Innovation and BIM in Architectural Education: Teaching Advanced Digital Technologies to Beginner Designers

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Introduction

Building Information Modeling (BIM) is currently creating a paradigm shift in architectural profession, changing the design methods that are used in contemporary architectural practice, as well as the ways in which architectural documentation is prepared. BIM is equivalent to the virtual representation of buildings, rich in information of relational nature. It is an intelligent, model-based process for designing buildings, since building elements, systems, schedules and specifications are stored within a single database, and can be shared among stakeholders [1]. Traditional architectural design documentation (floor-plans, sections, elevations, details) are only a single view of an integrated model, and this aspect is revolutionizing architectural practice.

For experienced architectural designers, it is a great method for improving the preparation of architectural documents, as well as project delivery. However, the challenge lies in architectural education, since beginner designers are learning the basics of architectural design process, and often do not have the necessary technical knowledge about building elements, systems and construction methods to easily use BIM for design exploration and representation. Therefore, courses that integrate digital technologies with design exploration and building technology topics become a crucial component in addressing this challenge in architectural education.

This paper discusses development of two laboratory courses that integrate advanced digital technologies and BIM with design exploration and visualization. The intention is to strengthen students’ ability to represent their ideas visually using different digital media, and also to teach the basics of building construction and technologies so that the students can begin to represent architectural design using BIM tools. The paper discusses a sequence of two courses that are interrelated and consecutive, as well as the structure and organization of courses, pedagogical approach, project assignments and teaching methods. The courses are based on the principle that certain digital tools are suitable for design exploration and form-making, while BIM is suitable for creation of architectural documentation. This allows students to simultaneously develop skills in digital design and representation, and successfully use complex BIM tools to express architectural design. The paper concludes with recommendations how to effectively integrate advanced computational tools and BIM with architectural education.

BIM and Paradigm Shift in Architectural Design

The concept of BIM is not new. It first emerged four decades ago with the conception of a "Building Product Model" in a research-oriented context [2], [3]. However, its adoption within the building industry gained momentum slowly, mostly due to the lack of robust software applications and computing power necessary for representing and documenting complex
architectural design. Only in early 2000’s, advancements in computer technologies and development of robust software programs allowed BIM to be widely adopted. Within the last decade, BIM has become a paradigm shift in architectural design and practice, impacting the way that buildings are designed and changing the way that architectural documents are prepared.

In architectural design, BIM is equivalent to the virtual representation of buildings rich in information of relational nature. It provides a common database of information about a building, including geometry and other attributes. BIM’s evolution to be an integral part of our design activities today has given the acronym a dual meaning that is often used interchangeably as both a noun: Building Information Model(s), the deliverable or deliverable-generator, as well as a verb: Building Information Modeling, a process.

The goal of BIM is to provide a common structure for information sharing that can be used by all agents in the design process and construction, as well as for the facility management after a building is constructed and occupied. BIM acts as an integrated, comprehensive building model which stores information contained in traditional building documents, such as drawings, specifications, and construction details, in a centralized or distributed database. Information that resembles traditional documentation (such as floor plans, sections, elevations, axonometric views, perspectives, schedules, and specifications) are specific views of common information. It virtually simulates design and construction, and provides groundwork for collaborative design, since all the relevant information, such as spatial organization, building components, building systems, materials and schedules are incorporated into building descriptions. Visualization of design in three-dimensional space is one of the advantages of BIM; however, it is not the only capability and the integrative nature of contents must be emphasized. Beyond visualization, BIMs are used to review constructability issues where the construction team is able to analyze design decisions while in the early stages of the process and provide responses to the design team. Information about the site, such as existing conditions, infrastructure systems and utilities can be included in BIM and analyzed. Construction schedule can be integrated with the building model to visualize the sequencing of construction activities, which is also referred as “4D” modeling, since the time dimension is included. Cost estimation is another dimension, commonly referred as “5D”, since materials and components are analyzed and directly linked to cost databases to produce financial information and assist in analyzing design decisions as they relate to the economic factors. Construction documentation is automatically generated and updated when the changes are made to the model.

Given the variance in possibilities and in an effort to define a common language for what and how much information is to be included in each model (the “I” in BIM), industry guidelines are available that define the level of completeness [4]. It defines this concept as Level of Development and consists of five clearly distinguished tiers:

- LOD 100: Overall building massing indicative of area, height, volume, location and orientation may be modeled in three dimensions or represented by other data.
- LOD 200: Model Elements are modeled as generalized systems or assemblies with approximate quantities, size, shape, location and orientation.
- LOD 300: Model Elements are modeled as specific assemblies accurate in terms of quantity, size, shape, location and orientation. Non-geometric information may also be included.
- LOD 400: Model Elements are modeled as specific assemblies that are accurate...
in terms of size, shape, location, quantity and orientation with complete fabrication, assembly and detailing information. Non-geometric information may also be included.

- LOD 500: Model Elements are modeled as constructed assemblies actual and accurate in terms of size, shape, location, quantity and orientation. Non-geometric information may also be included.

It is very important, however, to find the correct balance for conveying the design intent and providing the correct level of information. Typically, architectural BIM should never be modeled above LOD 300 level. Experienced architectural designers that have an extensive knowledge about building elements, systems, and construction methods certainly benefit from utilizing BIM for design and development of architectural documentation. In contrast to two-dimensional CAD, BIM allows for three-dimensional design, coordination and sharing of building information. However challenge lies in architectural education, and especially for beginning designers—the complex BIM applications may serve as a transformative technology and methodology for architectural curriculum, but need to be introduced deliberately to develop students' ability to analyze, visualize and organize space and building elements.

Methods for Integrating BIM in Architectural Education

A recent study, conducted to investigate adoption of BIM within architectural, engineering and construction curricula, concluded that 81 percent of architecture programs offer BIM courses [5]. Results also indicated that 28 percent of programs offer 1 to 2 courses, while 67 percent offer 3 to 4 courses. However, the study found that BIM courses are offered mostly at the senior and masters levels in architecture programs. BIM technology is currently being taught in only 10 percent of undergraduate programs, mainly in three ways as part of existing digital technology courses, as part of other construction courses or as a new stand-alone course. This raises a significant question—when should BIM be introduced into the curriculum, and what are the appropriate methods? In many architectural programs, BIM is seen as a threat to creativity, which may be inaccurate. Discussion around BIM's applicability to the early stages of design is an ongoing one. However, some disagree and argue that when BIM is defined as a process, it infuses performative information and simulative environmental conditions into design, and allows unprecedented improvements to the design process [6]. Perhaps the biggest challenge for design instructors is that BIM demands new teaching methods, as well as early introduction to students in order to be successfully adopted.

In order to address these two issues, BIM was integrated with two consecutive laboratory courses focusing on digital technologies and architectural representation at the University of Massachusetts Amherst. These courses are required for beginner designers (sophomore level architecture students). The objectives of the courses are to strengthen students' ability to represent and present their ideas visually, and to introduce different design software programs. Figure 1 shows the basic pedagogical framework, structure and organization of courses, design software programs and assignments that are covered. The courses are based on the principle that certain digital tools are suitable for design exploration and form-making, while BIM is suitable for creation of architectural documentation.

During the first semester, students begin learning about digital technologies associated with visual representation and graphic design. Early weeks of the course focus on images and representation; how we perceive an image. Students learn to manipulate and compose images. Then, the complexity of the covered
material slightly increases, and the course engages graphic design skills. The second part of the semester focuses on 3D modeling software and BIM applications, specifically Rhino and Autodesk Revit. Students learn to express their ideas and design in three dimensions. During the first semester, they use a built case study building to complete different assignments.

It is important to note that during the first semester students are exposed to multiple software tools, but they learn the basics of interoperability between different software programs. For example, they learn the basic 3D modeling techniques by first modeling simple geometries in Rhino, and then apply their skills to model a case study home. Then they learn the rendering procedures, application of materials, lighting effects, etc. They create different views of their Rhino model, and then use Adobe Photoshop to create photomontages, placing an image of a rendered model on a site, adding people and objects, etc. Then they learn how to transfer 3D geometry modeled in Rhino to Revit, to create simple masses and consequently building elements in Revit (equivalent to a BIM LOD 100). Students learn these programs through instructor-led tutorials and working labs. Students also learn from each other, through desk critiques, and group discussions throughout the semester. Since the course is fast paced, an online repository is used to share the drafts and final assignments, shown in Figure 2. This allows the instructor to keep tracks and review drafts and provide feedback to students, and also all students to visualize and comment on the work submitted by their peers.

During the second semester, students advance their digital skills. They begin the semester by advancing their modeling skills in Rhino. Students use their project from design studio (from the previous semester, which is the first architectural studio course for undergraduate students) to model three dimensional representations of their designs. The course then continues by reviewing graphic design skills, as well as relationships between the design and site. Students use Adobe Photoshop and Rhino to create representations of their buildings (interior and exterior perspectives). Using the rendered model from Rhino, they create photomontages of their building within the site in Adobe Photoshop, as well as interior perspectives. The students learn advanced rendering procedures and methods. Then, students begin to model their building in Revit, where they use building elements (walls, floors, roofs, windows, curtain walls) to create an LOD 200 BIM. Students then prepare design documentation (floorplans, sections, elevations, 3D perspectives), and learn the basics of annotations. This allows students to simultaneously develop skills in digital design and representation, and successfully use complex BIM tools to express architectural design.

The activities are structured and organized around one major theme and project, but allow continuous exploration and learning opportunities throughout the semester. As previously stated, students analyze and model a case study home during the first semester, and then advance onto their own design during the second semester (Figures 3 and 4). In both cases, final projects are used to showcase all activities, and create architectural presentations.
Fig. 1. Framework for integrating different digital technologies in architectural education, indicating the activities, tools and example projects.
Fig. 2. Online depository used to share drafts of assignments, review students' progress and provide comments.

Fig. 3. Final project example (end of the first semester).
INNOVATION AND BIM IN ARCHITECTURAL EDUCATION

This pedagogical method allows students to learn the complex digital tools and design processes, and how to successfully integrate these tools into their working habits. Moreover, they learn that certain digital tools are suitable for certain design actions, and that the exchange and flow between these different tools is necessary and appropriate. Therefore, this allows very early introduction and adoption of BIM in architectural education, but does not constitute a threat for developing students’ creativity. Rather, it fosters students’ exploration, adoption of digital technologies, and improvement of their representational skills.

During the course evaluations, 91 percent of students indicated that they learned much more in these two courses than other courses, and 86 percent of students indicated that the teaching methods were effective. Specific comments received from students indicated that the major benefits were:

- Independent learning opportunities
- Being exposed to different software programs, and learning how to interchange between different programs
- Having enough time to work on different activities that build up to a final project
- Having the ability to receive instructor’s feedback and comments throughout the semester, and improve the work
- Using class time for projects and hands-on experience in a laboratory setting, since they do not feel the pressure of architectural design studio
- Being able to apply the skills and knowledge obtained in these courses to design studio assignments

Therefore, this particular model for introducing BIM into architectural curriculum is a promising method for integrating advanced digital technologies with architectural education. The apparent benefit is that students are introduced to BIM as early as possible, and they become comfortable with multiple tools and working methods.

Conclusion

Integration of BIM into architectural education is necessary, since BIM is currently creating a paradigm shift in architectural profession. Preparing students through introduction of courses that teach advanced digital technologies is an essential action for architectural programs. However, current research indicates that majority of programs offer BIM courses at graduate level, and only a small portion of programs are offering courses at undergraduate level.

This paper discusses structure and organization of two laboratory courses for beginner designers (undergraduate architecture students at sophomore level) that integrate BIM into curriculum, along with other digital technologies. The intent of the courses is to strengthen students’ ability to represent their ideas visually using
INNOVATION AND BIM IN ARCHITECTURAL EDUCATION

different digital media, and also to teach the basics of building construction and technologies so that the students can begin to represent architectural design using BIM tools. The courses are based on the principle that certain digital tools are suitable for design exploration and form-making, while BIM is suitable for creation of architectural documentation. This allows students to simultaneously develop skills in digital design and representation, and successfully use complex BIM tools.

These following recommendations are offered as suggestions for effectively integrating advanced computational tools and BIM with architectural education:

- Architectural programs that integrate innovative digital technologies and design processes into the curriculum are keeping the pace with advancements in architectural design and profession. Administrators and faculty members should make a conscious decision about adoption of these advanced digital technologies within the architectural education.

- Early introduction of digital technologies into architectural curriculum allows students to learn and become familiar with the functionalities of different software programs, as well as digital design process. These courses should be integrated into the core, required coursework.

- For beginner designers, it is beneficial to first teach the basics of the software programs, interoperability and functionality by introducing case studies (rather than students' design projects). This allows students to learn the software programs without added complexity of having to design architectural spaces. Also, it provides an opportunity to learn the basics of building elements and construction methods (how buildings are put together), and how to transfer and represent building elements digitally. Then, after mastering the functionalities of different software programs, students can apply acquired knowledge for their own designs. Integration with design studio classes (after mastering the basics and understanding software capabilities) is highly recommended, since this allows the students to advance their knowledge and skills.

- Teaching methods and pedagogical models for digital courses are different than traditional design studios, lectures or seminars. Active, hands-on, tutorial-based laboratory settings are the appropriate environments for teaching advanced computational design approaches.

- Lastly, adoption of advanced digital technologies and software tools should be encouraged and incentivized.

Notes


