Parametric Modeling and BIM: Innovative Design Education for Integrated Building Practices

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Abstract

Parametric modeling and Building Information Modeling (BIM) present opportunities to radically change the architectural design process, which has similarly radical implications upon design education. These processes and technologies are demanding a broader knowledge base and deeper skill set. The same technologies and processes create opportunities to meet and surpass the traditional architectural knowledge base that forms the basis for design education. Outlined in this paper are the results of three studies that employed BIM and parametric modeling within the context of simulated professional project delivery and compares the results using the new process to the NAAB Student Performance Criteria. From these studies, it appears that the alternative design method that employs BIM and parametric modeling is more rigorous and effective than the traditional method of instructing students with respect to the Student Performance Criteria in Realm B: Integrated Building Practices.

Introduction

Parametric modeling and Building Information Modeling (BIM) present opportunities to radically change the architectural design process, which has similarly radical implications upon design education and the way architectural design is taught (Ambrose 2007). Parametric modeling and BIM are demanding a broader knowledge base and deeper skill set. At the same time, Parametric Modeling and BIM create opportunities to meet and surpass the traditional architectural knowledge base that forms the basis for design education (Clayton 2006). Effective use of BIM software for an architectural design requires the integration of multiple knowledge bases yet facilitates the integration of those knowledge bases. In this sense Parametric Modeling and BIM lead to a heightened, intensified design process that nevertheless addresses the essential objectives of sophisticated problem solving around integration of many functions and factors

Recognizing the importance of the simultaneous development of multiple individual understandings and abilities, in 2009 the National Architectural Accrediting Board (NAAB) issued the Conditions for Accreditation (NAAB 2009). Included in these conditions are a distinct set of Student Performance Criteria (SPC). The SPC state that the architecture student of today is expected to clearly demonstrate both understanding and ability within multiple different aspects of architectural knowledge. Additionally, the SPC require the student to show the ability to integrate these different aspects into a comprehensive design.

This paper makes a comparison between the results of three case studies of teaching parametric modeling and BIM to design students and Realm B of the NAAB SPC. The three case studies employed a new teaching method, called Studio 21, which contrasts with conventional teaching methods in the typical design studio (Clayton, Ozener et al. 2010). The studies demonstrate that implementing Parametric Modeling and BIM in the design studio using the Studio 21 process provides opportunity to address multiple aspects of the Student Performance Criteria. It also sets the framework for establishing BIM as a tool for both fostering Ability and generating Understanding as outlined by the NAAB.

The New Criteria

Architects are required to understand and implement a wide variety of technical, artistic, historical and even societal information as part of their professional responsibility. Supporting this supposition are the 2009 NAAB Student Performance Criteria's three realms:

Realm A: Critical Thinking and Representation
Realm B: Integrating Building Practices, Technical Skills and Knowledge
Realm C: Leadership and Practice

Under the NAAB conditions students are required to demonstrate either Understanding or Ability of different aspects within each of these three realms. The NAAB defines Understanding as "the capacity to classify, compare, summarize, explain, and/or interpret information" and Ability as "proficiency in using specific information to accomplish a task, correctly selecting the appropriate information, and accurately applying it to the solution of a specific problem, while also distinguishing the effects of its implementation". The SPC are very broad in their coverage and a typical curriculum relies on a multitude of courses to encompass understanding and ability within all three realms. This paper deals with *Realm B: Integrating Building Practices, Technical Skills and Knowledge*. Taken directly from the NAAB document Realm B is expanded:

Architects are called upon to comprehend the technical aspects of design, systems, and materials, and be able to apply that comprehension to their services. Additionally they must appreciate their role in the implementation of design decisions, and impact of such decisions on the environment. Students learning aspirations should include:

Creating building designs with well-integrated systems.
Comprehending constructability.
Incorporating life safety systems.
Integrating accessibility.

Applying principles of sustainable design.

It is clear, the amount of technical things required to be incorporated by students is immense. Practitioners know that a successful design incorporates all these things on extremely detailed levels. Doing so requires creating, keeping, integrating, and evaluating large amounts of information.

Critique of Current Practice

The traditional design studio process is limited because it assumes an outdated mode of practice, reinforces hierarchical team organization, and relies heavily on tacit knowledge (Fisher 2004). This method of workflow cannot address all the technical aspects of design project simultaneously. Students are given cursory introductions to several aspects, asked to integrate them and left to ambiguous, esoteric, and rarely constructive studio critiques as the definable measure of success. The process of design studio is as equally important as the product and the jury system loses this point along the way (Koch, Schwennsen et al. 2002). Therefore, when reviewing the understanding and abilities that students are required to demonstrate to meet the conditions of the NAAB Student Performance Criteria creating a design studio pedagogy that can address all of them seems daunting. The learning tool necessary to accomplish these goals can be found in technologies coupled with new design studio processes that mirror the emerging modes of practice these technologies support.

Outlined below are the results of three Action Research Cases done as part of an investigation spanning two schools of architecture within the Texas A&M University System. The goal of the research was to investigate a new method of studio education centered around emerging modes of Architectural practice supported by technologies: Parametric Modeling, and BIM. Parametric modeling requires defining a set of rules and relations or parameters that define and object or class rather than defining the object itself and BIM is defined as "a modeling technology and associated set of processes to produce, communicate, and analyze building models" (Eastman, Teicholz et al. 2008). These new processes led to the definition of a new studio method that has been named "Studio 21" to differentiate it from 20th century studio methods. From the study, the researchers found that changing the entrenched design studio framework was not a challenge of software or learning, but one of changing an entrenched culture of design. Once that culture was altered, students embraced a new method with the vigor and enthusiasm only students can muster (Ozener 2009).

The form of the cases was that of design courses within an architecture curriculum. The first case was undertaken as a graduate seminar in the fall of 2009. It met weekly over the course of a semester. The second case was held at a different university as a lecture/seminar course. The third case was a graduate charette project. There were a total of 27 participants in the case studies. They included nineteen M.Arch Students, one M.S. Architecture Student, four M.S. Construction Science students, and three PhD Architecture students. The M.Arch students collaborated with consultant teams made up of all other students. All three case studies began with an intensive introduction to Parametric Modeling and BIM tools. The intensive introduction was done to establish a common base among all participants. Pre-study surveys indicated a varying range of skills with regard to BIM software and as such, the intensive introduction was to get all students to the same level or at least a close as possible.

The process required students to make a "Base Case" in which a very simple solution was modeled using Autodesk Revit Architecture. This base case was used as a benchmark for performance by running it through various analytical tools to compute energy consumption, construction cost, construction schedule and other measures. The base case provided students with a starting point for their design work, allowing them to measure changes in performance with each design iteration. Because the projects were done with BIM and employed parametrically modeled components, changes could be made easily based on strong technical data from the simulations. Because the interoperability steps were worked out in the base case, each subsequent design could be analyzed quickly and accurately using the various analytical tools. This “base case” method became central to the Studio 21 model.

In all three studies students were given the same simple design brief; a train station on the Texas A&M University Campus in College Station, Texas. The project program was simple and straight forward: 4000SF of indoor space and an 8000SF covered platform with a budget of $2 million. The other condition was a 4 month construction time limit. The students were required to provide evidence to support design decisions and alternatives in twelve different areas:

1. Schematic alternatives illustrated with plans, elevations, and perspectives
2. Preliminary and detailed construction schedule proposals
3. Construction cost estimate
4. Structural component selection and design
5. Operating cost report
6. Energy consumption report
7. Mechanical systems integration
8. Sunlight studies and daylighting performance
9. Water balance and rain water harvesting strategies
10. LEED Silver Certification
11. Conformance with Amtrak design guidelines
12. Visual analysis to indicate sensitivity to the campus setting and design aesthetics

Making the Comparison

-The results of all three case studies were similar. BIM and Parametric modeling were shown to allow for a better integration of both structural and mechanical systems. Using reliable information students were able to make micro and macro level design decisions. Using parametrically modeled components changes could be integrated and students could quickly see how those decisions impacted form and spatial considerations (Ozener 2009). While the structural systems were not avant garde in their form, they were, in most cases, respective of their context. In every case the structural system met the constraints of economy and schedule (Figure 1). This clearly shows an Understanding of Structural Systems (SPC B.9) as well as being a key component in the Ability to produce a comprehensive design (SPC B.6). Canopy structures designed by the students, on the other hand, were quite interesting and innovative (Figure 2) and showed some exploration of parametric components. This shows an Understanding of materials and assemblies (SPC B. 12)

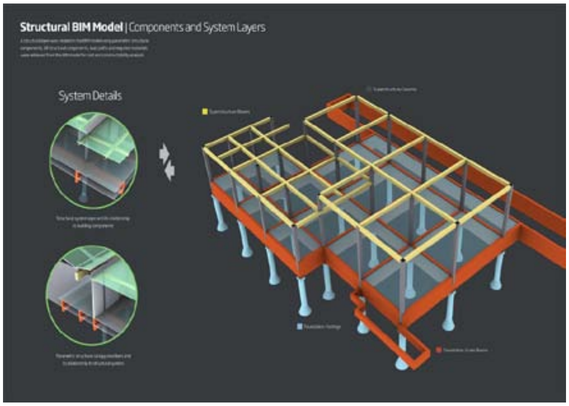

Figure 1 shows modeled structural system. Students built initial models then met with consultants to discuss feasibility, cost and member sizing

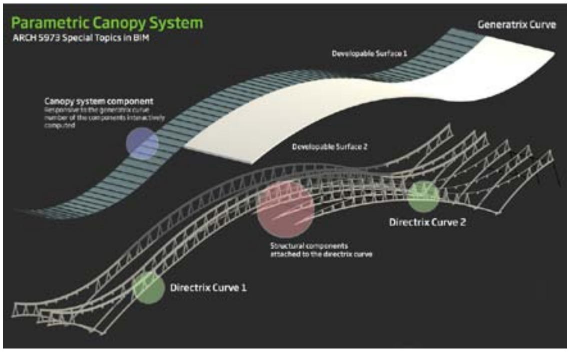

Figure 2 Parametrically Modeled Canopy Structure. Students experimented with parametric systems to produce canopy structures. Changes were incorporated quite easily due the parametric definition.

Because the main design tool was a BIM program students could generate quantity surveys that supported cost estimates from the construction consultants. Students could also get 4D construction visualizations and timelines using Microsoft Project and Autodesk Navisworks (Figure 3). This allowed students to see the cost and constructability impacts of their design decisions. BIM and parametric modeling allowed students to quickly make changes affecting the budget and construction timeline. Students were able to get cost comparisons for eccentric forms (Figure 4). This was shown to be a valuable method of addressing issues of cost and constructability as well allowing for a frontloading of project information (Ozener, Jeong et al. 2010). This aspect of the case studies shows an understanding of Financial Considerations (SPC B.7) as well as an understanding of Building Envelope Systems (SPC B. 10).

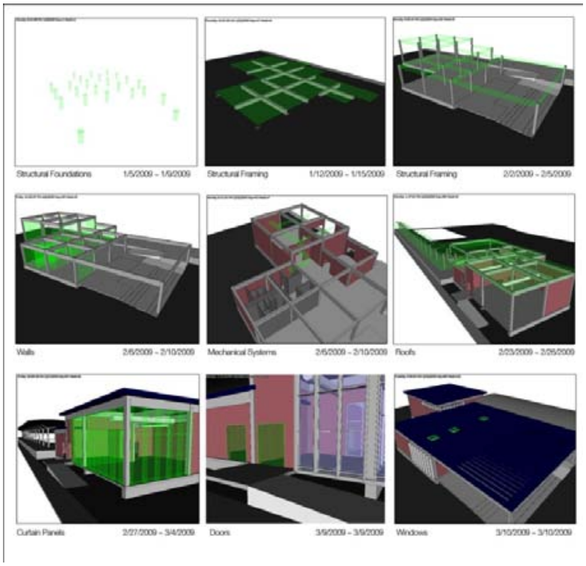

Figure 3 showing 4D scheduling and construction sequence

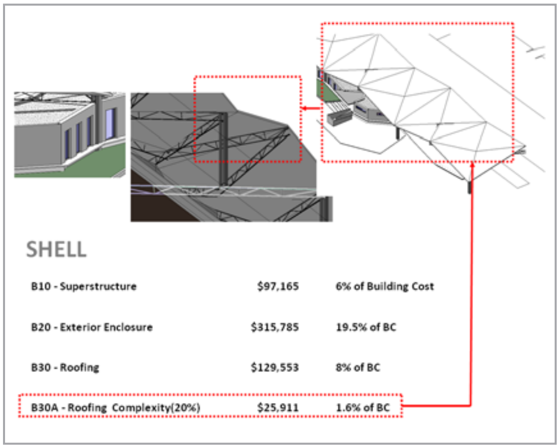

Figure 4 showing cost breakdown for eccentric canopy form

Designing for Sustainability was also a requirement in the cases. The third case involved incorporating daylighting problems. Students produced a progression of designs and evaluated each one using Autodesk Green Building Studio (Figure 5). This allowed students to see direct performance gains and losses between each scheme. Additionally students evaluated their models using Autodesk Ecotect software, giving them another dimension of performance and usable information (Figure 6) The findings showed that while students had difficulty adopting the software and mastering the associated learning curve, the BIM models coupled with analytical evaluation and rapid feedback helped students to "understand the impact of design decisions on the daylighting and sunlight performance of the design alternatives" (Ozener, Farias et al. 2010). These portions of the case study clearly show an Ability to design an energy saving system, test it, and modify it based on received data (SPC B.3). Additionally, they show students beginning to understand Environmental Systems and Service Systems (SPC B. 8 and B. 11).

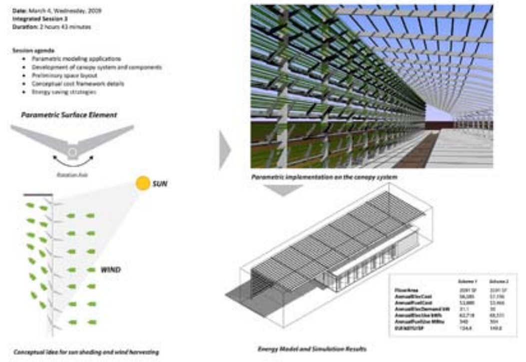

Figure 5 showing iterations of shading design and energy calculations

Figure 6 showing different shading options evaluated in Ecotect

Overall, the case studies produced some intriguing design solutions (Figures 7 & 8). Each solution met the constraints of economy, aesthetics, and schedule.

Figure 7 Final design solution

Figure 8 Final design solution

Conclusions

The cases demonstrate that the Studio 21 approach can be implemented in graduate settings, by more than one instructor, and at more than one school of architecture. They further show that NAAB SPC criteria can be well met in the courses that use the Studio 21 approach. In particular, requirement B.6 Comprehensive Design lists several criteria. Our experiments addressed most of these criteria at a demonstrably high level:

	NAAB SPC	Demonstrated Ability in Cases
B.1.	Pre-design	
B.2.	Accessibility	Yes
B.3.	Sustainability	Yes
B.4.	Site Design	Yes
B.5.	Life Safety	Yes
B.6.	Comprehensive Design	Yes
B.7.	Financial Considerations	Yes
B.8.	Environmental Systems	Yes
B.9.	Structural Systems	Yes
B.10.	Building Envelope Systems	Yes
B.11.	Building Service Systems	Yes
B.12.	Building Materials and Assemblies	Yes

We believe that the results of all of the courses are remarkable in the quality of designs produced, and, also significantly, the demonstrated technical excellence of solutions that were supported by simulation results. The methods used in these courses may be more comprehensive, better able to convey lessons in integration, and produce better designs than conventional methods. Students stated that the course changed their views of architectural design process. They appreciated the unique and powerful design method that they learned.

Parametric Modeling and BIM have catapulted design and design pedagogy into the twenty first century. The NAAB have recognized the challenges that face future professionals and are setting requirements that will ensure the knowledge and skills of licensed designers. Studies like the one outlined show the potential of technologies like Parametric Modeling and BIM to bridge the gap and produce Understanding and Ability within students.

As with any case study initiative these investigations raised as many questions as they answered, but they did advance the argument for BIM and Parametric Modeling in the design studio. More than this these studies elucidated the massive amounts of technical and specialized knowledge that an architectural design student is required to integrate in a typical design studio. What is required of architects will not get less, therefore it is incumbent upon educators to adopt methods and technologies that can best prepare students to deliver professional design services based on explicit analytical information. The studies outlined above illustrate the potential of Parametric Modeling and BIM technologies to directly address requirements of the Student Performance Criteria.

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