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Building Information Modeling (BIM) and Construction Simulation

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Introduction – A Critical Discourse for Building Information Modeling

Experimentation remains at the heart of teaching architectural design with studio being the main vehicle for architectural education. It provides the foundation for architectural creativity and knowledge, as well as establishing the framework for thinking, understanding and creating architecture. Organized around the development of a real project, studio class has a unique opportunity to investigate many themes.

The question of digital technology integration within the studio remains an open debate within the Professional Program at Southern Polytechnic State University (SPSU). Given the ubiquity of digital technology within the profession, integration seems like a natural progression within architectural education.

The third-year serves as an academic bridge within our program at SPSU. Spring semester seeks to explore the paradigm of design ideas through systems research and construction simulation while focusing on a vertically organized building in a dense urban context. The studio assignment integrates the content of technical support courses within our curriculum. It emphasizes the exploration of environmental and sustainable design strategies and encourages the students to examine enclosure systems as generators of building form and aesthetic solutions.

The digital environment can provide an excellent tool for thinking about architectural conditions, both as object and subject. My third-year studio section explored the integration of building technology throughout the design process with “Building Information Modeling” (BIM). This studio was not directed towards digital computation as a generator of form nor as a pure representational and documentation tool, but instead, we experimented with virtual modeling during the design process to understand and test their design solutions.

My interests lie in the integration of digital technologies into the design process. My goal is to establish methods and approaches that successfully integrate BIM into architectural education without impeding a student’s ability to develop critical thinking and design solutions.

To understand the context within architecture that we operate under today, this paper investigates: the call for integrated practice from the American Institute of Architects (AIA), Gehry Partners, a



Caption: Mandy Palasik - EPA Midrise

practice known for its digital technologies application, and an academic perspective from within the program at SPSU.

This paper provides a narrative of the integrated third-year studio experience and describes the framework, methodology, process and observations involved. It defines the method for incorporating design models, both physical and virtual and provides a description of the studio process for integrating BIM and how construction simulation models help to develop the design solutions.

Integrated Practice and the AIA

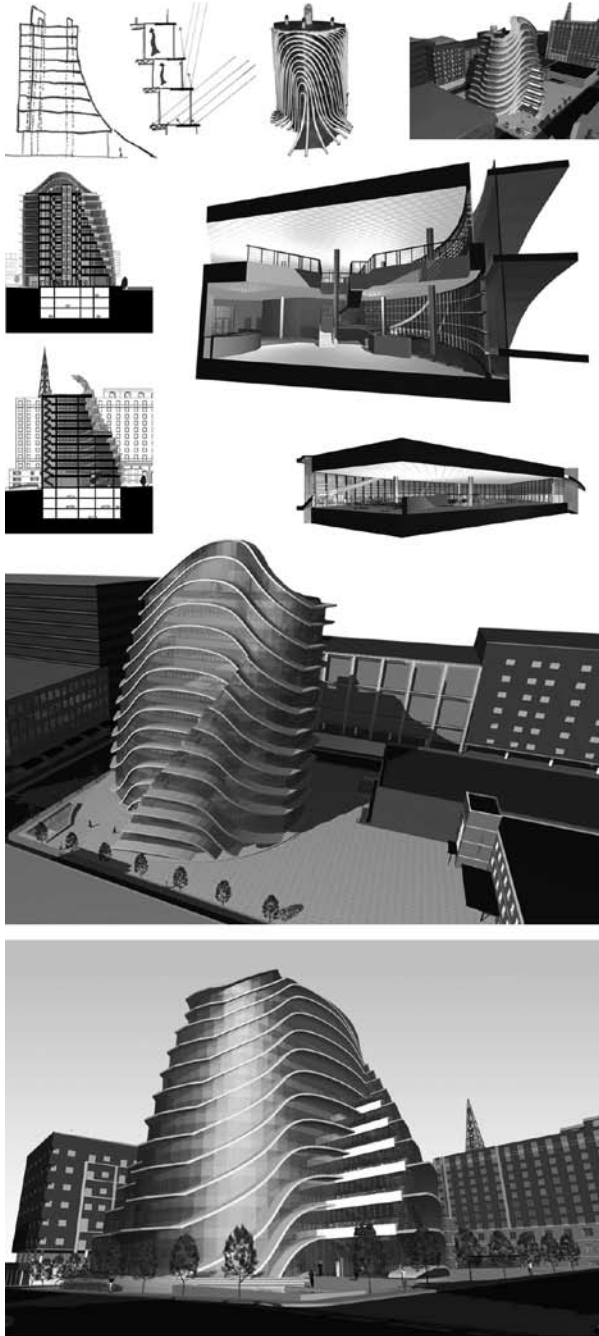
A call for integrated practice from the AIA has lead many to speculate about the future direction of architectural education. As such, there is an immediate need for architectural academia to prepare future practitioners who will catalyze change and capitalize on the emerging opportunities and thus, have the potential to transform both architectural design and construction.

In her report entitled “Suggestions for an Integrative Education”, Renée Cheng, AIA, of the University of Minnesota, asserts that to fulfill the promise of an integrated practice, practitioners must shift the way they think and work. “The Integrated Practice model is by far more the most demanding – requiring the integration of construction, practice and formal knowledge early and at a high level.”¹ Theoretically, BIM makes it possible to meld the sketchy design stages with production oriented building documentation, therefore, uniting schematic design drawings and construction documentation.

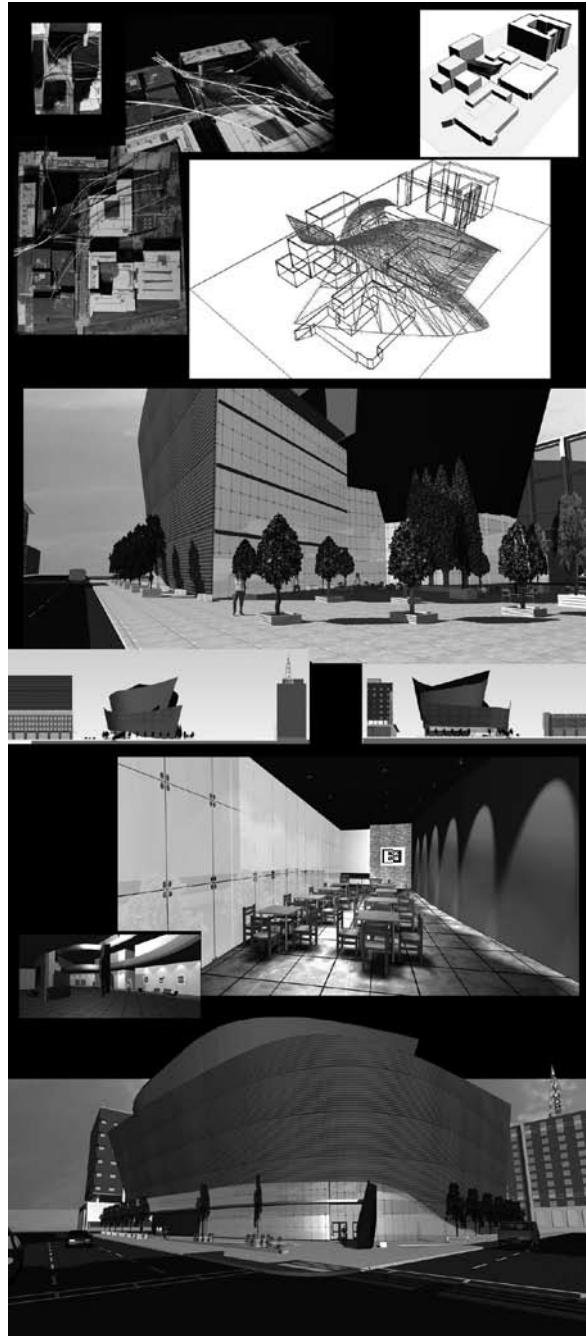
Many view BIM as the ideal mechanism for rethinking architectural education, though Cheng is quick to question the role of this tool within academia and considers its appropriate place in the curriculum. When addressing BIM in the curriculum, she contends that we must understand the difference between “problem solving” and “design thinking”. Problem solving seeks to find a correct or optimal answer while design thinking investigates the questions rather than seeking answers. The continuous query of design thinking requires the designer to pursue multiple and lateral options simultaneously. Many educators and skeptics worry that a heavy emphasis required on “how to” guarantees a loss of the critical “why”.

There is a fear that BIM's methodology, inherently answer-driven, will accelerate the demise of teaching design thinking. “The careless introduction of BIM with all of its prerequisite skills to a curriculum could overwhelm the subtleties inherent in nurturing design thinking – displacing it from its central role in the architectural curriculum.”² There is a danger that one can be easily overwhelmed by data with BIM thus reducing architectural design to a simple matter of problem solving. “Teaching students to distinguish between assumptions and speculation will reveal the true strengths and weakness of BIM as a tool for envisioning and testing design ideas.”³

Cheng warns that within the curriculum, the focus should not be on the facts and skills, which



Caption: Matthew Palmer - EPA Midrise



Caption: Chris Dorsey - EPA Midrise

are quickly outdated, but on the underlying logic of BIM's integrative practices. BIM's malleability allows operators to work in an environment that can support an iterative, open-ended process. Courses and exercises must be developed to encourage the practice of asking questions rather than seeking answers. Presented in this manner, students will learn ways of seeing and thinking that they can sustain throughout their careers.

Digital Integration Within Practice

Gehry Partners, are as renowned for their integrated technology techniques as they are for their dynamic architecture. Understanding their method is an analogous case study for the integration of technology in professional practice and their "real-world" experiences can provide guidance for an effective academic strategy.

Gehry Partners is a full service firm producing projects around the world. Founded in 1962 and located in Los Angeles California, the firm has a staff of approximately 140 people. Physical models and computational processes play a large part in their design and documentation process. The firm has been described to have the dynamism and vibrancy of an architectural school studio with physical models everywhere.

Physical models produced within the office are used extensively in the schematic design and design development phase. Design components are modeled in detail to explore alternatives. Full-size mock-ups are often used to test materials, construction techniques and performance. Over the course of the design process, the firm transitions from the physical to the computer with the 3D modeling beginning in conjunction with physical mass modeling. Often physical models are digitized to generate the curves of the building forms.

Formal and functional aspects are explored and developed using a variety of computer software programs from sophisticated Excel spreadsheets to NURBS based modeling using Rhino. Final refinement occurs in the software program CATIA, originally developed for the aerospace industry. The computer model yields the geometric data sent to fabricators and contractors used for the construction of the building. Traditional 2D construction drawings are still utilized for documentation of standard parts of a project using AutoCAD.

Over the course of their practice, Gehry Partners has developed a design process that allows them to create the architecture for which they are known. Though they recognize the promise and potential, they have not adopted the traditional software packages labeled as BIM products (Autodesk Revit, ArchiCAD, or Bentley Architecture). They are less interested in the productivity gains cited with BIM and more interested in utilizing technological processes from design to fabrication. This has led them to develop their own design software. Their process remains a mix of high-tech and low-tech in which technology is critical but not the determining factor. ⁴

An Academic Perspective

An interview with Associate Professor Richard Cole reveals some interesting perspectives on the relationship between architectural education and practice. Cole teaches Senior Design Studio and the Professional Practice sequence within the Architecture Department of SPSU. "Design education is a time to develop critical thinking skills that, hopefully, will have applicability to the 'real world' but design education primarily should develop critical thinking capacities that can be applied to challenging paradigms in (or out) of architectural practice."⁵ Cole expressed that he was probably in the minority, but feels strongly that architectural academia has to allow the freedom of expression and exploration without the constraints often found in professional practice.

For Cole, digital technology is a mixed blessing for both the profession and academia. He fears that the skills for digital imaging have led to a marginalization of hand-drawing and physical modeling within the academic community and thus the professional practice. He attributes recent digitally generated trends in the profession, especially in the Atlanta area have created "hermetically sealed" design solutions concentrated on the object and in turn disregarding the quality of spaces between these objects.

Academia must be careful to prepare "thinkers" accepting that the practice can be the best teachers of technology. "I think architectural educators have to work diligently to maintain a balance of the "wow" factor of digital technology with critical thinking demonstrations."⁶ To Cole, the most fundamental skill a student can learn is the ability to organize complex information and formulate a plan of action. He often remarks that "it is critical for students to design their method of design before they design."⁷

However, within his own studios, Cole has embraced digital technology for its opportunities to experience space, yet he sensitizes students to the rewards of exploring a problem by the more traditional methods of hand-drawing, quickly constructed physical models, diagrams, and the like. Understanding the rationalization of mastering technology as fundamental to the preparation for practice, Cole hopes that architectural programs do not miss the overall point of architectural education.

Context Within the Program at SPSU

To better understand the decisions and strategies stated in this paper's experience, observations and conclusions, it is necessary to define the framework from which this studio section operated. SPSU offers a five-year professional degree that is comprised of two years in Design Foundation followed by three years within the Professional Program. This professional degree allows one to complete their internship and take the licensing exam, which often deters many of our students from even considering graduate school. The main focus of most of our students is on completing the program, finding a job and becoming a registered architect within the state.

As previously discussed, the third-year studio serves as an academic bridge within the program at SPSU. The advancement to third-year, the first year of the professional program, requires that the student complete all beginning design core classes, have a minimum GPA and submit a portfolio of their work that is reviewed and accepted by the faculty.

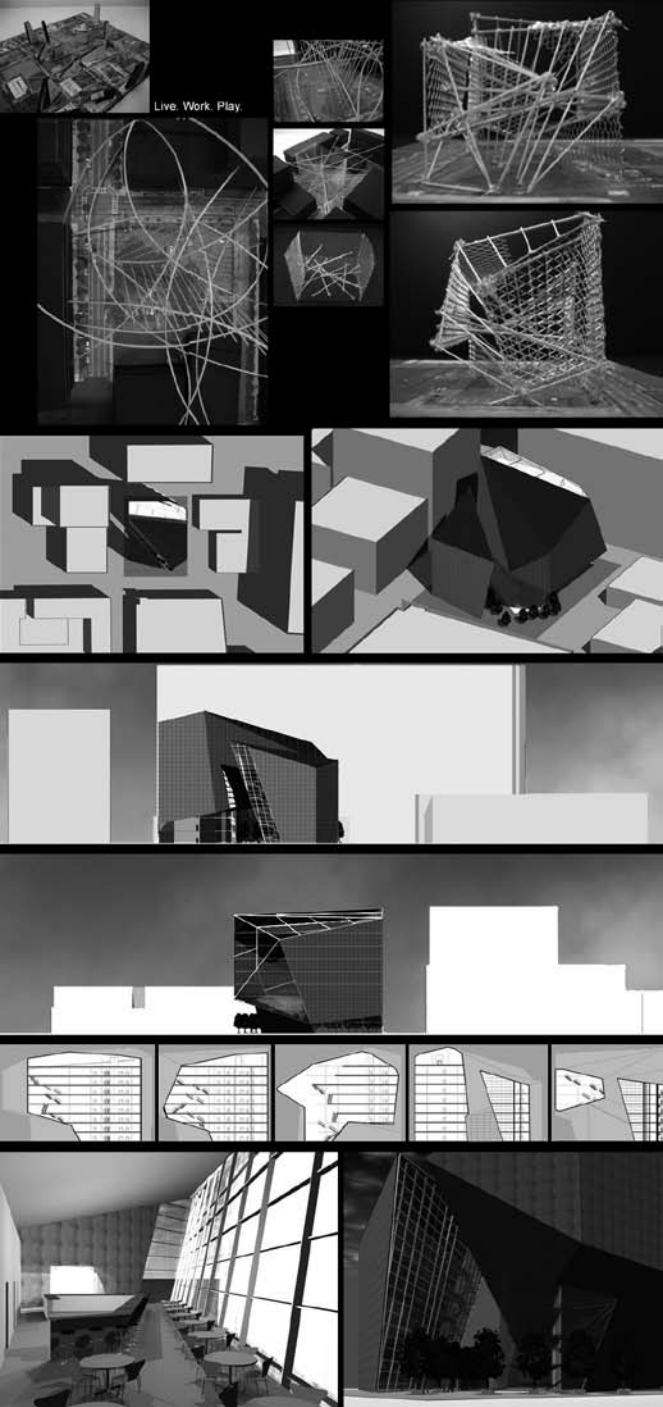
The second semester of third-year studio seeks to impart the forming of a holistic design process through exploring the construct of design ideas with systems research and construction simulation. This studio examines the relationship between architecture, technology and society. The project investigates the fundamental ideas and interrelationships between building systems, form, space and program within architecture. It focuses on a vertically organized building in a dense urban context, the studio assignment integrates the content of technical support courses that provides the technical foundation for examining building design. The primary pedagogical focus of this third-year studio is the exploration of environmental and sustainable design strategies as well as enclosure systems as generators of building form and aesthetic solutions.

My third-year studio section explored the integration of building technology throughout the design process with “Building Information Modeling” (BIM). This studio section was not directed towards digital computation as a generator of form nor as a pure representational and documentation tool, but instead, the studio experimented with virtual modeling during the design process to understand and test their design solutions.

Review of Building Information Modeling

A closer look at Building Information Modeling reveals that BIM is much more than simply a new software package nor is it just another type of CAD. It is a process more than a product as it embodies a culture and attitude that requires a shift in thinking. What separates BIM from CAD? Conceptually, it is objects verses lines and is often referred to as “Virtual Building” or “Building Simulation”, since it uses computer technology and virtual models to produce design solutions. These virtual computer models supply a multitude of information as they are rich in data. BIM is a platform for communication comprised of four main components: a central repository of information, a virtual description, a database, and objects with parametric variables.⁸

As a central repository of information, the BIM model is stored as a single computer file. The complete building model and all of its representations are included in this single file. This virtual description contains many layers of both graphical and non-graphical information. Drawing representations include floor plan, section and elevation views. Plan representations are scale sensitive and adjust graphic conventions such as fills, backgrounds, etc. Model representations are created with 3D objects that illustrate materiality with surface color and texture. From this virtual model one is able to produce both orthographic projection drawings and experiential perspectives.



Caption: Courtney Morrison - EPA Midrise

The virtual description represents a database of building information. The virtual model contains a list of objects with attached data that can be easily quantified. The objects in the virtual model are comprised of model elements and drawing elements, each of which is interconnected. Changes to the virtual model affect all related representations as any modifications made to the drawings change the model and any changes in the model are updated on the drawings. Element creation and manipulation can occur in either drawing or model representation. The object data can include material descriptions, quantities and volumes. Unique attributes can be attached to individual objects that can include descriptions for product details, construction details, safety details and cost. A simple query of this information can lead to real-time calculations for items such as quantity take-offs, inventories and schedules.

Another advantage of the central database is that the virtual model allows for external collaboration. Different disciplines can work on individual components simultaneously. Further processing of BIM data allows for a wide range of analytical activities such as collision detection and code compliance. The information in the model can also be used for analysis such as structural calculations and energy efficiency analysis.

Parametric objects are a core component within the central database. Within a BIM model, objects are represented with real architectural elements via the use of libraries comprised of architectural elements and content. The parametric objects within these libraries are composed of elements that use parameters to control information. These variables can range in information from the very simple to the extremely complex and can include design selections to object geometry.

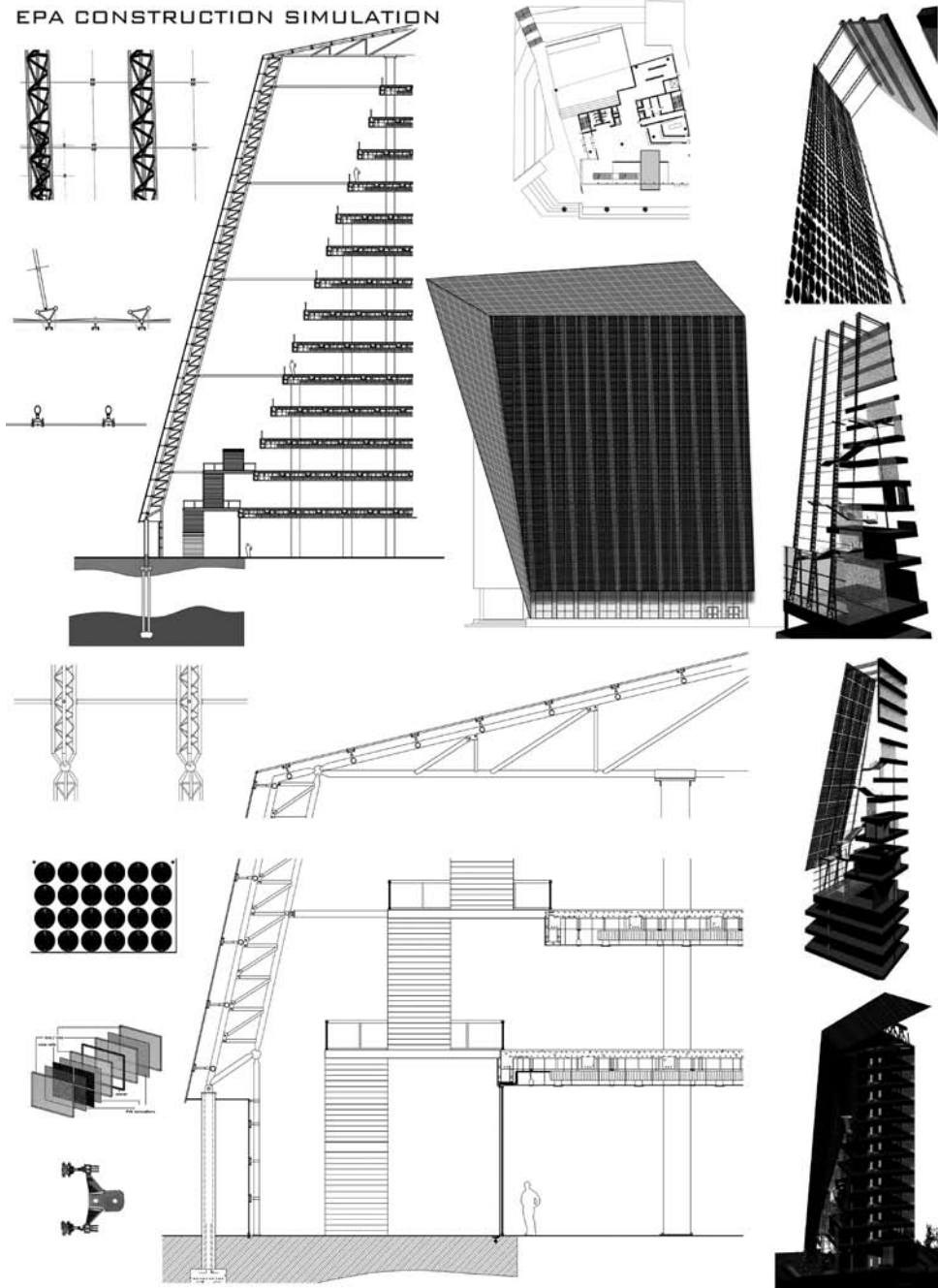
Even though BIM is not a product there are several software packages that contain the basic components of BIM. The three evaluated for this study were Revit by AutoDesk, ArchiCAD by Graphisoft and Bentley Architecture. Sketchup is sometimes added to this list and does produce virtual models but currently it does not integrate documentation, so it was not considered. ArchiCAD provides a solid foundation for BIM with relative ease of use. ArchiCAD was used for this study due to the following factors:

- the cost - our local Graphisoft dealer is a graduate of our program and worked with us to provide the studio with access to an educational version of the software complete with technical support
- familiarity with the software
- and the software learning curve

Though ArchiCAD was the main program used, the students also employed other software packages like Adobe Photoshop and FormZ by Autodesk.

ArchiCAD is extremely user-friendly, especially for the beginning design student, it must be stressed that all software packages have their strengths and weaknesses. The objective for my studio was to learn and understand the value of logic behind this process. It is important that the students understand the value and appropriateness of each medium whether using analog tools or digital software.

EPA CONSTRUCTION SIMULATION



Caption: Many Palasik - EPA Midrise

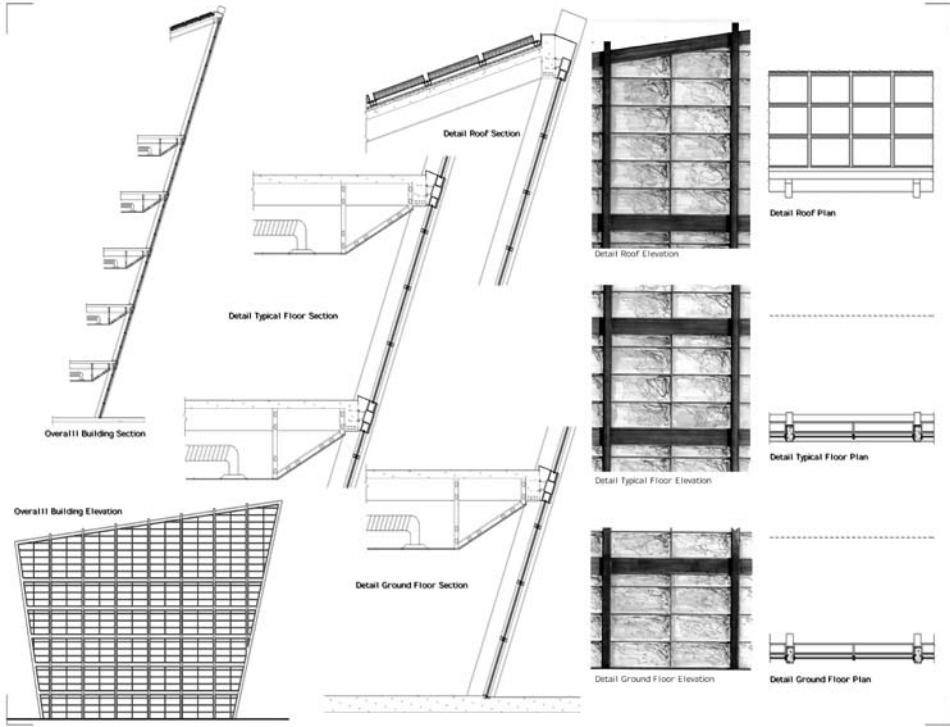
Studio Organization

My Spring third-year studio section was comprised of twelve students and was organized as an “active learning studio” – part lab, part classroom, more akin to a small design firm. All the students in this section had a basic set of digital skills. Prior to this spring section, all had completed an introductory course in basic digital concepts of pixel editing with Photoshop and 3D model creation with Form•Z. While the experience level of the students varied, several had experience with the BIM software and used (ArchiCAD) in the fall semester of this studio. However, for the most part, it was their first exposure to integrating digital technologies beyond its production and visualization capabilities (Other studio sections within the program also encourage the use of the computer, though it tended to be used as a drafting aid or representational tool as opposed to a decision-enhancing method.). Our process was developed to integrate digital technologies and traditional techniques to advance our design process.

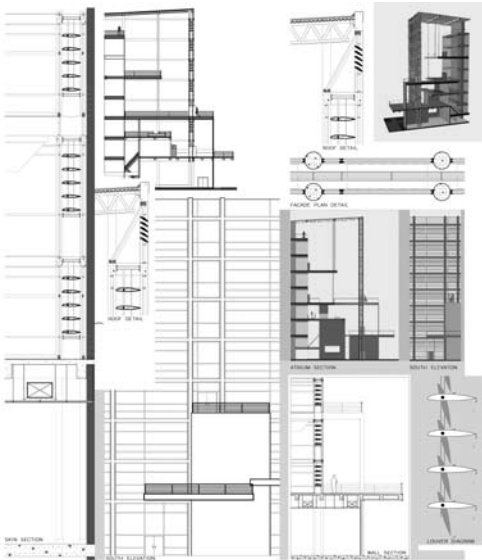
Obtaining digital skills required for incorporating BIM was a major concern even with students who had some basic knowledge of the software. How would the students gain proficiency with the BIM software? Could they reach a level of competency that did not consume all of their time? Discussions of our methodology for integrating analog and digital started from day one. Short daily group discussions typically at the beginning of the studio helped as we addressed implementing the digital tool.

Many early discussions centered on the relationship between the software programmer and the designer/architect. It is imperative that the students understand that often the programmer has no idea or understanding of the architectural design process. Software tools are developed in response to constructing an object or producing a solution and must sometimes be thought of and used in an unconventional manner. For instance, a designer could as easily use a tool that might be labeled a wall by a programmer as a mullion. Later discussions highlighted specific skills or techniques as the knowledge level advanced. In addition to the discussions, a series of classroom lectures on digital concepts were presented. Initially lectures contained information on a “need to know basis” and then as the students advanced, they were centered on specific skills.

Though we were not collaborating with external sources we looked to explore the collaborative components of BIM by sharing information developed in the studio. We intended to use a central server for this component to store files, however, technical difficulty did not allow this to happen. As a result, each student worked on their own laptop (required after first year of SPSU's program) with all files stored locally. The studio group quickly learned to work together to collect and distribute information on flash hard drives instead of the central server. One unforeseen benefit of this process was the face-to-face interaction that allowed students to learn from each other and helped create an excellent support system for technical issues.



Caption: Courtney Morrison- EPA Midrise



Caption: Johnathan Hambrick - EPA Midrise

Based around a fictitious real-world scenario, the studio project proposed an 80,000 sq ft mid-rise office building for the new regional headquarters of Environmental Protection Agency aimed at creating the example of environmental and sustainable design in the region and in the country. Located in a dense urban environment in the Midtown area of Atlanta, Georgia. The program included: a small café; 10,000 sq ft of retail space on the ground level; a public plaza with an outdoor dining space for the café to act as the connector between the urban space and the building; and a lobby that acted as the nucleus of daily social activities.

The project development was organized into three phases; research, design development and construction simulation. Site analysis and research were approached in a typical fashion with library and site visits both individually and as a group. Individually each student was responsible for researching precedents of sustainability strategies in building design. The studio was split into four groups for site analysis. Each group was responsible for developing an analysis of the site in relation to the city and urban context. They defined the relationship of site amenities, circulation, and services producing photo and sketch documentation of the spatial character and boundaries of the site. The studio constructed a physical chipboard site model. At this point most of the digital integration was contained to scanning hand drawings and Photoshop analysis even though we had begun to talk about our process of BIM integration. This phase concluded with board presentations of group work and digital slide shows of research presented by each student.

As we moved into the design development phase of the project I began to apply some of Gehry Partners' methodology of the integration of digital technologies. In the early phases of Gehry's process and prior to any digital exploration, physical models remain indispensable as an investigative tool. Validated by a previous section of my studio, that incorporated BIM integration, this method allowed students to develop ideas that were not constrained by their digital competency. They produced individual physical models based on their analysis and interpretation of the site. Each student was free to express their ideas before incorporating virtual models.

Concurrently, with site investigations, the studio began producing a digital site model of the context. This proved to be an effective exercise for learning the BIM software. Each student constructed an individual part of the site while complicated buildings and elements were assigned to the students with more advanced digital skills. As proficiency increased, the students began translating their physical study model ideas into the BIM software for further development. At this point the interconnected aspects of virtual model really became beneficial. Beyond form and compositional studies the virtual models provided the students a flexible vehicle to test ideas of materials and systems. Students were able to experiment with design solutions within the virtual model quickly producing plans, sections and elevations for study. Spatial relationships were explored in axonometric and perspective. Because of the linked system BIM utilizes, any change made whether in plan of model, update and spread throughout all drawings and model. For instance, patterns and textures were created and applied as materials within the virtual model,

which allowed quick studies of building skins prior to detailed development. This interactive process provides almost instantaneous feedback to design decisions. The virtual model allowed the student to be immersed within their design ideas throughout the design development phase leading to a better understanding of their design decisions.

For the construction simulation phase of the project, the BIM models were used to create the schematic details and outlines. In some instances the students were able to explore the construction details with the virtual models to illustrate an understanding of the construction methods and speculate about construction sequencing. As revealed in Gehry Partners process, two-dimensional drawings became the primary means of developing detail drawings. Portions of the exterior building skin typically including one bay of the structural system were isolated for further development. The section was developed from the ground to the roof. The students augmented 3D model information with conventional flat 2D drawings. Formal presentations comprised of digital animations, board presentation and construction models concluded the semester and investigation.

Observations and Conclusions

Overall the students responded well to designing in the virtual world. They spent a great deal of time with their explorations of spatial composition and building materials and seemed to enjoy increasing their computer skills. The BIM integration allowed the students to document, test and experience their design decisions in real time. Incorporating physical models, during the initial design phases, allowed the students to persevere no matter what their computer competency. With this approach, the students seemed freed of the constraints they often encounter due to the onset of computer skill building. Only after the project direction or initial ideas were established, were the students required to integrate into the BIM components.

During the schematic design phase, where things tend to be swift, physical models and sketching still remained excellent tools. From the start of the project conceptual physical models were incorporated into design decisions. These physical models proved to be invaluable for developing ideas and exploring concepts before moving into the virtual computer world. They helped the students express ideas and break away from the precision of the computer. Even though the studio relied heavily on the digital technologies, students commented that they sketched more often than they expected and during the design process found it faster to illustrate simple ideas by hand rather than in the computer. Once their ideas were generated, they then moved on to the digital environment to test and further develop those ideas.

It is hard to quantify, but the ease at which the students were able to experiment with design solutions seemed to bring about a better understanding of the design decisions they were making. Being able to immerse themselves within their designs also appeared to have helped heightened their sensitivity of spatial relationships. The rapid feedback features of BIM quickly informed students of their design decisions. Students were able to better understand the exper-

rience and sequence of spaces because the virtual model allowed them to “walk-through” their projects. The variables within BIM allowed them to investigate materials and issues associated with construction as they designed. This process allowed them to effectively test their design ideas and communicate them efficiently while the ease in which drawings were produced allowed students additional time to explore their design decisions.

In the studio, productivity increased with the students producing high quality drawings. Since drawings were linked to the virtual models, they stayed current in simulating 2D and 3D in “real-time”. The software allowed students to produce very graphically appealing drawings that in some cases compensated for their weaker graphic skills. Several studio sessions were devoted to the pros and cons of representation techniques and good drawing conventions such as line weights and line styles. It still had to be impressed upon the studio that presentations are a tool for communication. The students realized a large disconnect between their computer screen and the output of printers and plotters. Students found that they had to adapt the software to produce their presentations.

For reviews traditional board presentations augmented with digital presentations were used. As the studio skills progressed, the students wanted more lessons on advanced techniques such as representation and animation. Individual studio sessions were used for student skill enhancement and only towards the end of the semester were animation sequences explored. A more regimented scheme for producing process drawings and representations needs to be developed further.

Without the traditional “trash paper” record, it was difficult to follow the student’s design process. It should be noted that there seems to be a loss of plan decisions or even the value of understanding plan relationships. Orthographic projections were treated more as just part of the project requirements and not viewed as tools for investigation. It was not uncommon for desk critics to include an instant “walk-through” of their project. It was easy for an observer to become lost when the student panned and zoomed around in the virtual model while explaining when each design decision. At times, the studio resembled a large video game convention rather than an architectural workshop.

After several semesters integrating this approach, I have learned to accept some level of frustration, not with the students or their work but, instead with the technology. Within each studio technical problems persisted and many times were due to circumstances beyond the student’s control. Some examples experienced were:

- computer hard drives crash causing students to lose work
- bottlenecks at the plotter not anticipated and not solved
- laptop computers usually needing more power and RAM to handle the sophisticated software
- and many students who do not have the background or funds to address such issues

Students also learned the software at different rates so it was important that the studio's framework allowed for flexibility. The organization of the studio must be able to adapt to the students approach and be willing to accept that individuals accomplish things differently when presented with so many variables. Simulating a small office, the studio's organization was key to creating an environment that provided design synergy and technical support for many of the issues the students faced.

BIM should not be thought of as just another software, but rather as a powerful tool and as a receptor for information that embraces a multiplicity of advantages. It is important to emphasize when instructing students that design decisions still reside within the designer and that the validity of design comes through a process of investigation, research and analysis, which does not change even though the ideas reside in the computer.

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Caption: Mary Adams - EPA Midrise

