

Lessons Learned from a BIM-Enabled, Multi-Disciplinary Global Team Student Project

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Globalization and the increasing adoption of building information modeling (BIM) and other technologies in the AECO industry have changed the way we prepare construction management graduates for the current workplace. Construction and engineering accreditation bodies have acknowledged this need for change with recent updates to accreditation requirements emphasizing coursework in collaborative teams and use of technology to accomplish work. The Sky Classroom is a collaborative project offered by several global universities that focuses on the use of BIM processes and tools for project coordination. This global team project provides a unique opportunity for students to work together on a multi-disciplinary, interdependent project while learning about construction practices in other cultures. In this paper, we describe the organization of the course, project objectives, lessons learned based on student feedback, and proposed course design moving forward. We found that teaching students how to develop a comprehensive BIM Execution Plan is important for the success of a project, working in multi-cultural teams was beneficial to students, and large time differences discouraged synchronous communication resulting in a need to rethink 'messy' collaboration methods.

Keywords: Building Information Modeling, Global Collaboration, Digital Literacy

Introduction

Globalization and the increasing adoption of building information modeling (BIM) and other technologies in the AECO industry have changed the way we prepare construction management graduates for the current workplace. According to a 2014 SmartMarket Report, 75% of global contractors are reporting a positive return on investment in BIM with the number one reported benefit being reduced errors and omissions the second highest reported benefit being the ability to collaborate with owners and design firms (McGraw Hill Construction, 2014). As a result, contracting firms are increasingly expecting new hires to be prepared to work with BIM technologies. Additionally, because improved collaboration technologies allow firms to reach out to talent across the globe, much of the collaboration in the AECO industry takes place in distributed teams (Harty & Whyte, 2009; Nayak & Taylor, 2009; Rezgui, 2007). Therefore, there is an increasing need to prepare construction management students for a BIM-enabled workplace where they will be expected to work in collaborative environments (Ahn, Annie, & Kwon, 2012; Zhao, McCoy, Bulbul, Fiori, & Nikkhoo, 2015).

Construction and engineering accreditation bodies have acknowledged this need for change with recent updates to accreditation requirements emphasizing coursework in collaborative teams and use of technology to accomplish work. In order to meet accreditation requirements of the American Council for Construction Education (ACCE) and the Accreditation Board for Engineering and Technology (ABET), undergraduate construction management and construction engineering programs, respectively, must develop curriculum that incorporates application of technology to manage the construction process and apply construction management skills as part of a multi-disciplinary team (ACCE), and understand the impact of engineering solutions in a global, economic, environmental, and societal context (ABET). Construction management programs are tasked with developing curriculum that teaches students how to work collaboratively and develop technological skills. This paper describes a project that incorporates these elements and outlines the challenges of implementing these goals in the context of a global team project.

Background

Construction management (CM) programs are increasingly adopting BIM courses into their curriculum (Abdirad & Dossick, 2016; Becerik-Gerber, Gerber, & Ku, 2011). In 2012, a survey of construction schools indicated that 53% have a BIM-dedicated course as part of their existing curriculum and 40% offer two or three classes that implement BIM (Joannides, Olbina, & Issa, 2012). Because BIM is often used in collaborative functions such as 3D coordination and site logistics planning, many programs are developing courses that incorporate a multi-disciplinary collaboration element (Fruchter, 2006; Soibelman et al., 2010). Few institutions, however, incorporate both BIM and collaboration in a single course (Zhao et al., 2015).

The literature emphasizes advantages of colocation such as the ability to engage in impromptu sidebar conversations or discovery and discussion through pointing or sketching, resulting in a trend in the industry to collocate project teams (Boland Jr, Lyytinen, & Yoo, 2007; Dossick & Neff, 2011; Ewenstein & Whyte, 2007; Kemmer, Koskela, Sapountzis, & Codinhoto, 2011; Staub-French & Khanzode, 2007) However, members of AEC teams are often involved with several projects simultaneously (Rezgui, 2007) and with the increasingly global nature of project teams, it becomes impractical to meet face-to-face. Because the construction industry is heavily reliant on visual media for the communication of ideas, globally distributed teams are challenged with finding an effective way to communicate with models and drawings over distance, mediated by technology, but this becomes difficult when collaborating via e-mail, for example. As the use of both BIM and global collaboration become more prevalent in the industry, there is a need to further understand how to manage global work and associated challenges.

This paper describes a globally distributed course project in which students learn to work collaboratively with multicultural and multidisciplinary teams using BIM tools and various digital communication technologies. The project was designed to replicate a collaborative and BIM-enabled scenario they may encounter upon entering the AECO industry. In this paper, we discuss the evolution of the course, project objectives, lessons learned based on student feedback, and proposed course design moving forward.

Course Design and Project Description

The Sky Classroom project is part of a 3-credit undergraduate (400-level) construction management course at Washington State University and a 3-credit graduate construction management course at the University of Washington. Students at the non-U.S. schools were also graduate students. Students in the U.S. were asked to meet with their global teammates outside of scheduled class time, typically late in the evening due to the time difference between U.S. and non-U.S. schools. Students from non-U.S. universities took the lead in setting up initial meetings as part of their project management responsibilities and the U.S. students were responsible for developing a BIM Execution Plan, resulting in all students ultimately taking responsibility for producing work and meeting deadlines. The intent of the project design was for students to work collaboratively and interdependently.

The objectives of the global team project were as follows:

1. To give students an opportunity to increase their understanding of the practice of distributed team project management and BIM execution planning in the context of a global team,
2. To expose students to advanced tools for project collaboration and planning, and
3. To help understand how global virtual design teams can work together effectively.

This project builds on lessons learned from a similar course offered in the spring of 2015 in which students from seven global universities were participants (Dossick, Homayouni, & Lee, 2015). With each university having different academic start dates and holidays, faculty encountered challenges when trying to coordinate their schedules. As a result, some universities joined the project later than others and found it difficult to integrate their roles because they had little familiarity with the project and no input in the early stages. Faculty revised the global team project schedule and format the following year, Spring 2016, to resolve the issue of conflicting academic schedules – that is, rather than having one common starting date that forced some universities to join the project late because students were still on break at the start of the project, the new format staggered the start date such that two universities started early and the remaining three universities started several weeks later. The result was a project with two parts (Part I and Part II) that were loosely coupled. The results described in this paper focus on Part II of the project, but a description of both parts is provided below.

Part I Project Description

Two universities, Indian Institute of Technology Madras (IITM) and the University of Washington (UW), participated in Part I of the project. Part I was divided into two modules. In the first two-week long module, IITM students modeled an addition to a residential house located in Chennai, India, using Autodesk Revit while UW students developed a construction schedule. UW students then integrated the model and schedule to create a 4D model. At the end of the first module, the entire team reflected on what they would do differently if they had to do it over. The second module was a more complex four-week project. UW students developed a BIM execution plan, IITM students modeled a new structure in Revit, and UW students used BIM tools to develop a schedule and determine ways to reduce cost. After reflection, the 3D and 4D models were optimized and resubmitted.

The Part I universities completed their portion of the project in mid-March and as a final deliverable developed a presentation that described their portion of the project and lessons learned. As the project transitioned from Part I to Part II, an all-team meeting with students from the five participating universities planned to meet in Sococo where the Part I teams presented to the Part II teams. The Part II universities, National Taiwan University (NTU), National Cheng Kung University (NCKU) and Washington State University (WSU), then commenced their portion of the project.

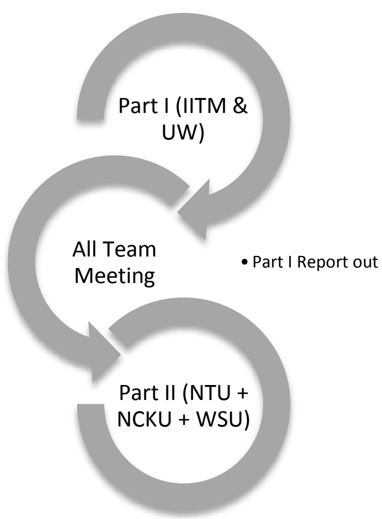

Figure 1. Project Structure

Part II Project Description

Fifty graduate and undergraduate students participated in the Part II portion of the global collaboration project: 25 students at WSU, 9 students at NTU, and 16 students at NCKU. Students from the participating universities divided into 15 teams to match the number of teams from Part I. At WSU, the 25 participants were placed on teams of either 1 or 2. NTU placed 3 of their 9 students on each team, meaning that each student was assigned to meet with 5 different teams. NCKU had 1 or 2 students on each team. The total number of students on each team, therefore, was either 5 or 6. Among the 25 students at WSU, there were 21 seniors, 1 junior, and 3 sophomores. The sophomores and junior were paired with seniors so at least one senior was on each team at WSU.

In Week 1, the Part II students were asked to meet in Sococo, a commercially-available 2D collaboration environment that allows users to video chat, text chat, and share screens. Students from NTU were given the role of project managers and meeting facilitators. During this meeting, they were to decide on a regular weekly meeting time and be introduced to the Virtual BIM Reviewer (VBR), a 3D virtual world developed at NTU in which students could import their 3D models and explore them as avatars.

In Week 2, WSU students were tasked with developing a BIM Execution Plan modeled after the Penn State BIM Project Execution Planning Guide (Messner et al., 2010). As part of their plan, they had to determine (among other things) participant roles, project milestones, deliverable due dates, meeting procedures, model structure, and file exchange protocols. NCKU students developed Autodesk Revit models for structures to be placed in southern Taiwan (Shanlin, Kaohsiung) on a piece of land at the base of a mountain. The team was to assume modular construction with as much of the structure as possible being prefabricated off-site for rapid assembly on site. Local labor, materials, and off-site facilities were to be used.

In Week 3, the team was tasked with reviewing the 3D model and discussing the schedule. WSU used this information to develop schedules in Primavera P6 for off-site prefabrication and on-site assembly.

In Week 4, WSU developed a 4D model in Autodesk Navisworks using the Revit model developed by NCKU and their own construction schedules. Running the construction simulation allowed them to visualize errors in the model or schedule and identify potential optimizations which were to be incorporated into the next iteration. NTU also performed a structural analysis and shared the results with the team.

In Weeks 5 and 6, the models were optimized and re-analyzed. Teams prepared a 15-minute presentation for delivery in Week 6 describing the project and lessons learned regarding global collaboration.

The schedule, responsibilities and project deliverables are listed in Table 1.

Table 1. Part II Global Team Project Schedule, Responsibilities and Deliverables

Week	Week Of:	Task (during meeting)	Deliverables (end of week)
1	March 21	BIM Virtual Reviewer Orientation and Teambuilding Exercise (NTU Leads)	
2	March 28	BIM Execution Plan (WSU Leads); 3D Model Development (NCKU leads)	BIM Execution Plan (WSU) 3D Model (NCKU)
3	April 4	Review 3D Model with team in BIM Virtual Reviewer (NCKU leads); Develop Schedule (WSU leads)	Construction Schedule (WSU)
4	April 11	Create and Review 4D Model (WSU leads); Structural analysis (NTU leads); Discuss optimizations needed (All schools)	4D Model (WSU); Structural Analysis (NTU)
5	April 18	Presentation Prep; Discuss and incorporate optimizations	Optimized 3D Model (NCKU) and Structural Analysis (NTU); Optimized 4D Model (WSU)
6	April 25	Presentation	Presentation file

Methodology

Both direct and indirect assessment methods were used to evaluate the success of learning outcomes. This paper reports on the indirect assessment methods of collecting survey data from the WSU participants. Five weekly reports and one longer survey at the end of the project were distributed to students. An average of 21 out of 25 reports were submitted each week, with at least one member of 14 teams out of 15 total teams reporting (84% average response rate). At the end of the project, 22 out of 25 WSU students responded to the longer survey (88% response rate).

The weekly report distributed during the first five weeks of the six-week project requested the following information from students:

- Meeting date, start time, and end time
- Communication methods used (e.g. Sococo, e-mail, Google docs, VBR)
- Participants (who was in the meeting?)
- Agenda (what was discussed in this meeting)
- Comments (Are things proceeding as expected? Were there any challenges or difficulties?)

The survey distributed at the end of the project included the first four items in the weekly report (above) and requested the following additional information:

- [Likert Scale] Satisfaction Level (1-7, 7 being very satisfactory)
- [Open-ended question] Things you liked about the global team project
- [Open-ended question] Difficulties: Project issues, Communication issues, Tool issues, Other issues
- [Open-ended question] Lessons Learned
- [Open-ended question] Suggestions for next year's class

Findings

Results described in this paper focus on Part II of the project in which students from Washington State University collaborated with students from National Taiwan University and National Cheng Kung University. The overall response from WSU students to the global team project was positive. As part of the end-of-project survey, students were asked to rate their satisfaction level with the project on a 7-point Likert scale, with 7 being very satisfactory. WSU students gave the project an average rating of 4.9 with a median of 5.0. Three primary themes emerged from analysis of the open-ended responses to survey questions:

1. *Teaching students how to develop a comprehensive BIM Execution Plan (BXP) is important for the success of a project.* Teams reported three primary weaknesses in their BXPs: not properly establishing deadlines or file exchange protocols early in the project, not establishing regular meeting times and not establishing which software version was to be used resulting in software incompatibilities. Some of the U.S. teams also received models in Chinese rather than English. Comments from student indicated that these issues could have been avoided with a more comprehensive plan established at the beginning of the project. Some representative views from students were: "I learned that when dealing with global partners that it is going to be worth the effort to put a strong plan together before proceeding … otherwise your project will suffer" and "Get involved with the project early on and … define communication methods and times early on so you don't get left out of the loop."

2. *Working in multi-cultural teams was beneficial to students.* Over half of WSU students responded that what they liked about the project was working with global students and learning about how other cultures approach design and construction methods (see Figure 2). Some representative quotes were: "It was cool getting to work with students from around the world," "[It was] interesting seeing how other cultures approach projects," and "[I liked] learning about their culture in Taiwan and how they build around more community rooms and less for personal space."

3. *Large time differences and poor connectivity discouraged synchronous communication*. Taiwan is 15 hours ahead of Washington State University in the Pacific time zone. This made it difficult to find meeting times that worked for everyone. Representative quotes from students were: “It would be nice to team with students in a time zone a little more compatible with our zone” and “Working with people half way around the world can be frustrating at times due to large time zone differences. Hard to get quick answers from team members because of this.” Additionally, use of the synchronous software Sococo often didn’t work well. Teams wound up using the chat function in Sococo instead of using voice for communication. Some reasons were: “There was a connection problem with the microphone and we could not hear what [NTU] was saying,” “The internet connection is poor so it is hard to hear,” and “Sococo’s audio at times was very low quality making it harder to understand what partners were saying.” Communication methods used by the teams over the six-week project are shown in Figure 3.

Discussion/Course Design Moving Forward

Part II of the project began halfway through WSU’s spring semester. Many students stated that they liked applying new knowledge from the first half of the semester to the global project in the second half of the semester. This is a format change from the previous year when the project started earlier and the students were simultaneously learning concepts that they were asked to apply in the project. This caused confusion and frustration for students.

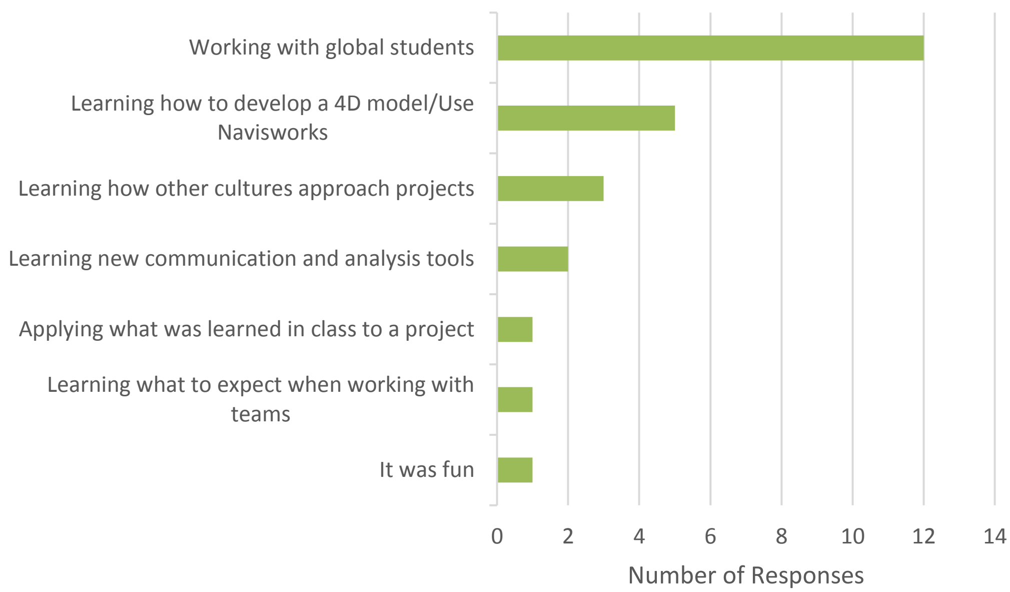

Figure 2. Responses to Survey Question: What did you like about the project?

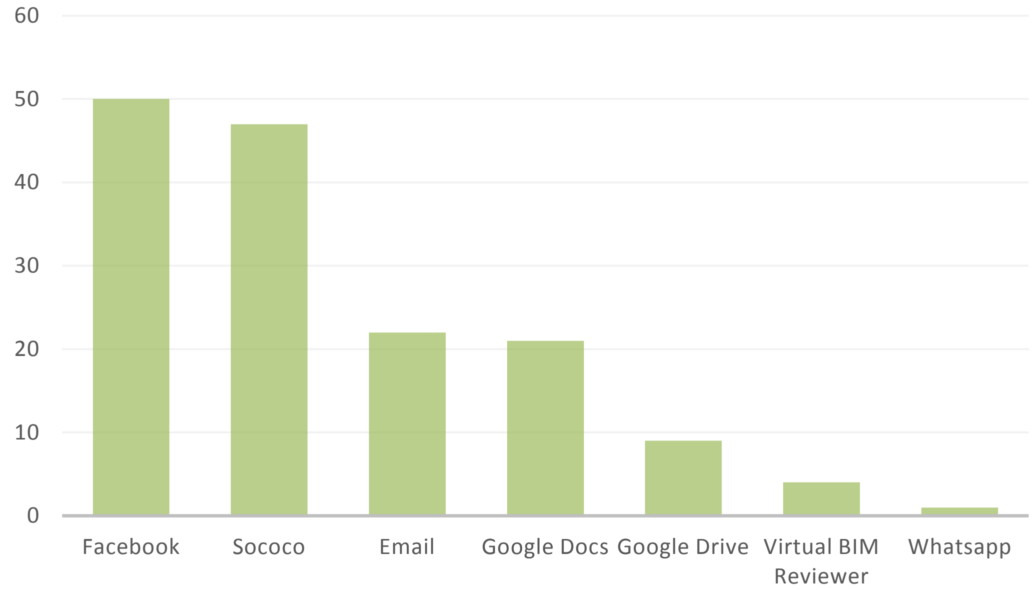

Figure 3. Communication Methods Used by Part II Global Teams (Weeks 1-6)

Student feedback, both positive and negative, indicated they learned critical lessons about the importance of planning and developing a comprehensive BXP. Part I of the project, at UW and IITM, is divided into two modules where the second module builds on lessons learned from the first module. Moving forward, this model may also be adopted in Part II so WSU students have an opportunity to first learn the importance of developing a comprehensive plan, then apply that lesson in the second module.

The majority of WSU students in this course had experience working with U.S. construction firms, either as interns or as full-time employees. This can create an insular understanding of construction practices. By exposing students to the construction practices in other cultures, our graduates have a more well-rounded understanding of construction practices which is important as industry teams become increasingly global.

Students at WSU, NTU and NCKU were asked to meet 'live' each week in Sococo as their project progressed. It was challenging for the students to find times to meet since so few of their waking hours that were not devoted to class time overlapped. As a result, the majority of their communication was asynchronous via communication methods like e-mail and Facebook. In some weeks, some teams were unable to meet at all. The value of synchronous communication has been established in the literature, especially when working with visually rich media like drawings and models, but it may be necessary to rethink the synchronous collaboration, evaluating the tradeoffs and perhaps examining alternative ways for them to accomplish 'messy' work asynchronously. For example, one function of the Virtual BIM Reviewer is the ability to leave notes in the 3D model. Using this as a means for 'messy' encounters could be explored further in future studies.

When students were asked for suggestions regarding next year's class, the most common response was advice for students who will be taking the class next year: the importance of communicating deadlines to teammates. While over half of the students mentioned that time zone was a difficulty, only 18% specifically mentioned working with schools in more compatible time zones as a suggestion for next year. Other suggestions included using better communication tools, having faculty provide more details about the project, and have the BIM portion of the project be more complex (see Figure 4).

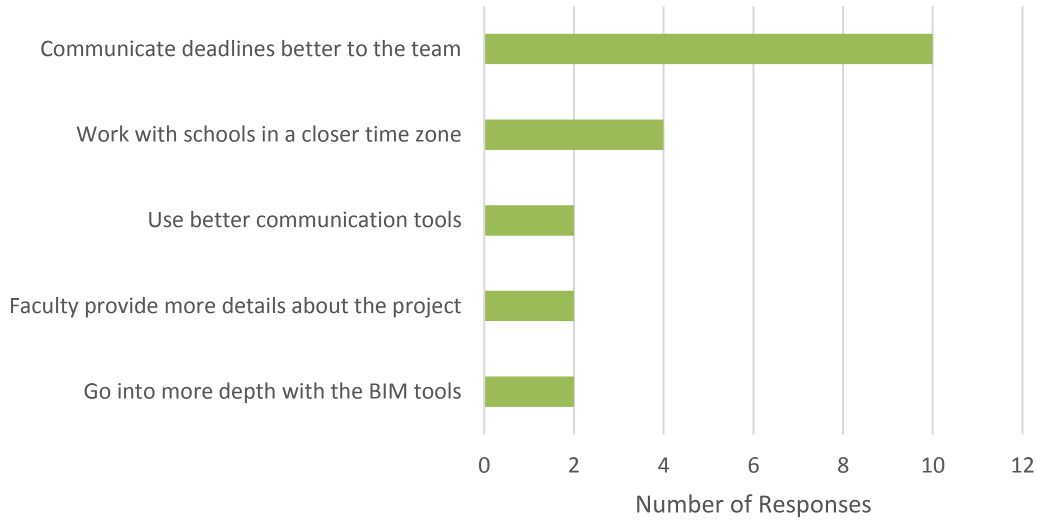

Figure 4. Responses to Survey Question: Suggestions for next year

Conclusion

Results indicate that students learned the importance of developing a BIM Execution Plan, discovered the value of various tools for collaboration (some were more useful than others), and developed an awareness of different cultural practices in the construction industry. However, further research is needed to understand how the challenges of larger time differences can be addressed while maintaining advantages of synchronous collaboration. Considering that students chose to communicate primarily through Facebook (Figure 3), we would like to explore the role of social media as a collaboration platform and possibly as a course delivery method. Next year's survey will ask students to reflect on their own role in improving communication among the team and how technology (both BIM tools and collaboration platforms) affected the collaboration process.

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