STUDENT COLLABORATION AS THE FOUNDATION FOR LEARNING BIM SOFTWARE: IDEAS FROM A PROJECT-BASED INTRODUCTION

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ABSTRACT

Through the tools of building information modeling and management, collaborative practices in the AECOO professions are a function of the activities of integrative thinking. In AEC education, integrative thinking is often addressed as a consequence of BIM rather than a condition of BIM; in other words, current undergraduate coursework tends to teach software before teaching skills of collaboration. High-quality interdisciplinary thinking is much less likely to develop where BIM is taught as an end rather than as a means.

This paper describes coursework with beginning-level construction students that used student collaboration as the foundation for learning Revit Architecture. In this project, students are introduced to building assemblies through the collaborative work of investigating, measuring, and producing as-built section drawings and BIM documentation of an existing building. Students worked through embedded assessment activities designed to 1) open students up to the value of working with their peers, 2) direct the development of collaborative relationships that foster project progress, and 3) institute resource management structures across the class that build construction knowledge as well as the applied skills of Revit. The project’s proposition is that BIM software should be learned as a function of collaborative thinking so that students are more likely to fully realize BIM’s capacity for integrated practice later in their studies.

Keywords: collaborative learning, BIM education, beginning students
1. INTRODUCTION

The normative pedagogies and instructional strategies of incorporating BIM in AEC curricula are beginning to be well documented (Barison & Santos, 2010; Joannides, et al., 2012, Peterson, et al., 2011; Sacks & Barak, 2010). However, too often BIM is seen in AEC education as a technology rather than an integrative practice tool dependent upon collaboration. As it has been implemented, BIM instruction “falls under current definitions of technology, thereby overlooking its potential for more radical conceptual shifts affecting the nature of design expertise or collaboration” (Tombesi & Deamer, 2011, p. 23). Since building information modeling and management serve the AECOO professions best as a function of integrated practices, BIM in AEC education might be better viewed as a subset of the larger realm of collaboration. This proposition would suggest a different path for BIM instruction.

There is little doubt that BIM will affect the relationships between the AEC disciplines—making them “more collaborative and less adversarial and sequential. As more things occur in parallel, better communication will need to occur and will occur” (Smith & Tardiff, 2009, p. 177). Smith and Tardiff’s point about “parallel” activities and their demand for better forms of communication offer a potential route to building these collaborative skills at the beginning level of AEC education. In the project described here, students work on very similar tasks in parallel. At first, students work in teams to develop resources and produce documentation. During this phase, emphasis is placed on building concepts of collaboration through explicit attention to the project “convergence” that occurs during the management of teamwork. Then the students begin to work individually on two similar drafting tasks that are identical in skill but are different in content. This “iterative” and “comparative” parallel project work encourages continued conversations and comparisons of work between students. The essential collaboration concept explored during these last two stages of the work is how collaborative peer-to-peer activities of assessment and comparison affect the individual development of better solutions.

These questions are investigated in this paper through the means of a reflective instructor narrative on a project assigned to second-year construction students in the Building Construction Science Program (BCS) at Mississippi State University. The BSC curriculum is based around six-credit “construction studio” courses, one of only two such inquiry-based undergraduate construction management degree programs in the United States (Monson & Hauck, 2012). The studio course, BCS 2116, met in a dedicated studio classroom space for twelve hours per week. This project was the very first long-term assignment in students’ first construction studio.

2. STUDENT AS-BUILT DOCUMENTATION OF THEIR CLASSROOM SPACE

The assigned project was to collaboratively produce a set of as-built drawings of the BCS studio spaces and faculty offices in the Howell Building on the Mississippi State University campus. The documents were to be a complete and accurate representation of the building structure, all systems, all components, and all materials from the foundation through the roof. The Howell Building is a 200’ by 60’ steel-framed structure with a variety of cladding, materials, and wall types offering a good introduction to basic assemblies and detailing. Later in the project, students would be expected to develop well-detailed wall sections and axonometric sections.

As this was the students’ very first construction course, the scope of this work was admittedly far beyond the immediate capacities of their knowledge and skills. However, it wasn’t the intention of the assignment that it be solved without significant gaps in accomplishment. The project’s difficulty meant that there was always some aspect of the solution that could be improved. This kind of difficulty demands that students see their peers and the work of the class as a whole as a necessary resource during problem solution; in essence, the difficulty provokes collaboration and communication.

The project followed a six-week arc through a team work phase and two stages of individual work with frequent organized peer assessment. The project was built around the notion that one of the most effective routes to Revit modeling is through the software’s 2D drafting capabilities. Familiarity with the Revit interface through the 2D toolset reduces the difficult learning curve for beginning students and allows other important content issues to run concurrently. Of course, this notion requires that an understanding of two-dimensional orthographic representation be learned before engaging the software. However, the most significant conceptual learning outcome of the whole project was to show students the benefits of and demands for collaborative practices in
Instead of learning the software as a series of click-and-point actions, it was the intention of the project that students engaged the software by embedding themselves in the collaborative practices of content generation. The proposition in this project is that if students learn BIM software as a function of shared and collaborative thinking, they are more likely to fully realize BIM’s capacity for integrated practice in more complex content realms later in the curriculum.

2.1 Team project phase: Collaboration through convergence

Students were divided up into two groups of ten. The students had not worked in large groups before, did not know each other well, and most had no drafting or construction detailing experience. As students had no prior knowledge of management strategies and were unable to adequately define the problem or generate multiple solutions options, they went straight to planning the project by dividing up what they thought was the work to be executed (Figure 1).

Quickly, the strategy of “just try to get it done” was recognized to be inadequate. The teams reconsidered their project management plans and went back to structuring their efforts according to the six management steps from James P. Lewis’ text *Fundamentals of Project Management*. Through a series of short instructor-led workshops, students were introduced to methods of axonometric and perspective sketching as well as hand drafted orthographic drawings. Subsequently, students better organized their efforts in problem definition, problem solution strategies, and planning execution of the work.

At the beginning of the project, weekly peer evaluations were established where students provided specific feedback on the performance of individual members of their teams as well as themselves. The peer evaluations provided a structure of conscious reflection for the work, and its terms of evaluation—teamwork, decision making, time spent, dependability, quality of work and thought—became standard assessment tools as well as internal jargon for the studio. As these methods of monitoring work coalesced with the requirements of project planning and execution, the ideas of “convergence” of effort and synthesis of product were gradually illuminated to students. They became aware of some basic facts inherent to high-quality team work: 1) collaborations can be organized through management strategies, 2) student work can be assessed fairly and productively by peers, and 3) building assembly content can be accessed and learned through group activities.

With these learning outcomes, the as-built portion of the assigned problem was given a final due date so that the team project phase could come to a completion. When turned in, the team-produced documents were largely incomplete, missing explanatory text, underdeveloped in terms of planning and execution, and very weak in the quality of drafted orthographic drawings and the correct understanding of building assembly content. Given the fact that the assigned problem would have challenged professional AEC firms, this result was completely expected of beginning students. Through discussions, students came to realize that the point of this first phase was to expose how collaboration works rather than expect them to produce a product at a professional level by using collaboration. This awareness of collaborative processes could then be pushed through further skill and content development in wall section drafting.

2.2 Individual drafted wall section: Collaboration through iteration

Students were then assigned specific locations to develop into 1” = 1’-0” hand-drafted wall section drawings. Sections were cut at seventeen windows and doors spread over eight structural bays in the Howell Building (Figure 2). Because students had previously used the structural bays to organize their team products, each
assigned wall location included a number of other students who had researched and drawn the same details. So, each student had a set of peer resources to help guide them in their own work. These resources were similarly applied across the entire studio because all of the wall details—though unique at each location—shared many pattern, detail, and material qualities.

Engagement with these peer resources began immediately after students sketched their first wall section. With sections pinned up on the studio walls, students were given review sheets to assess other students’ efforts regarding assembly details, construction lines, line weights, line tails, and general completeness (Figure 3). Students also assessed each other on the use of correct component terms and references to information in the course textbook, Allen and Iano’s *Fundamentals of Building Construction*. Students put their names on their assessments so that the student being assessed could talk with them further about the review. At the end of this exercise, students filled out their own assessment of their own work. Because the peer assessments had been pinned up next to their original wall section drawings, students had to acknowledge what others had said about their work. From this feedback and their own reflections, each student could begin their next iteration of the wall section.

Three important collaborative outcomes came immediately from this kind of assessment process. First, students are charged with reflecting on the accomplishments of other people’s work that is parallel to their own. This means that they have to conceptualize their own understanding of the project outcomes and apply it to other similar work. Second, students have to recognize and integrate the reflective assessments of others in their own understanding of their own work. This requires that they objectively sit outside of their own products and make modifications to their conceptual understanding of project outcomes as well as the appropriate measures of accomplishment. Third, by looking closely at other work, students recognize the skill sets and knowledge bases across their peer resources. This allows them to broaden their opportunity for improvement in their own work after realigning their understanding of the project outcomes and tightening their standards of achievement. These outcomes embedded the student work within all of

![Figure 2: Howell Building plan showing structural bays on gridlines and wall section locations at windows and doors](image)

![Figure 3: Peer assessment review sheets](image)

![Figure 4: Wall section and axonometric section draft](image)
the constructs for successful collaborative practice: ongoing communication, willing participation, brainstorming and teamwork, trust, and diversity with mutual respect (Sanker, 2012). This is why this work can be seen as “parallel”—individually driven efforts running concurrently within a larger project context—and yet still build necessary skills of collaboration as though the work itself was integrated. Here is where the project experiences provide a foundation for practices central to more complex BIM collaboration.

At this point in the project, the scope of the wall section assignment was modified. Students were given the challenge of constructing a 10’ section axonometric at the same 1” = 1'-0” scale and adding it to their wall section documentation (Figure 4). The purpose of this additional requirement was to prepare for the production of the same representation using the modeling capacities of Revit Architecture.

Following the initial peer assessment effort, students continued developing the content of their wall sections. However, they were assisted in that effort by four in-class activities across two weeks that reconnected them to their previous as-built team members. In the first of these collaborative assignments, students sketched other students’ wall sections and pointed out where they didn’t understand the detailing as shown. Questions were then addressed by peers and the instructor. In the second in-class assignment, students worked in small groups to diagram partial sections documenting all of the consistent details that repeated themselves throughout the building. The third in-class assignment was a much more rigorous peer assessment of twenty-one specific detail and drafting elements. Students had to find and assess the quality of completeness regarding such things as wall connections to foundation, lintels, and roof cladding and insulation. The assessment rubric provided another resource for students in examining the quality of their own work. The fourth in-class assessment was a final peer review of all of the requirements of the wall section detailing and drafting content. These peer assessments were used as a partial component of the grading evaluation of the hand-drafting phase of the project.

2.3 Revit wall section: Collaboration through comparison

Finally, the Revit phase of the project began. Students were given eighteen hours of Revit workshops taught by the instructor across five studio days. The textbook used was Daniel Stine’s Design Integration Using Autodesk Revit. Students were given daily assignments along with the development of the law office project in the textbook. These included initial attempts at copying a large-scale canopy detail, a multi-story wall section, and a number of simple building plan layouts.

The entire arc of the as-built project was designed around the notion that one of the most effective routes of Revit instruction is through its 2D drafting capabilities. By first learning the 2D drafting tools in Revit, the software’s complex interface is greatly simplified and the steep learning curve for BIM modeling is reduced. Since BIM skills are integrated in the BCS studio curriculum, the introduction to Revit occurs in the first studio rather than in a lecture course.

After completing the Revit workshops, students began to work on their own iterations of recreating their wall section and axonometric views (Figure 5). This “parallel” collaborative work began with students individually constructing the entire structural bay at the location of their wall section as a 3D model in Revit. Since they had done similar work previously in their as-built teams, they could use those peer resources in this model. The model was then cut to produce the wall section and manipulated in 3D to produce the identical axonometric section drawing that had been drafted previously by hand.

These first drawings were greatly underdeveloped. Students quickly realized that Revit
does not automatically detail complex assemblies, nor does it graphically represent those details in the same ways when compared to how the wall sections looked when drawn by hand. Students were disappointed to see that BIM was not “magic” in its capabilities to represent building assemblies. But since they had a good understanding of how their wall sections were meant to look from the work of their hand-drafted drawings, it was simply a matter of harnessing their skills to modify the model and adding drafted elements to create the desired computer representation.

Students produced a series of drafts of their wall sections and axonometric drawings on plots and worked collaboratively on red lining the drawings with necessary corrections. At this point in the project, key components to project success were the peer resources and the multiple methods of collaborative engagement that students had developed. Tied to their drafting boards during the hand drawing phase, students had built habits of working in their studio workspace and continued with those habits while working with Revit on their laptop computers. “Co-location” had been learned as a collaborative skill across the project, and so the work to build Revit skills and develop the building assembly content in their BIM documentation relied on the now-familiar interaction and communication skills they enjoyed with their peers. Some of the students asked if it was acceptable to share components across their projects—a recognition of how BIM is effectively used in AEC practice. Instructor approval was given for sharing provided that students documented their own abilities to produce other Revit components for their own work so that they developed the appropriate skills. During the last few class meetings before the final Revit drawings were due, students demonstrated great skills at managing workloads, finding resources, raising the expectation of quality outcomes, and relying on each other for critique, feedback, and content information. Final drawings and peer assessments demonstrated the content knowledge learned during the project and the significance of peer collaboration essential to the success of the work (Figure 6).

3. DISCUSSION AND CONCLUSION

The learning outcomes of this project for beginning construction students were a rich introduction to many realms of building assemblies and their documentation. Content issues were engaged through the most important skills and competencies demanded by twenty-first century AECOO practices: collaboration, communication, and critical thinking. While learning the depth of BIM collaborative practice was not the goal of the project, it offers an important example of how a foundation of collaboration can be laid for BIM practices later in a curriculum. Given the fact that BIM instruction is generally treated as a technological tool rather than a collaborative practice at the beginning levels in AEC education, this is perhaps the most substantive innovation of this project’s work.

There are many BIM collaborative practices that are introduced and developed during the length of this project. Students are able to see collaboration as a natural part of the complexity of BIM application in building assembly detailing. The time spent in the dedicated classroom studio environment offers a profoundly important example of how co-location creates better quality solutions in collaborative AEC projects. Productivity is enhanced by availability of peer resources and through the development of shared communication skills. Work
flow knowledge is fostered by the demanding nature of the tasks and by the easily accessed opportunities to see how a student’s management efforts compare to their peers. The repeated peer-to-peer assessment activities provide new knowledge about professional terms, industry jargon, and communication protocols. Students become well familiarized with scheduling and action lists and can measure their productivity against their peers because of their parallel efforts. The project from start to finish is transparent; all of the products of the work are posted around the classroom space of the studio and available for discussion. Together, the entire collaborative nature of the assignment and the class environment creates engagement across students where more questions are answered by peers rather than instructors or other faculty.

While the difficulty, complexity, and time demands of this project may limit its immediate applicability to other AEC curriculums, the narrative example of this work may challenge other educators to embed collaboration at the beginning levels of undergraduate BIM instruction. Perhaps the most encouraging suggestion is this: one of the best ways to get AEC students to work together is through a problem difficult enough to provoke—and benefit from—the authentic experiences of their own collaborative engagement.

REFERENCES


