BIMSTORM: A PLATFORM FACILITATING INTEGRATED DESIGN AND CONSTRUCTION PROCESSES

McCuen, Tamera, Associate Professor, tammymccuen@ou.edu
Construction Science Division, College of Architecture, University of Oklahoma, Norman, OK
Pober, Elizabeth, Assistant Professor, epober@ou.edu
Interior Design Division, College of Architecture, University of Oklahoma, Norman, OK

Abstract

Collaborate...Create...Construct is the mantra for the design and construction faculty at the University of Oklahoma to develop curricula that demonstrates this mantra through project based learning. BIM inherently supports collaboration, creation, and construction with its integrated methodology and technology.

BIMStorm is best described as a charrette in which design and construction teams collaborate to create solutions using a macro level BIM approach. Academic instruction about BIM frequently focuses on the micro level, the software used for authoring and analysis of a BIM. While software skills are a necessary component for students of the built environment, education about BIM needs to extend beyond this level and prepare students to use BIM as a tool to solve the complex and ill-structured problems common to the built environment. BIM instruction should also focus on methods used to achieve the higher level coordination necessary for successful integrated practice. The challenges faced by students working in a macro level BIM charrette extend beyond the discipline specific technical knowledge. The challenge requires critical thinking skills about large scale conditions and constraints frequently faced by design and construction professionals. This paper focuses on the instructional strategies used to teach integrated processes through the activities of BIMStorm OKC.

Keywords: BIM, BIMStorm, interdisciplinary teams

1. INTRODUCTION

Collaborate...Create...Construct is the mantra for faculty in the University of Oklahoma College of Architecture and describes the approach for teaching and research efforts in the design and construction disciplines. The university provided internal funding for BIMStorm OKC as support of the experiential learning opportunity for students to collaborate across disciplines and with industry professionals on a project situated in the real world. Designing course curriculum for the interdisciplinary experience challenged the faculty to develop instructional strategies that integrated multiple aspects of BIM. The faculty determined that the strategies must include targeted instruction about methods used to facilitate the information exchange between individuals, as well as integrating information exchanges between software applications. Instruction about BIM methods for team work was supported with instruction about BIM tools at both the micro and macro level.
BIM facilitates integrated processes for the design and construction of facilities and is transforming the way industry approaches building projects. Industry needs educators to prepare the future design and construction professionals with the skills and knowledge required in a collaborative environment to create and construct the built environment. This paper provides an overview of how the faculty utilized the BIMStorm platform and their approach to the design and development of instruction for integrated and collaborative processes.

2. COURSE DESIGN

2.1 Definition of the Problem Type
The primary consideration by the professors when developing the instructional strategies for the BIMStorm project was the type of problem. Inherent in the building industry are problems that require knowledge about multiple inputs and variables that can impact a project at different times, not only during the design and construction processes, but across the project’s life cycle.

The problem solving literature refers to this type of problem as an ill-structured complex problem. It is important to note that a problem may be complex without being ill-structured and vice versa; however, in the case of the building industry, the preconstruction process is a classic example of an ill-structured complex problem. Below are two lists that describe the features of a complex problem and then the elements of an ill-structured problem. The first list is that of the features typical in a complex problem, with a brief description of each from the problem solving literature (Funke, 1991). Along with the description is an example of how the feature relates to design and construction student teams in BIMStorm.

- Intransparency - A feature in which only some variables in the problem may be directly observable. The students must complete independent research about project sites to gather more information about project parameters, conditions, and constraints.
- Polytel – Refers to the fact that the problem situation involves multiple goals. Each student team must complete preconstruction design and construction analyses to meet academic evaluation, but also produce a solution that is preferred by the project owner.
- Complexity of the situation – This feature concerns the number of identification and regulation processes involved in the problem. Multiple design and construction codes, ordinances and requirements must be successfully met by each team.
- Connectivity of variables – The problem variables are highly connected, making it difficult to anticipate all the possible consequences of the situation. Variables such as the project owner, preferences, site, budget, resources, and other factors will ultimately impact the project and determine its viability.
- Dynamic developments – A complex problem situation may change often, forcing the problem solver to act immediately. The project owner may change their mind during the preconstruction process about a design feature thus causing redesign and new analyses.
- Time delayed effects – This feature describes the fact that not every action taken by the problem solver may show up immediately as a consequence of the solution decisions. As students are designing and analyzing options they may simultaneously discover the possibility of future economic constraints that require analyzing options in consideration of providing alternatives.
The following is an abbreviated list of elements common to an ill-structured problem according to the problem solving literature (Jonassen, 1997). Each element includes an example of how it relates to the BIMStorm design and preconstruction activities.

- The problem appears ill-defined because one or more of the problem elements are vague or unknown. The project area includes multiple sites with acceptable types, use, size, and density that students must decide between prior to the start of a possible solution.
- Possible multiple solutions, solution paths, or no consensual agreement on the appropriate solution exists in an ill-structured problem. Students are challenged to propose unique solutions by the faculty and project owner.
- There are multiple criteria for evaluating solutions. Evaluation criteria on each BIMStorm project include aspects of creativity, feasibility, building performance, cost, time, location and other criteria defined by the faculty and the project owner.
- A prototypic case does not exist for how to solve the problem. Each site within the project area is required by the owner’s programme to be unique and fitting for the surrounding neighborhood and greater Oklahoma City community.
- The problem solver must express personal opinions or beliefs about the problem. During the process of design and analyses, the students must develop a representation for what they believe is the most important element to the owner for their site choice.
- An ill-structured problem requires the problem solver make judgments about the problem and be prepared to defend their judgments. The student teams must thoroughly analyze the owner’s programme and existing conditions to determine if the problem stated is the problem in its entirety, or if there may be some additional underlying elements contributing to the problem.

The faculty’s goal was to apply instructional strategies that would support student learning in an environment where the macro BIM instruction about solving ill-structured complex problems provided the framework, and the micro BIM provided the tool supporting the idea generation and analyses necessary for this type of problem. An important early step for any team using BIM is to establish the procedures and process by which ideas will be shared and analyses performed. The Project Planning Guide (CIC, 2011) provides a method for project teams to utilize to establish responsibilities for authoring and procedures for information exchange.

### 2.2 Instruction about Coordination Strategies

Integrated practice requires collaboration among team members, and BIM depends upon unrestricted information exchange between all team members involved in the building process. In order for this collaboration and information exchange to work successfully in building information modeling, a project team must create and implement a detailed comprehensive plan for the project (AIA, 2007). A BIM Project Execution Plan provides a template for the team to define the BIM goals and uses, the execution process, the deliverables and also the infrastructure for implementation of the project (CIC, 2011).

The BIM Project Execution Plan provides a framework for the fundamental coordination strategy the student teams can use for their BIMStorm projects. The teams form at the beginning of the semester with each team member defining their primary role in the group. Prior to forming teams however, each student must complete a personality profile, the results of which assist the team in defining the project team roles along with discussion of their discipline specific skills and strengths. The students are aware of the general project background, site, program and
budget prior to the actual charrette. This information allows them to develop and complete the BIM Project Execution Plan and practice it prior to the actual BIMStorm charrette.

The teams begin with identifying the BIM goals and uses for the project. Traditionally, the goals are based on project performance, and advancing the capabilities and experience of the project team members (CIC, 2011). The students’ goals are similar, with more emphasis on advancing their capabilities and experience and less emphasis on project performance. The specific BIM uses are then identified. The BIM Project Execution Planning Guide outlines twenty-five common uses for building information models along with a thorough explanation of each to guide interdisciplinary teams. These BIM uses are provided based on completed projects that have been studied as well extensive research and interviewing with experts in the industry (CIC, 2011). BIMStorm OKC student teams will not utilize all of the possible uses of a BIM for several different reasons. One reason is due to the existing conditions of the project itself, and also due to the twenty-four hours of time given for the BIMStorm charrette. The twenty-four hour time constraint provides only enough time for the students to develop a BIM to a Level of Development (LOD) somewhere between a 200 and 300 (AIA, 2008). In terms of traditional stages in the design process, an LOD 200 is at the schematic phase and an LOD 300 is at the design development phase. While not all of the uses specified in the BIM Project Execution Plan are utilized, the course professors think it is reasonable to expect teams will use approximately twelve of the twenty-five categories.

The focus of student teams on the BIM uses during their planning for the BIMStorm charrette are: building systems analysis, space management and tracking, site utilization planning, construction system design, design authoring, engineering analysis, sustainability (LEED) evaluation, programming, site analysis, design reviews, phase planning (4D modeling), and cost estimation. Building systems analysis is partially utilized for the students, where they study ventilated facades, analyze lighting and look at solar analysis in developing their design solutions. Space management and tracking allows the team to utilize BIM for proper space allocation and management of space resources (CIC, 2011). Site utilization planning focuses on site logistics and phasing during the construction process. The construction system design BIM use allows the team to design and analyze complex building systems in order to increase constructability (CIC, 2011). Design authoring is the primary use of building information models, where the design is developed through utilization of a BIM in order to translate the building’s overall design (CIC, 2011). The student teams use engineering analysis to determine the most efficient methods and systems for structural, lighting, energy and mechanical systems. LEED criteria are required for the project, so the students utilize the sustainability (LEED) evaluation in order to evaluate the required LEED requirements for the project. Programming is used by the students in the early phases of the charrette to quickly and accurately assess design performance in regard to spatial requirements provided for the project (CIC, 2011). BIM and GIS tools are used for the site analysis use to evaluate and analyze the conditions of the project site.

Throughout the charrette, design reviews allow the team members as well as external members involved with BIMStorm to view the models and provide feedback. This feedback and information exchange is the heart and soul of BIMStorm, where not only the individual teams exchange information, but everyone involved in BIMStorm from any location can contribute feedback. The final BIM uses are utilized primarily by the construction students and include phase planning and cost estimation. Phase planning allows the students to prepare phasing and sequencing schedules that show the critical path of the project, it provides for integrated planning
of human, equipment and material resources, and planning for procurement of project materials (CIC, 2011). The cost estimation use process utilizes the BIM to accurately assist in generating quantity take-offs and cost estimates. The students plan for all of the described BIM uses and assign responsible parties prior to the charrette.

The final portion of the BIM Project Execution Plan incorporated in the coordination strategy for the students is to define the information exchange between the members of the team. This is a vital planning tool that allows the team to define the content and level of detail for the various categories of components in BIM, as well as to define the associated responsible parties for each category of components within the model (CIC, 2011). The teams complete the Information Exchange Worksheet provided in the Project Execution Planning Guide.

As mentioned previously, the definition of BIM refers to both a methodology and tools that support a collaborative interdisciplinary approach to a project across its life cycle. Within both the methods and tools category, a further distinction can be made to describe BIM at the micro and macro levels. Ultimately BIMStorm required student teams work at the macro BIM level; however, they first had to develop skills and knowledge relevant to the micro BIM level.

The BIMStorm OKC project was the semester project for sixty-seven students, twenty-four from the fourth year architecture studio and thirty-three from the senior construction science BIM course. It is important to emphasize that there was not an entire course dedicated to BIMStorm course, but instead an interdisciplinary project for collaboration between the courses. Consequently, instructors for each course had specific learning objectives to meet as required by their respective discipline curriculum. Some of the learning objectives included prerequisite knowledge that students had prior to working in the interdisciplinary project scenario for design and preconstruction analysis. Following is a discussion about micro BIM and macro BIM as introduced and utilized in each course and for the project.

3. BIM INSTRUCTION

2.3 Micro BIM – The tools and process for detailed information

As the integration and use of building information modeling has increased in recent years, so have the various software applications and their abilities. According to the National Institute of Building Sciences, “A Building Information Model is created with digital technology that generates computable representations of both the physical and functional characteristics of a facility as well as its related project/life-cycle information, while also acting as a repository of information for the facility owner/operator to use and maintain throughout the life-cycle of a facility,” (NIBS, 2007). The entire process for building information modeling relies upon virtual models and databases that are interrelated and interconnected. These models and databases provide the mechanism for information to be shared between all members of a design and construction team. Multiple software applications provide a variety of tools from which owners, designers, constructors, and facility managers may select to create, analyze, and sustain the building information model on a facility.

The primary applications are centered around virtual building technology where the design can be conceptualized, developed and detailed, and constructability can be analyzed and construction can be realized. Applications also focus on site analysis, structural analysis, energy analysis, mechanical simulation, lighting analysis and simulation, acoustic analysis, cost analysis, phasing, schedule development, procurement, maintenance and facility management. The many tools and applications available provide an opportunity for numerous skilled team
members to collaborate and contribute to the development of a BIM. This method facilitates sharing information and making decisions with this information together in order to improve project delivery, as well as increase the quality of a design and construction project outcome.

Academic instruction on the use and application of BIM should begin at the micro level. Acquisition of software skills and the depth of information each micro solution offers provides students with the cognitive tools they will need to support working in BIM to solve the project problem. This sequence of instruction is a typical strategy in learning environments where students are presented with complex, novel and authentic tasks (Jonassen, 1999). Instruction at the micro BIM level occurs in technology specific courses as well as in the more discipline specific technical courses.

As mentioned earlier in the paper, the teams assembled for BIMStorm included students from both the design and construction disciplines and each with varying technological skillsets in the BIM related software applicable to their specific discipline. The design students focus on applications specific for design conceptualization, design development, site analysis, structural analysis, energy analysis, mechanical simulation, lighting analysis and simulation, and acoustic analysis. The construction students focus on developing their skills with applications specific for design analysis, constructability analysis, structural analysis, cost analysis, phasing, and schedule development. The students from each discipline bring their own technological skills to the collaboration table and are also able to share those skills with their other team members, providing an opportunity to learn from each other. Additional advanced instruction related to BIM specific technologies utilized in the college, as well as industry, were included in the schedule prior to the actual BIMStorm charrette.

Although there are numerous software applications available to contribute in the development and analysis of building information models, these models must be able to exchange information between their individual software platforms so that data can be shared between building team members (McGraw-Hill, 2007). It is important that data from the models be supported by an integrator or available for sharing using the Industry Foundation Classes (IFC) format. With translators, some information might not be transferred and some information might not be able to return to the original software platform after it has been manipulated. IFC classes are not available for all types of data, and because of this, there can be some data loss of the originating application will support functionality that is not modeled in IFC classes (Ashcraft, 2008). It is extremely important to coordinate the team and the various software platforms being used by the team because each offers different levels of data and interoperability. Some BIM software applications do not provide interoperability, so collaborations between team members are often limited based on the software chosen for the project (Cavallero, 2006).

The software platform and discipline related software available for students provides support for interoperability, integration, and information exchange. In addition to instruction about the desktop solutions at the micro BIM level, the macro BIM level instruction is important. Instruction for macro BIM focused on the processes and a web-based project management solution.

### 3.2 Macro BIM – The tools and process for conceptualization

The sequence of instruction starting first with the micro BIM and then the macro BIM may seem counter intuitive, but it is actually consistent with the traditional training approach companies take with young professionals. Graduates from architecture and construction programs will begin their careers working in positions that focus on the detailed minutia of a project, and only after
experience with the details on a project do they understand the ‘big’ picture enough to be able to conceptualize a project.

For example, architects typically spend their first few years in practice drawing details and completing the construction documents for a project. It is only after years of experience, that an architect is given the opportunity to be responsible for the conceptualization of a project, or a project at the macro level. The same is true for preconstruction professionals who typically spend their first years in completing detailed cost estimates and schedules. Only after years of experience in preconstruction will an estimator have the knowledge and skills necessary to generate a conceptual cost estimate to determine the feasibility of and risk associated with a project. In addition to the technical aspects for each discipline in macro BIM, instruction at this level was designed to emphasize a holistic approach to the design and analysis process during preconstruction.

As with micro BIM, there are computer tools that facilitate the macro BIM process of design and analysis. This type of BIM tool differs from the micro level BIM tools in that the amount of information and project definition that can be achieved is less. However, the categories at this level are expanded to include geographic information along with the project resource information. Traditionally in the predesign and schematic phase of the design, architects generate hand sketches to visually depict their ‘idea’ of what the building may look like. A cost estimator would generate a conceptual estimate pulling data from prior experience with similar jobs and heuristic models. A project manager would estimate the time and resources in a similar way as the estimator. BIMStorm students were introduced to BIM tools that supported the activities described above. The BIM tools introduced allow for more rapid conceptual design generation, analyses, and revisions than the traditional method. The ability to generate multiple design options with the information for preconstruction activities was emphasized as the strength of macro BIM.

Students are instructed on various analyses that should be considered in a large redevelopment project such as BIMStorm OKC. For example, because the project sites are in an urban area, students must consider the socio economic status of residents in that area and the support resources necessary for the area. The owner’s programme reinforced this point in its descriptions about the types of businesses that should be planned for the area in an effort to retain a significant number of area residents. The programme also stressed the importance that housing be designed for several price points. The community aspect for BIMStorm OKC is stated in its tag line “Building Community and Enhancing Connectivity” and instruction was designed to highlight the importance of community.

Instruction about at the macro BIM level focuses on higher order thinking such as critical thinking and judgment about creating and proposing a project solution. At the macro level, a BIM is used for decision making based on the feasibility of a proposal and project improvement (Scopano, 2006). Given that the goal of utilizing macro BIM is to improve the outputs and productivity of the project team, instruction about macro BIM was designed to introduce ways students might improve on a project’s early design and preconstruction activities.

4. Discussion and Conclusions

At the time of this paper’s submission, the BIMStorm OKC event had yet to occur. However, the authors participated in developing the curriculum and instructional strategies focused on advancing student knowledge and skills for solving complex problems typical to the design and
construction disciplines. A real-world project was utilized for the design and preconstruction activities in BIMStorm. The faculty focused on providing instruction for students on the processes and tools that would enable the students to perform the responsibilities for their specific disciplines. In essence, this is micro BIM. The faculty also organized the participation of industry professionals throughout the semester who provided feedback about student project development and also presented best practices for working in an interdisciplinary team using BIM. This feedback provided the students with a support system for advancing their knowledge and skills in the areas of decision making and also facilitated selection of alternative project solutions based on valid information from credible sources. In essence, this is macro BIM. Application of strategies for teaching micro BIM and macro BIM supported tools and processes used daily by professionals for solving complex ill-structured problems in the built environment using BIM. Expected outcomes will allow the faculty to reinforce the mantra of collaborate, create, construct.

References