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Building Information Modeling (BIM) and the Impact on Design Quality

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Abstract

The integrated studios in which architecture students are paired with engineering and construction manager students works on the assumption that the common denominator-BIM-is a tool of equal meaning and value to all. This is not the case: each discipline has its own values, procedures, and protocols that bend BIM to its own needs. When these differences are not recognized, design, which has traditionally been the province of architecture, gets short shrift. The BIM process offers the opportunity for cross-disciplinary contamination without sacrificing design emphasis. How to blend engineering student input with architecture student design input so each group learns equally from the other and high quality design outcomes are empowered rather than diminished will be discussed.

Introduction

The integration of Building Information Modeling (BIM) procedures and the consequent earlier and more collaborative interdisciplinary design workflow is changing the nature of architectural design idea generation. The pre-BIM workflow usually consisted of a patient and sometimes solitary search for meaningful architectural form, to an interactive multi-disciplinary group activity where mechanical, structural, electrical, lighting and construction engineers and landscape architects are involved in evaluating and proposing changes to early architectural design ideas and concepts.

The ability to recognize the differences between AECO cultures – and hence, architecture with its design thrust - isn't helped by the fact that efficiency and cost-effectiveness are the banner under which the different disciplines mutually latch onto BIM. While engineering and construction management might legitimately (but also might not, as will be discussed) have efficiency as their primary goal, architectural design does not; what distinguishes architecture from mere building and architects from developers and contractors is the concern for aesthetics and design quality. One could argue that efficiency (in particular in material and energy use as well as operations) should be a criterion of architectural design, but certainly not the only (or perhaps even the most important one). Without emotional and aesthetic impact a building is not architecture. Without consideration and achievement of a certain amount of efficiency or function, there is a real risk that a piece of architecture is a building with an unhappy client. Such unhappy clients may turn to design/build entities (usually lead by contractors or engineers) as a way to get what they perceive as better architectural results. It is our architectural position that the BIM workflow has the potential to positively impact the creation of meaningful architecture. However the nature of architectural idea generation is a delicate process, which does not always benefit from early and quantitatively rigorous engineering analysis. Of course early engineering input can greatly aid the creative development of the architectural design concept. Herein lies the core position of this paper. The BIM workflow shows great promise. Precisely when and how engineering analysis should be brought to bear on the architectural idea will be discussed.

Having said this, BIM challenges many of the tenants of traditional "good" design practice, and the manner in which BIM adjusts the process of design needs to be understood, agreed upon, and secured. The unchartered territory has to do with a number of things: BIM software's general awkwardness with non-orthogonal designs; its potential for collaboration (in the case espoused here, between architecture students and engineering student designers); its ability to conceive/insistence on constructability; the immediacy with which it integrates design decisions with 2-D and 3-D representational output; its access to and limitation of its library of elements.

The things in this list that limit ones design repertoire will, for some, be the reason to shun BIM and/or wait for Revit and other BIM software to become more adroit. But this strategy puts design in a passive position, waiting for change/perfection instead of participating in its technically and culturally unfolding context.

It is for this reason that, if one is concerned about the quality of design while working in a BIM environment, each discipline might explore the potential for BIM individually. This is not to say that at a point in the future, or at a more advanced stage of a designer's education, the inter-disciplinary collaborative potential of BIM should be denied; only that the delicacy of design, for now, needs attention as it moves into unchartered territory.

BIM Studio Examples

While this position of design delicacy affects design strategies in practice, it more directly implies pedagogical tactics in the academy. How does one introduce BIM in schools of architecture as well as schools/programs of building management, landscape architecture, engineering, and other AECO academies, in a manner that supports design? In this regard, it is fruitful to examine studios that variously explore the location of design as it adjusts to the protocols for BIM. Three

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such studios provide interesting and contrasting examples: the Penn Studio lead by Robert Holland, with Ute Poerschke, Madis Pihlak, John Messner and Kevin Parfitt. Columbia University's Building Intelligence Project (C-BIP) led by Scott Marble, David Benjamin, Laura Kurgan; and the University of Texas, Austin core studio led by Danelle Briscoe. These studios explore the location of design in differing ways, from the most inter-disciplinary example to the most architecture-centric, and offer interesting lessons regarding the status of design.

The penn state interdisciplinary collaborative BIM studio

In a prototype Interdisciplinary Collaborative BIM Studio at Penn State, some fifth year and graduate architecture and landscape architecture students worked in multi-disciplinary teams with fourth year architectural engineering students from four different engineering disciplines. (structural, mechanical systems, lighting electrical and construction engineering) This prototype BIM studio has occurred each spring term from 2009 through 2011 [1]. (This BIM studio is currently being integrated into the curricula of all six disciplines as a regularly scheduled alternative design studio). In this studio, three teams of students – each made up of an architect, a landscape architect, and the four types of engineers - were given the same real design project, the "reality" of the project (which is to say, one that was slated to be built) making apparent the multiplicity of players that have input into the making of a project[2]. Each BIM team developed their design project through group meetings outside of studio time and with desk critiques with each of the five faculty. Since for the first two years of the BIM studio only Robert Holland, the Professor in Charge, was given administrative/teaching credit for the class and the other four faculty taught pro bono, not all faculty attended each studio session for desk critiques. On a three week schedule there were formal design juries where all five faculty and invited administrators and real project design, engineering and client participants actively critiqued the student design and engineering proposals. Design quality and overall aesthetic impact, high functioning creative teams and software integration were major focus areas of the BIM studio. BIM workflows and the interoperability of the various software was a necessary concern. The architecture students used Revit, Sketchup, AutoCAD, Ecotect and 3D Studio, while the landscape architect student experimented with Vectorworks Designer, Revit and AutoCAD Land Desktop. The engineering students used Revit MEP, Navisworks(4D and Clash Detection), Timberline (cost estimating), GBS (energy modeling), RAM (structural), Project and Primavera. Learning workshops with Vasari (Beta software) were also conducted with Autodesk representatives throughout the term.

With such a complete engineering contingent and only one architect and one landscape architect on each BIM team there was a concern for productive and creative group dynamics. For each of the first two years Professor Sam Hunter of the Penn State Industrial/Organizational Psychology Department lead a team of Grad students to study the functioning of the creative design teams. The most interesting finding was that the teams that were able to manage a certain degree of conflict lead to the most innovative architectural, landscape architectural and engineering solutions. The BIM teams that strived to minimize conflict produced the least innovative designs. Dr. Hunter's team also found that stressing the equality of expertise of each of the student discipline areas lead to the development of the most creative learning environment. The importance of each of the student expertise areas to actively promote their area and then to be mature enough to compromise when necessary lead to the best solutions. Again, too much compromise lead to less than optimal design solutions. Finding the balance of just the right amount of conflict proved to be one of the determinants of a successful creative design solution.

Figure 1: Robert Holland Associate Professor, Architecture and Architectural Engineering leading BIM studio students in a discussion in the Stuckeman Center, Stuckeman School, Penn State.

In comparison to the traditional architectural studio, early engineering and landscape architecture advice to aid in the development of an architectural design concept sped the design process. Likewise, the collaboration between the designers – landscape and architecture – and the engineers was productive when two conditions were met: when the designers were strong and confident and when the engineers were flexible enough to fly with the non-linear creative process. But in the other cases, the designers floundered with the need to explain their sometimes poorly developed design concepts to four different types of engineers. Either the designers felt the need to absorb the logic of the engineers (which they cannot be blamed for doing poorly) or the engineers could use their quantitative abilities (so much more justifiable than the subject product in of design) to overwhelm the formation of a concept (Figure 1,2,3).

The Penn State Interdisciplinary Collaborative BIM Studio has won a NCARB Award (2011), an ACSA Award (2010) and a National AIA Award (2009).

Figure 2: Students of six different disciplines present their project to invited guests form practice and academia.

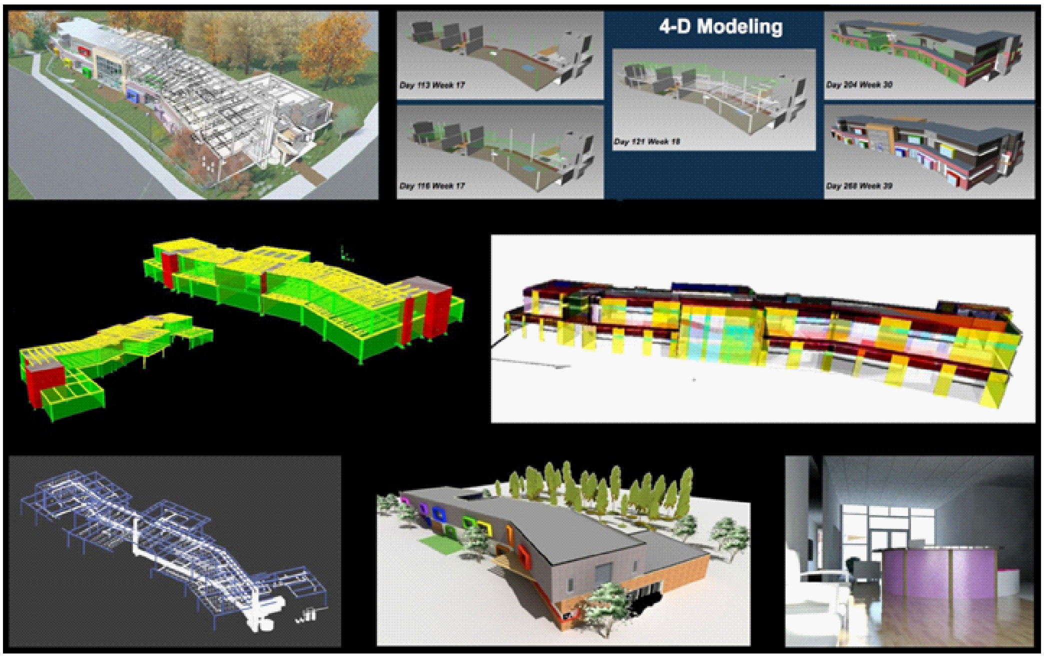

Figure 3: Digital models used in a project by different disciplines (from top left to bottom right): coordinated model, construction scheduling, structural analysis, energy analysis, coordination of structure and mechanical systems, architectural models.

Columbia university C-BIP

This fourth semester studio in a 3-year MArch program, as student's transition from the core sequence into advanced studios, combines three traditional studios (hence the three instructors) and employs outside consultants from environmental studies and engineering. In addition, the studio builds on the ideas, expertise, and suggestions coming from the "Think Tank" symposiums that include all the players of the AECO industry as they gather around BIM capabilities. As the brief says, "The single critic/single student/single project model of architectural education can no longer address the design potential found in the complexity of projects or the increasing role that collaboration will play in future practice." The students are given existing buildings to modify for environmental updating. In the first phase, students are asked to design components or "Elements", designed in CATIA and documented with a design manual that can be attached to the building's skin roof, or ground plane and will adjust the building's environmental performance. These components form a library of elements available to all students in the studio in the second phase, in which the students form groups and establish their "Integrated Building Strategies," consisting of combining and synthesizing elements from the first stage library into a parametric building solution. These strategies, like the Elements, are intended to be flexible and reusable. Because the Elements can be adjusted to the new groups' concept/strategy only by the original author, who has to be responsive to the request for modification while adhering to the parameters that initiated its creation, collaboration happens in two ways: the original Element author adjusting his/her element according to new demands and each student participating in a team that forms its Strategy for building performance renovation. The final project is thus a collaboration of various authors who maintain an individual sense of authorship while taking advantage of the wisdom of many.

In comparison to the Penn State Architecture/Architectural Engineering Integrated Studio, the Columbia architecture students utilized the information of the non-architecture AECO industries via the consultants attending the Think Tanks and the studio, leaving intact the design-specific method of architects. However, much else challenged the nature of traditional design methodologies: the collaboration and sharing between architects; the inability at all stages of starting from scratch, since the program was on existing buildings, the Elements had to function according to environmental criterion, and the eventual Strategies were compilations of ideas/forms generated by the elements. The strongest projects at the Element level were those that did not forget all of the other things beyond function and adaptability that make good design: appropriate scale of solution to problem; scalability in general; elegance; context. Likewise, the input of environmental and structural engineering, made the performance –driven nature of this problem richer, but did not determine for better or worse the quality of design; it merely changed its content.

The austin/briscoe studio

This studio, taken concurrently with a Visual Communication course, was offered for 1st and 2nd year students who are taking the first of a seven-semester studio sequence and who have varying degrees of design and drawing experience, some with no design background at all. The students are given a typical design problem of designing a building that must be responsive to program and context, with two initial exercises: the first was the analogue design of a canopy design, its mechanism, and its relationship to a wall. The second digitized this and brought it into BIM. The rest of the semester was spent developing the wall system as it applied to the building in its urban site. After the initial analog design of the canopy, all else is designed in Revit, where the aim was to avoid separating parametric modeling from BIM and to take advantage of the "optimized geometry" when parameters were set up for the performance of the components, their relationship to each other, and their interaction with the building and site as a whole. The challenge was to see how students new to design would handle the potential overload of information as they established a concept and developed them into spatial ideas.

Danelle Briscoe indicated that the students were not inhibited by the amount information and took particular advantage of the representational ability of Revit, both in 2-D representations and in the physical models facilitated by the workflow between BIM and fabrication methodologies (laser-cutter; 3Dprinter, 3-D scanner); that they had more sophisticated designs as a result of the construction information required of their design decisions; and, as a result of these two conditions, they produced work more sophisticated than the norm for that level. At the same time, she indicated that the complexity of the software makes it desirable for a separate instruction prior to or parallel to the studio.

In this case, there was no desire to mine BIM neither for its inter-disciplinary nature nor even for it collaborative, sharing capabilities. Rather, the imperative of constructability - that means that lines can't be drawn innocently; the power of 2-D to 3-D to 2-D - that makes architectural representation not just sophisticated but information heavy; and the parametric possibilities of Revit without recourse to other parametric software - were tested. In this, the students were not given the same depth of "content" of the two other studios discussed, but the essential tools of design were transformed from something moving from general gesture to specific detail to something moving, like the Columbia studio, from buildable part to overall building/site design. In this, the natural limitations of such a process – the ability to think more abstractly – is understood by the teacher, but needs to be grasped and overcome as well by the students. The strongest designers, again, will be those that latch on to the power of the new, bulky information while also being able to step back and see the success of design solution as a whole concept - integrated, appropriate, elegant, coherent, and diagrammatically clear. Likewise, despite that fact that collaboration was not a primary agenda, the students grasped the advantage of sharing knowledge, sources and design, such that the success of ones project was not predicated on originality, but rather on access to and judgment regarding choices.

Observations

As discussed, the Penn State, Columbia University, and UT Austin studios' primary aims in using BIM to advance design competence were very different. The Penn State studio focused on robust engineering integration with landscape architecture involvement; the Columbia studio focused on design collaboration; and the Austin studio on the formal possibilities for an individual designer. The Columbia Studio concentrated on renovating existing buildings; the Austin studio on developing buildings from scratch and Penn State used real building projects, with design juries with the architect of record and their engineering consultants. The Columbia studio emphasized environmental parameters; the Austin studio, the geometry potential resulting from programmatic and site parameters and the Penn State studio emphasized detailed engineering integration. Thus, one cannot draw any singular conclusions about how "design" with BIM can/should be taught in an architectural school.

However, certain observations can be made:

1. The three studios indicate that BIM can be incorporated successfully at either the upper or lower level of design education.
2. They show that the two main aspects of traditional design – singular authorship and a formal abstraction dependent on limited information – may rightfully be rethought as sine qua non of design education.
3. They indicate that design sensibility is not aided by or thwarted by BIM. Briscoe emphasizes that while BIM helped the students visualize their decisions, it neither made "design" automatic nor took the place of aesthetic judgment. Marble/Benjamin/Kurgan implicitly indicate this by not making the studio about design invention (supposedly happening elsewhere in their education) but rather affective performance. The Penn State studio had somewhat weaker design teams and somewhat stronger design teams.
4. Columbia and Austin concentrated on the creation of components as the starting point of BIM design. Penn State benefited from professional engineering students who created original engineered design solutions. This is both a comment on the limits of the existing BIM library and an indication that BIM's greatest potential at this stage is in the small scale, where the specifics of performance is able to be intimately navigated and the limits of formal synthesis (the inability to easily blend wall, roof and floor, for example) less immediate.
5. The studios indicate that collaboration is facilitated by BIM. While this was clearly the goal and stated pleasure and success of the Columbia studio, Briscoe indicated that the "open source" attitude of the students and the facility to share with BIM meant that without specific direction, the students shared their knowledge and resources. The Penn State BIM Studio benefited greatly from busy professionals making time to attend multiple design juries.

Conclusion

The ability of design to not only NOT be sacrificed in teaching BIM, but to be explored in new ways, is an indication that BIM design is not an oxymoron. These examples indicate that there is much that needs to be and should be explored as BIM enters architectural design studios. That this exploration needs to happen with attention, vigilance and, to reiterate the thrust of this article, within the arena of the architectural design discipline is also clear. This is not to say that architecture must be the dominant player in collaborations or that collaboration should not happen. Rather, it merely but strongly suggests that design, always economically unquantifiable and unjustifiable, can easily get lost in an expanded playing field where numbers, time and money are so present. Collaboration is vitally important and central to a changed definition of architectural practice. The hope in this is not that each discipline bends BIM to its traditional aims but takes advantage of being moved out of its comfort zone and looking for innovative ways to consider "problem-formation," not only determine "solution-finding." That this is an attitude shared not merely by architects, but by those other disciplines is indicated in the following observation made by Scott Marble in the description of one of the think Tanks that framed his C_BIP studio: "During one of the discussions, Hanif Kara of Adams Kara Taylor proposed design engineering—the integration of engineering ideas at the outset of concept design—as one step toward a more collaborative relationship between engineers and architects with principles that could expand to an entire design and construction team. He insisted, though, that this not be seen as a casual blurring of disciplinary boundaries, where architects become engineers and vice versa. On the contrary, he suggested that each discipline become more skilled at what they do and, most importantly, respect and value the contribution of each other as a first step towards new working processes [3]."

Additionally, the case can be made that engineering and building management will move towards an engagement with design. The point

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of saving design within architecture is not to keep either architecture or design in a privileged position, but to realize that all the AEC players contribute to (a larger definition of) design. If this occurs, design not only will NOT be sacrificed, but enhanced, and all players will be in a position to think about quality, not just quantity; to think about innovation and risk, not just cost-effectiveness. The reality is that these disciplines already play this role more than we have traditionally acknowledged, and as we understand instead of challenge each other's contributions to design thinking, we displace prejudices that benefit no one, least of all the quality of our buildings.

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Foot Note

[2]The first year involved an elementary school with a real site, which was never built due to concerns over the subsurface super fund site. The next year the new campus early childcare center was chosen as a design project. The third time another elementary school was chosen in the State College School District. The two later sites allowed extensive interaction with the consultant team of architects and engineers.