The Technology Conundrum: Faculty Perspectives of Opportunities and Challenges when Implementing Technology in a Collaborative Classroom

Tom M. Leathem, CPC and Emily M. McGlohn, AIA
Mississippi State University
Mississippi State, MS

As the AEC industry moves toward more collaborative project delivery approaches, such as IPD, so too does the adoption of collaborative technologies such as building information modeling (BIM). Since the early part of the 21st century institutions of higher education have been implementing aspects of BIM learning into their curricula. Many have been teaching BIM as a tool for design, design coordination (clash detection), and visualization. However, simply teaching these fundamentals does not expose students to the collaborative powers of BIM that is cited as one of its key benefits. In this vein, some education programs have begun attempting pedagogical approaches intended to focus on the collaborative benefits of BIM. This paper will focus on challenges faced by the authors in attempting to implement BIM in a cross-disciplinary collaborative course between architecture and construction students. The authors will present how they have attempted to teach cross-disciplinary collaboration through the use of BIM as a design, design coordination, scheduling, estimating, and communication tool between disciplines. Outcomes of the current approach related to identified challenges and benefits will be addressed. Challenges faced by faculty related to technical expertise, technology/hardware, assessment, and interoperability are presented. The paper concludes with discussion for addressing the identified challenges and potential benefits.

Keywords: BIM, Collaboration, Curriculum, Cross-Disciplinary, Technology, Software

Introduction

Since the early part of the 21st century institutions of higher education have been implementing aspects of BIM learning into their curricula. While many have been utilizing BIM for design, coordination, and visualization - following suit with research findings of industry usage (Langar & Pierce, 2014) - some are trying to harness its benefits as an interdisciplinary collaborative tool. These endeavors are beginning to highlight challenges and benefits of the approach (Poerschke, et al. 2010). This paper focuses on opportunities and challenges identified by faculty after two semesters of integrating BIM into an upper-level cross-disciplinary course. Collaborative Studio II is the second of a two-part course experience between construction and architecture intended to expose students to collaborative practice strategies at the pre-construction phase of a project. An overview of the collaborative studio approach is presented along with focused information about Collaborative Studio II and how BIM is being integrated into the course. The intended learning outcome of the BIM integration is to highlight the collaborative support aspects, while learning hard skills of using the software. The authors then present information about identified challenges specific to hardware, software, personnel, and facilities.

Collaborative Studios

Overview

The approach taken between the Building Construction Science Program and School of Architecture at Mississippi State University (MSU) employs the ideals of exposing students to collaboration early and often while trying to overcome some of the challenges identified in previous studies. With this in mind the pedagogy is divided into two semester components called Collaborative Studios I (CSI), and II (CSII). Collaborative Studio I takes place in the fall of a student's second year while Collaborative Studio II takes place in the spring of a student's third year of their respective program. The intent of this approach is to provide one full year of separation between the experiences allowing for maturity, intellectual development, and alignment with topical content relevant to the collaborative goals. As such the curricular aims for each semester are vastly different.

In CSI the curricular aim takes a more fundamentals approach, acknowledging the students in the course are lower-level students just starting their second year of college. The student experience is much more hands-on with the topical content centered on materials and methods. It is situated in a design/build format utilizing a small project that the students have to design and then construct. Past example projects have included the design and construction of bus stop shelters, golf course bathroom and rain shelter pavilions, and community garden sheds. The design/build approach is an important aspect of the collaboration because it gives all students a common goal for the semester. Students are required to develop, apply, and communicate their individual expertise to design, plan for, and construct a shared project. Collaboratively, CSI is focused around breaking down barriers between disciplines and developing communication skills. In contrast, CSII emphasizes exposure to collaborative experiences more commonly seen by design and construction professionals during a project's pre-construction phase. For this reason BIM in CSII is a critical aspect.

Each collaborative course is formatted in a six-credit per semester studio that meets 12 hours per week. Unlike traditional lecture type courses a studio format provides increased student contact hours and a classroom construct conducive to prolonged collaboration. Studio classrooms are populated with workstations that are assigned to students for an entire semester. The assigned space becomes their personal workspace that they have access to at all times for the semester. Each collaborative studio serves every architecture and construction student in their respective year levels. Consequently, class sizes are typically 40 to 50 students for each studio. Given the class size and nature of the courses being project-based a typical studio format will have a student faculty ratio around 15:1. To facilitate this, three to four faculty representing both disciplines are assigned to each studio.

The classroom relationship between disciplines is possible due to the construction program's unique studio based curriculum that matches the School of Architecture's typical design studio framework. Rather than the three-hour lecture course typical in most construction programs, the Construction Science Program uses an architecture framework of a six-credit studio. At its conception, the program's intent was structured to accommodate interaction between the architecture and construction disciplines. The common classroom frameworks and schedules facilitate interaction and eliminate schedule coordination challenges across departments.

Developing the objectives and learning outcomes for the program required a collaborative approach amongst architecture and construction faculty to ensure necessary learning outcomes were being met. Priorities included the establishment of common ground between the disciplines (a common goal), a collaborative pedagogy (an ethos of one), and joint assignments that would ensure learning outcomes related to the pedagogy. Careful consideration to the development of these objectives also had to acknowledge associated accrediting bodies of both disciplines. As such an in-depth evaluation of American Council for Construction Education (ACCE) and National Architectural Accrediting Board (NAAB) requirements were conducted. The results of these efforts formed the goals and objectives of the course (Table 1).

Table 1

Collaborative Studio II Course Objectives and Accreditation Criteria

Objectives
Students will learn the basic factors associated with effective collaboration
Students will learn the importance of individual versus group work in a collaborative environment
Students will build an understanding of the relationship with and values held by their building industry partners
Students will learn construction budget estimating and scheduling
Students will learn the importance of Building Information Modeling and Integrated Practice as a means to foster the above listed goals and objectives

ACCE Accreditation Criteria (ACCE, 2015)	
SLO 2	Create oral presentations appropriate to the construction discipline.
SLO 4	Create construction project cost estimates.
SLO 7	Analyze construction documents for planning and management of construction processes.
SLO 9	Apply construction management skills as an effective member of a multi-disciplinary team.
SLO 10	Apply electronic-based technology to manage the construction process.
SLO 12	Understand different methods of project delivery and the roles and responsibilities of all constituencies involved in the design and construction process.

NAAB Accreditation Criteria (NAAB, 2014)	
A.2	Design Thinking Skills
A.4	Architectural Design Skills
B.3	Codes and Regulations
B.4	Technical Documentation
B.5	Structural Systems
B.7	Building Envelope Systems and Assemblies
B.8	Building Materials and Assemblies
B.10	Financial Considerations
D.2	Project Management

Collaborative Studio II

Collaborative Studio II attempts to mimic a real-world project approach in which designers and constructors communicate at the early stage of a project to collaboratively develop the project plan from a design and construction viewpoint. Students work in collaborative teams to work through development of design, cost, schedule, and coordination of a joint project. Facilitating delivery of these milestones is done in the project assignments issued throughout the course of the semester (Table 2). Collaboration development is situated at a contractual level and how the two disciplines work together in practice. Students are told their goal is to collaboratively develop a project proposal that emphasizes “client value.” This term is situated in the criteria of optimizing elements of the design to fit the client’s needs; while maximizing quality, cost, time efficiency, and safety. Structurally, students are divided into cross-disciplinary teams of construction and architecture on the first day of class, in which they remained throughout the semester. Teams are comprised of 4 to 5 members in an attempt to allow for equitable participation by all students within a team.

BIM Integration

Many institutions have been teaching BIM as a tool for design, design coordination (clash detection), and visualization. This follows suit with research highlighting the industry's most common uses of BIM (Langar & Pearce, 2014). However, simply teaching these fundamentals does not expose students to the collaborative powers of BIM. Studies have cited one of the key benefits of BIM to be a tool facilitating collaboration across the disciplines (Azhar et al., 2008; Krygiel & Nies, 2008; Ku & Mills, 2010; Taylor & Olsen, 2012). The intent of integrating BIM into the CSII course is to expose students to both benefits of using the technology. BIM is used to complete specific tasks related to design, coordination, and visualization; but also requires students to collaborate to complete the tasks successfully. To emphasize the collaborative benefits of BIM, it is integrated into the class in a phased format.

Table 2

Collaborative Studio II Assignments and Activities

	Assignment/Activity	Description
Module 1	Assignment #1.0: Project Delivery Methods	This assignment asks students to review the four primary project delivery methods to analyze their collaborative nature. This analysis will help students understand the importance of collaboration before beginning the design of the project as a team of architects and constructors.
	Activity: Project Delivery Skit	Students will be divided into four teams, one for each of the primary project delivery methods. Each team will then take what they have learned from Assignment 1.0 and reenact a given scenario from their primary project delivery method as a skit to educate the rest of the studio.
Module 2	Assignment #2.0: Project Research	Students work collaboratively with their team and assess, both individually and collectively, how each member of the team can contribute to executing the research topic of their assigned building project. Once complete, each team is to equally divide the responsibilities and students will work both individually and collaboratively to complete the assignment.
Module 3	Assignment #3.0: Conceptual Design	Students utilize information from previous assignments to collaboratively develop a building preliminary design that demonstrates consideration for achieving the desired client interests while addressing design and construction conventions.
Module 4	Assignment #4.0: Design Development & Construction Review	This assignment is designed to assist in the further development of your collaborative project to include structural design, cost, and schedule. Students are expected to defend their reasoning for design decisions based on the impact of cost, schedule, and constructability consideration.
Module 5	Assignment #5.0: Project Completion	This assignment begins the final portion of the collaborative project and will develop the deliverables for the final project proposal. Building on the knowledge and understanding developed in previous assignments, each team will bring their project together in an optimized final design, cost estimate, schedule, constructability analysis, and proposal presentation. It is expected that all teams will have fully developed arguments supporting their material and assembly choices for the form and structure.

The student groups work together throughout the semester to design, estimate, and schedule the assigned project. Students use many methods of communication throughout the semester for preliminary studies such as sketching, hand tabulations, drafting, model making, and schedule diagraming. The use of a computer is restricted during the first two assignments to encourage development of alternative analog skills. Once students are allowed to enter their work into digital format, the common BIM platform is Autodesk Revit.

Autodesk Revit is the choice platform because students are exposed to this software prior to entering CSII and for the potential of work-sharing this program offers. Students enter the studio with a base education in how to operate this BIM system and further develop their skills during CSII. However, numerous challenges to fully utilizing this program have prevented complete adoption. Hardware capabilities, software usage, faculty/personnel knowledge, and infrastructural inadequacies are the four main problems this studio has encountered.

Challenges

Hardware

In the College of Architecture, Art & Design at Mississippi State University, all students are required to purchase a laptop before entering school. This policy has been in effect for more than 15 years. No communal computer labs exist in the college. This allows the college to save the large overhead expense of maintaining a computer lab, related software, and personnel. Students purchase or acquire the necessary software for each class and are responsible for maintaining their computers throughout their academic career. While this policy has given each student unlimited access to a computer – a necessity for their futures – it has presented challenges for CSII. The laptop computer requirements are stipulated by each department for new students. These requirements for both programs are listed below. Please note the requirements are different between departments.

Revit is an intensive software program that requires robust hardware for smooth operation. Several issues consistently arise with students' hardware. The first issue is that most students purchase a computer with only minimum capabilities. Reasons for this are cost and lack of understanding of what they will need during the next four to five years of their education. Autodesk provides system requirements for Revit. Typically, students will acquire computers with hardware capabilities that meet the minimum requirements suggested by Autodesk. In CSII it is not uncommon for students to need to have multiple programs running consecutively with Revit. This creates performance problems for many students that distracts them and the faculty from on-task learning.

The second issue is that a large number of students own Apple computers and are required to divide their hard drive before using Revit. This reduces the capacity of the computer and often makes for slow processing when the students are working. In some cases students do not even have the Windows platform installed on their Apple computers which adds cost, time, knowledge, and resource obstacles.

Table 3

Hardware Requirements for Students

School of Architecture 2016	
Hardware	
Processor	Intel Core i7
Hard Drive	Minimum 250GB (Recommended 500GB or above)
Memory	Minimum 8GB (Recommended 16GB) w/ expansion capability
Video Adapter	Minimum Video Adapter 256MB Nvidia or ATI (Recommended 512MB DIrect X 10 Capable with Shader Model 3)
Storage	CD/DVD/RW Required (Internal or External), 1-8 GB portable flash drive. 250GB or greater External Hard Drive Required

Building Construction Science Program 2016	
Processor	Intel Core i5 or Intel Core i7
Hard Drive	Minimum 500GB (Recommended 750GB or above)
Memory	Minimum 4GB (Recommended 8GB) w/ expansion capability
Video Adapter	Minimum Video Adapter 256MB Nvidia or ATI (Recommended 512MB DIrect X 10 Capable with Shader Model 3)
Storage	CD/DVD/RW Required, 1-8 GB portable flash drive. (500GB or greater External Hard Drive Recommended)

Third, students are responsible for hardware maintenance. As an undergraduate program, students are inexperienced with taking care of a personal computer. While not always the case, this often leads to issues of operability. Most recently problems have been encountered with students who computers with the Windows 8 and 10 platforms. These new platforms have issues to be solved that faculty are not attuned to dealing with. Add to this issues with BIM software integrating with these platforms and it makes for virtually insurmountable challenges for the faculty.

Software Usage

Similar to the differences related to computer requirements, departmental differences also exist in student exposure to BIM software training. Autodesk Revit is not taught in a dedicated course in the School of Architecture, while the Building Construction Science Program does have a dedicated three credit course. The lack of dedicated courses to teach BIM is not uncommon. In a recent survey of Associate Schools of Construction (ASC), it was determined that approximately 10% of schools offer dedicated BIM courses (Sabongi, 2009). In the School of Architecture at MSU, Revit is taught as a piece of one architecture course and training is sometimes offered in CSII. Architecture students have the option of taking a BIM course in the Interior Design Department, but it is not a requirement like that of the Building Construction Science students. Regardless, the large majority of students in both departments learn Revit and other related BIM aspects through experimentation, online tutorials, and helping each other.

Research has shown the issue of being distracted from intended learning objectives by lack of software operation knowledge to be a common problem when integrating BIM. Faculty and students in the CSII have identified this as a key issue as well. While it is not the intent of the CSII course to use studio time to provide software training, the ability for students to effectively use Revit and other BIM programs is problematic. Other software was considered to be included in the course to influence the construction side of the collaboration such as Assemble Systems, Vico

Office, and Synchro. However, the previously mentioned challenges associated with training time availability made reality of this incorporation too limiting. A wide range of abilities exists between students and the way in which they work together is affected. They cannot equally distribute the work load if not everyone in the group has equal ability to use the software. Students tend to get distracted from the project goals by trying to figure out how to use the software or overcome problems with its operability.

Staying current with the latest trends in software versions and new platforms available is challenging as well. Revit and most other BIM software is updated annually; while numerous new software platforms are introduced every year. Revit has been the mainstay for modeling so keeping up with version updates is fairly manageable. However, software for scheduling, estimating, and clash detection makes it difficult for faculty to know which software is most relevant to industry.

Faculty/Personnel Knowledge

The integration of BIM into CSII has also encountered challenges related to faculty knowledge. In addition to not having a computer lab, the college does not employ dedicated Information Technology (IT) personnel. As a result the faculty are required to be knowledgeable in the use of the software, and they must also bear the responsibility as the resident "IT experts." Knowledge of different computers, operating systems, and software acquisition – installation - and operability is necessary to successfully implement the use of BIM.

In CSII numerous issues arise from software installation and software functionality. Reasons for these problems range from firewall issues to computer types and operating systems. In these cases faculty often deal with these issues. This takes time away from on-task learning and distracts the students from the intended learning objectives. The university does offer IT assistance to students but the specialty software CSII requires is not common at the help desk.

In one situation, faculty spent an entire four-hour class attempting to install a program on students' computers. After two classes and hours of time invested by students and faculty, the software remained a problem – despite help from product support services. Because of this difficulty, this particular software was removed as part of the course requirement. Assignments related to use of the software were modified accordingly. This is perhaps one extreme example but is representative of typical problems encountered by the authors.

Gaining access to the different software can be more time consuming and challenging than installation and operation. While the Autodesk products are easily obtained, others require more knowledge and time by the faculty. Many require licenses that have to be renewed as early as every semester through an educational representative. Some have a unique license for each student while others have one license for all students in the class. Some companies require students to contact them directly for the license or software access while other companies require the faculty to acquire it for all students. In the case of CSII there are two to three programs required for the course which can mean up to three different acquisition processes required by the faculty.

Infrastructure Inadequacies

Work-sharing in Revit is revolutionizing how AEC professionals work together. One central model is shared between team members so that costly mistakes are avoided. Work-sharing is also a tool that can benefit cross-disciplinary courses like CSII. Sharing one model between students in a group mimics professional BIM relationships. It can also help students work more efficiently as a team. However, this tool is underutilized in CSII. The reason is that hard internet connections are limited in the studio space. This makes utilization of work-sharing features - such as with the use of cloud servers - nearly impossible.

For server space to be available to each student and the internet speed necessary to access a shared model, a data drop must be installed at each desk. For each student to be able to work simultaneously, almost 70 data drops are necessary. This infrastructural improvement is expensive, and the cost must be shared between two departments. Other shared data storage options are available but all at a cost to the students. Most students simply share portions of a model by swapping jump drives. Although this works, it does not simulate work-sharing as it is intended. Students are unable to see changes others have made. They also tend to divide portions of the building into responsibilities of an individual.

Discussion

This paper addresses the problems one cross-disciplinary studio has faced in trying to implement BIM for design and collaboration. Challenges with hardware capabilities, software usage, faculty/personnel knowledge, and infrastructural inadequacies have limited the full adoption of BIM and sacrificed potential learning. Although faculty believe this platform is necessary in teaching students about future collaboration, many issues remain to be solved.

Hardware capability requirements for student laptops need to be updated as system requirements for software expand. It is not foreseeable that the college will invest in shared computer labs so it is the responsibility of the faculty to communicate with administration about what system requirements are necessary for selected software. Before entering their program students should be advised to purchase more than the minimum requirements so their computer will remain valid throughout their academic career.

As Apple products continue to gain popularity, students will continue to purchase Mac computers. Although Autodesk and other program manufacturers offer programs for Mac computers, Revit and other BIM related software are not currently available. Students will need to continue to divide their hard drive to accommodate Windows and Revit. Recognizing the increased adoption of the Apple hardware and the utilization of BIM it seems the two industries should make better efforts to circumvent these interoperability obstacles. In the interim; departments should make these issues and their associated challenges clear to prospective students and their parents. The Building Construction Science Program currently discourages students from using Apple computers – even though all faculty in both departments use Apple products.

Software usage and training remain a debated topic. Revit is a complex and powerful tool and for effective use, training is required. It is not the responsibility of the studio instructors to serve as software technicians. Currently, Revit training occurs in several unconnected courses. For the most part, students learn this program outside of class through online tutorials and experimentation. A curriculum discussion between both programs which addresses joint software education can help develop a more fluid approach to BIM in CSII. A focused course addressing specific software usage could help overcome challenges identified by the authors in the CSII course and allow the focus to shift back to intended learning objectives of the course.

Faculty and personnel knowledge of BIM related software will continue to be an issue because it is not possible to be fluent in each new software. One solution to this problem is for the college to offer faculty and personnel training and to provide IT support for students. A dedicated IT support staff would be useful to students having hardware issues as well as software installation problems. Removing computer labs drastically cuts costs to the departments and most students have personal computers. However, removing computer labs does not negate the need for support personnel. It is unrealistic for faculty to be expected to bear all the responsibility associated with heavy computer use in classes and appropriate IT personnel is still needed to successfully implement computer based learning.

Work-sharing is currently underutilized in CSII due to server space access. Hard connections to the internet are necessary to access the server that is available but only a limited number of data ports exist in the studio. Alternative server space that can be accessed through a wireless internet connection needs to be researched. As seen in other research, hardware and infrastructure costs are a key obstacle to the implementation of BIM by industry. Institutions of higher education are not immune to this issue and advancements in BIM education are affected. Continued advancements in cloud-based computing should help, but further work is needed by providers of these technologies to make their products more easily accessible to the education community. Educators are training those that will be consumers of these products and educating the future of tomorrow in the use of such will only enhance adoption.

References

ACCE Document 103 OBS. (2015). *Standards and criteria for accreditation of postsecondary construction education degree programs.* Retrieved from http://www.acce-hq.org/images/uploads/Doc_103_OBS_final_0429151.pdf

Azhar, S., Abid, N., Johnny, M., & Brian, L. (2008). Building information modeling: A new paradigm for visual interactive modeling and simulation for construction projects. *First International Conference on Construction in Developing Countries, Karachi, Pakistan.*
Computer Requirements. (2016, January 03).
Retrieved from http://www.caad.msstate.edu/bcs/bcscomputerrequirements.php

Krygiel, E. & Nies, B. (2008). Integrated design teams. In W. Knibbe, J. Leland, S. Johnson, R. McConlogue, & L. Welch (Eds.), Green BIM: Successful sustainable design with building information modeling (pp. 53-73). Indianapolis, IN: Wiley Publishing.

Ku, K. & Mills, T. (2010). Research needs for building information modeling for construction safety. *Proceedings of the 45th ASC Annual International Conference, USA.*

Langar, S. and Pearce, A. (2014). State of adoption for building information modeling in the southeastern United States. *Proceedings of the 50th ASC Annual International Conference, USA.*

Poerschke, U., Holland, R., Messner, J., & Pihlak, M. (2010). BIM collaboration across six disciplines. *Proceedings of the International Conference on Computing in Civil and Building Engineering, UK.*
School of Architecture Computer Requirements. (2016, January 03).
Retrieved from http://www.caad.msstate.edu/sarc/computerrequirements.php

Sabongi F.J. (2009). The integration of BIM in the undergraduate curriculum: an analysis of undergradate courses. *Proceedings of the 45th ASC Annual International Conference*, *USA*.

Taylor, M, & Olsen, D. (2012). Integrated project delivery: Not a panacea for everyone. *Proceedings of the 48th ASC Annual International Conference, Birmingham City, UK.*
National Architectural Accrediting Board (NAAB), Inc. 2014 Conditions for Accreditation. (2014, July 18).
Retrieved from
file:///Users/emm17/Downloads/01_Final%20Approved%202014%20NAAB%20Conditions%20for%20Accreditation%20(1).pdf