major systems	Objective: Computer application course teaching BIM processes as an overall concept and concentrated on learning **BIM software applications**	Objective: **Collaboration, interaction** and preparing for common real life challenges faced in the industry
		
Understanding **drawings and deliverables** which form the **steps** for complete BIM/technology knowledge	Better understanding of **skill sets** by incorporating technology	Application of the skills learned on **case based scenarios**

Table 1 - Stepped progression of BIM Curriculum

Including BIM in some form at three levels helped students retain the skill of using BIM tools through the years. While it helped remove the time constraint associated with mastering a skill, few other challenges were apparent (4) –

(a) Struggle with lack of flow from other classes – Since BIM was being taught and used in just one course each year and not every semester, students were restricted to learning only in the hours permitted by the particular course. There was not much use of or discussions about BIM in other classes.

(b) BIM tools being taught failed to permeate to other construction specialties like heavy civil, underground etc., and

(c) Scenarios were needed to effectively demonstrate the use of BIM for collaboration.
These observations reinforce the need for a holistic approach to BIM-CM education through a system of 'vertical integration' of curriculum and students.

Literature Review

Vertical integration is a common concept used in medical education. It is the result of an initiative to improve medical education and enhance the transfer of knowledge and skills by grouping curricular content and delivery mechanisms (8). For example, undergraduate students possessing lesser skills are paired with post-graduate students for purposes of simulation training such as medical emergencies (8). These skills are required by both sets of students but at a lesser skill level for the undergraduate students. Such exercises enable students to gain an early appreciation for certain skills and their relevance in future stages. This pedagogical style aims at delivering each subject as an integrated function of several disciplines. Students are therefore better prepared to apply a complete conceptual knowledge instead of a fragmented presentation of the same topics (9). This method requires some planning considerations - which subject should be integrated with which subjects and how, competency of the instructor to present the particular subject and the additional details and scheduling of courses (9).

The same concept can be seen in practice in architectural studio environments, where the software programs and skills become a part of the education. Students are expected to have the knowledge of and use certain software's for the physical representation of their ideas and designs. The software application is then just a tool that facilitates presentations and inbuilt into the system of education.

Proposed Implementation Method

The undergraduate CM program at ASU is a 4-year semester system requiring a total of 120 credits for graduation. To assess the areas for BIM intervention in the existing curriculum, the course contents of a few relevant subjects were studied and some broad topics contributing to BIM education were identified (Table 2). If all these classes spent 4-8 hours discussing BIM concepts and actively using a BIM authoring tool, the combined effort would elevate the level of BIM education and help students retain the knowledge. Further, vertical integration across these courses would emphasize the collaborative nature of BIM, as students will use BIM in scheduling, estimating, and design courses, rather than simply in a methods course. Thus, students gain an appreciation for the full capability of BIM in revolutionizing project management and execution. Included internships in the program also help in strengthening the use of technology and the importance of information management in CM. It is during the internships that students get a real world experience of the use of BIM tools and understand how deeply embedded are the concepts in practice. ASU also maintains a close-knit relationship with the local construction industry, assuring a well developed and up to date curricular content, guest lectures from industry experts and easy access to live construction sites.

Course Name (Currently offered)	**Core Concepts**	**BIM Concepts**

Year I	Building Construction Methods, Material & Equipment	- Tangibility of materials, visual understanding of equipment's, developing a sense of how a building comes together - Identifying roles in the process of construction	Introduction to 3D models and navigating
Year II	Working Drawings Analysis	- Read and understand construction drawings, symbols, specifications and terminologies - Introduction to 3D modeling and visualizing information	-Introduction to hand drawing to CAD drafting and a glimpse of 3D modeling. -Visualization of digital 3D information
	Microcomputer Applications for Construction	- Geometric modeling to represent operation of construction equipment (such as a crane) - 3D Visualization	Spatial requirements for productivity and safety
Field Internship			
Year III	Introduction to BIM	- Software applications taught at present: Revit Architecture, SketchUp, Navisworks - Future: Bentley Systems, Synchro etc.	Learning BIM as a tool for future use
	Planning & Scheduling	- Project Scheduling methods such as Bar Charts, CPM and PERT, AOA, AON and VPM techniques; resource allocation and time/cost analysis - Software used: Primavera P6, MSProject, Navisworks for linking to a model and simulation	Creating schedules, and simulating activities
Managerial Internship			
Year IV	Advanced Estimating	- Concepts of pricing and markup, development of historic costs, life cycle costing, change order and conceptual estimating - Groups work with Construction companies on real construction projects	Extracting quantities and applying cost and estimate using BIM
	Project Management Capstone	- Using case based scenarios for simulating common Project Management issues faced during pre-construction and construction	Collaboration, interaction and preparing for real life challenges faced in the industry

Table 2 - Core and BIM Concepts in the existing curriculum

Vertical Integration

The core concept of vertical integration is to share knowledge between different levels of expertise - allowing students to gain an appreciation for certain skills and the academy to deliver an education that is holistic and integrated. It mirrors the practices of the construction industry where alliances are formed between experts from different fields to collaboratively come up with an effective solution. It is also a common practice in the industry to pair veteran employees with new hires or interns to foster a team that has the knowledge of experience and new technology. Bringing this model to academia, the main idea is to promote collaboration by employing a method of 'subcontracting' between classes at different levels. Students from two different classes, work together on a class assignment, sharing knowledge and learning from each other.

For example - students from 'Building Construction Methods, Material & Equipment', 'Working

Drawings Analysis' and 'Project Management I BIM Lab' can use the same project or site as their case studies to study the different aspects of construction taught in the respective subjects as shown in Table 3. They can trade information related to their specific areas of expertise and get a complete understanding of the project and the various different aspects that form a part of it.

Project	Building XYZ		
Subject	Building Construction Methods, Material & Equipment (Year I)	Working Drawings Analysis (Year II)	Project Management I BIM Lab (Year III)
Assignment Example	Develop a pictorial glossary of materials, building systems and equipment that have been used in the project with their specifications	Analyze how the various materials, systems and equipment are represented in the working drawings and the specifications written	Perform clash detection (using a BIM tool) between different building systems to detect co-ordination issues

Table 3 – Vertical Integration example I

Proposed Evaluation Plan

In order to estimate the impact and effectiveness of BIM education via the proposed 'vertical integration', a common set of Learning Objectives have been identified. These will be used as general-purpose guidelines for student learning and also as metrics to measure student outcomes. The same set of learning objectives will be pre- and post- assessed each year to see how students understanding evolve, both through an individual course and across the curriculum. We anticipate that younger students will show aptitude and knowledge but will lack the ability to evaluate and create early on, but will identify themselves as capable of evaluation and creation later in their tenure at ASU.

BIM education learning objectives:

- Develop an understanding of BIM as an information management process.
- Demonstrate the ability to use BIM tools for purposes of documentation, co-ordination, visualization and information exchange.
- Apply the concepts of BIM to a Construction Management problem.
- Gain an understanding of BIM as a collaborative tool

Based on these learning objectives, an evaluation plan is developed that lists the cognitive learning indicators that serve as the benchmarks against which the students learning outcomes will be measured. Each of these indicators can give us a background for developing performance indicators for each level.

Learning Objectives	**Cognitive Learning Indicators**		
	Knowledge	Application	Evaluation

Learning Objectives	Cognitive Learning Indicators		
Develop an understanding of BIM as an information management process	Identify what is BIM and what is not BIM		Ability to define BIM in terms of CM processes
Demonstrate the ability to use BIM tools for purposes of documentation, co-ordination, visualization and information exchange	Memorize steps and methods of operating software. Identify what tool is used for which purpose.	Operate a BIM tool	Ability to use a BIM tool effectively and in the correct method to get desired results
Apply the concepts of BIM to a Construction Management problem	Recognize the employment of BIM for certain CM cases/scenarios	Use BIM tools to inform decisions	Justify the use of BIM for certain use-case scenarios mirroring a real world situation
Gain an understanding of BIM as a collaborative tool	Define BIM use for collaborative decision making	Apply BIM in a collaborative environment	Ability to use BIM effectively as a team to solve a common problem

Table 4 - Evaluation Plan (10,11)

Conclusion and Future Work

Construction Management is a discipline that is a part of a larger industry that includes design, engineering, construction, management and operations. As in the real world it borrows from multiple different areas of expertise, the same must be mirrored in education also. To demonstrate the importance of BIM as an important tool and process for information management and collaboration, it must be seamlessly integrated within the curriculum without disturbing the existing structure of courses. Rather it must be ensured that there is an understanding that BIM is just a new and advanced way of looking at the processes and concepts previously taught and learned. Two methods have been discussed in the paper –

(a) A stepped progression that has already been employed at ASU
(b) Proposed vertical Integration of students – the plan for which has been described and will be executed in the near future

Apart from the implementation methods, an evaluation plan based on common BIM learning objectives has also been developed which will be used to measure the knowledge gain and effectiveness of BIM education.

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