BIM collaboration across six disciplines

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Abstract
To prepare future building professionals for interdisciplinary collaboration, the model of a vertical “Collaborative BIM Studio” was developed and performed in the academic year of 2008/09. Students of six different disciplines – architecture, landscape architecture, construction, structural, mechanical, and lighting/electrical engineering – were given the task to revise the prototype design of an elementary school while using building information modelling (BIM) technology for data collection, analysis, design development, data coordination, and project presentations throughout the semester. They were instructed by faculty of architecture, landscape architecture, and architectural engineering. The studio was evaluated using internal and external observation methods and surveys. The gathering of all design information in coordinated digital models provided the students with tangible experience in team organization and BIM workflow. All disciplines were closely engaged in each other’s work, and feedback and synchronous communication were facilitated. Workflow observations and design actions indicated that the planning of model content and workflow at the beginning of a project are critical to successful design collaboration. The integrated environment and the use of BIM led to an intensive collaborative educational experience for both undergraduate and graduate students of the participating disciplines and to mutual understanding of technical, aesthetic and social aspects of a collaborative design process.

Keywords: collaboration, academic setting, integrated design, BIM, interdisciplinary studio

1 The need for collaborative studios
The architectural design and construction process is highly interdisciplinary by nature. In order to prepare students for interdisciplinary collaboration, many accrediting boards of different disciplines require collaboration as a learning content while they are committed not to dictate which disciplines should collaborate and in which setting (studio, seminar or lecture) collaboration should be achieved (ABET 2009, NAAB 2009).

Attempts at studio collaboration between departments of architecture, landscape architecture, architectural engineering, civil engineering, and other design disciplines have been ongoing for decades (Fruchter 2003). They have still not become a common setting since they are challenged with coordinating different learning objectives, curricula schedules and teaching responsibilities, as well as different research and design cultures that exist among the disciplines. However, facing the current increase of design complexity, as apparent in integrated practice and sustainability, it seems even
more urgent to shift toward intensified academic collaboration of the disciplines involved in the design and construction process.

Also, the use of building information modelling (BIM) is becoming widespread in the architecture, engineering, and construction (AEC) professions, and it is increasingly expected from graduates to know this technology. Academia should not only react to this expectation but should take the lead in researching the effects of BIM concerning, for example, the changes of collaboration structures, business models, and the design process.

Concluding from these observations, the motive for the studio course was twofold: first, to investigate a new interdisciplinary teaching model with BIM as an underlying design and organization tool that might become a regular alternative interdisciplinary design studio better preparing future building professionals for collaboration across the disciplines; and second, to explore the strengths and weaknesses of current BIM technologies for addressing changing design demands of different disciplines. Since the potential of BIM is neither fully exploited nor even fully explored, the course is inherently a learning environment for both students and faculty.

2 The organization of the collaborative BIM studio
The course was organized as a one semester vertical studio including undergraduate students of 3rd-to 5th-year standing and graduate students. Eighteen students from the three different departments of architecture, landscape architecture, and architectural engineering were involved. The studio was initiated by four professors from the three departments, but was mainly instructed and administered by one professor holding a dual position in architecture and architectural engineering. As a prerequisite for the course, basic skills in program analysis, design, modelling, and visualization of the built environment were expected. Three design groups were formed, each with six students from the disciplines of architecture, landscape architecture, construction, structural, mechanical, and lighting/electrical engineering. The groups were given the task to design an elementary school in Pennsylvania. The project brief emphasized sustainability as a major goal for the school project.

The students had to use BIM technology for data collection, analysis, design development, data coordination, and project presentations throughout the semester. In addition to a detailed program and site information, the students were given a preliminary prototype design of an elementary school in the form of a basic building information model with only room layout and building volumes in order to speed up the initial design process and to allow time for tasks such as lighting design, construction scheduling, cost estimating, clash detection, etc. The first task of the teams was to critically review the initial prototype model, perform a cost analysis, and develop preliminary construction schedules. Through this, students immediately worked together as a team, analyzed the model and discussed the school design. The teams were then asked to modify the prototype design as well as locate the building on the site to maximize the potential for sustainable design. They were asked to optimize and redefine the design for usability, aesthetic expression, sustainability (including life-cycle), constructability, and cost.

Beside the project overview, three introductory lectures were given on “Integrated Design and BIM,” “Sustainability and Green BIM,” and “Effective Teamwork.” A BIM Wiki website was developed in previous semesters, which was expanded for the studio course (BIM Wiki 2009). The purpose was to provide additional workflow and BIM software tutorials to the students participating in the Collaborative BIM Studio. The studio was held in the Immersive Construction (ICon) Lab, which provided an immersive and stereoscopic viewing environment. Each student was also provided a tablet PC for use during the studio class.

Each team had to demonstrate their progress in four distinct presentations, the first emphasizing analysis and evaluation of the given prototype school; the second and the third focusing on the design process and BIM workflows; and the fourth presenting the finalized project including architectural,
landscape and engineering design, energy analysis, cost estimating, scheduling (including 4D modelling), constructability, and clash detection.

3 Observations

In the following, the outcomes of various observation and survey methods used to assess the collaboration process and the use of BIM technology will be discussed. It can generally be stated that the Collaborative BIM Studio setting described in this paper led to an intensive collaborative educational experience for both undergraduate and graduate students in the mentioned disciplines. The collaborative environment facilitated with BIM led to an excellent understanding of the professional processes to synthesize technical, aesthetic and social aspects to a design. The gathering of all design information in coordinated data models provided the students with tangible experience in team organization and workflow.

3.1 Team organization and collaboration dynamics

A graduate class of psychology students conducted two observational studies of the creative design process during the middle and the end of the BIM studio. They identified three important factors in the collaboration process. First, leadership within a group was important for effective meetings, with naturally emerging leadership being more effective than assigned leadership. Second, technology was observed to facilitate as well as hinder teamwork. Floor plans projected on the large screens in the ICon Lab, for example, allowed for intensive group discussion about program layout [Fig.1a], while laptops often invited independent work [Fig.1b]. Third, active contribution to a positive group climate was emphasized to be a key factor for productivity and creativity.

![Figure 1. Working session and group discussion using the large screen setting (a) and tablet PCs (b)](image)

In addition to the external observation, a teammate survey, administered at the middle and end of the semester, was developed to obtain feedback on the performance of fellow team members. Each student was asked to provide a self-evaluation on the same criteria to identify areas of significant divergence between self-awareness and teammate opinions as these discrepancies can be as important as any single criteria positive or negative evaluation. Second, a detailed student survey on the course was conducted after completion of the course. Students generally appreciated the interdisciplinary work, the opportunity to gain insight in the work processes of other disciplines, and the designing of a building in a more holistic way. Being asked if the Collaborative BIM Studio “was a more effective design studio learning experience than previous design studios” architectural engineering students answered with 4.4 on a scale from 1 (strongly disagree) to 5 (strongly agree) while architecture students answered with 2.7 and landscape architecture students with 3.0. The students remarked that the design process took longer when so many people provide input and that the lead-lag of
information from one discipline and analysis by another discipline proved to be a significant workflow management challenge. While the BIM platform allowed them to engage in each other’s work, the majority of students found interoperability of software challenging as well as having to learn some of the software on the fly.

3.2 BIM technology and workflow

The faculty observed that the inclusiveness of such a diverse participant group made the concept and potential of BIM apparent. Students from different disciplines could draw upon one central model, redefine it for their own needs, perform complex analyses in discipline-specific software using separate models [Fig.2a-e], and then re-inform the central model (with some hurdles of information backflow into the main model). In contrast, a studio that embraces just one discipline seems limited in exploring the collaboration potentials of BIM.

![Figure 2. Examples of models used in the Collaborative BIM Studio: structural analysis (a), construction sequencing (b), energy model (c), spatial visualization (d), and mechanical systems (e)](image)

The primary building information model contained a high level of data early on in the design process. As a downside, the amount of generated data turned out to be difficult to handle, for example when exporting the model to other analysis tools, which needed only particular, abstracted information. However, since reducing data of advanced models for particular analysis is a common problem also in professional practice this became a very useful experience for the students. Since integrating all information in one model is neither feasible (because the amount of data is too big) nor appropriate (because not all information is relevant for all team members), it became obvious that model content and workflow planning are critical to design collaboration in an integrated environment.

Interoperability between different software packages is still a challenge and this made technical instruction and support necessary throughout the semester. The assistance of an architectural engineering graduate student with a comprehensive knowledge of many of the software packages used and a general overview of BIM was immensely helpful.

The large screens of the ICon Lab were heavily used for presentations followed by intensive discussions [Fig.3a,b]. The laptops in some cases seemed to be a barrier to collaboration, even with the swivel screens. Only one team used repeatedly the large screens in connection with the laptops for design review and collaborative discussion.
In the surveys, students repeatedly expressed that it would be helpful to first gain more experience with the software before using it in a design project. In contrast, the course was developed by the faculty as a project-based learning experience that focused on the integration of the disciplines. Pre-knowledge of BIM programs and integrated project delivery were made a prerequisite for the course, and students were additionally provided with the BIM Wiki website and references (Eastman 2008, Krygiel 2008). However, the actual digital skills of the students varied widely and it became obvious that not all of the analysis applications can be learnt beforehand. As a conclusion, a smaller project might have been more adequate to reduce the challenge of learning software during the design process.

As a major faculty observation, there was a seduction to consider the managing of the model and simulation as more important than the design task. At times students seemed to opt for the easy compromise rather than push for alternative design solutions. It might seem obvious that BIM does not replace creativity, however often enough, the students were so deeply occupied with interoperability questions and getting the model and simulation right that they almost forgot the more important next steps to critically reflect and evaluate the model, the simulation outcomes and the design alternatives.

3.3 Administration

While implementing this education model two main administrative challenges emerged. Architectural engineering students normally take three-credit studios while architecture and landscape architecture students take six-credit studios. This led to the situation that architecture and landscape architecture students had to take the Collaborative BIM Studio as a studio parallel to their ‘real’ studio thus diminishing the weight of the collaborative studio.

The second challenge was finding a common meeting time for students and faculty from the six different disciplines. The existing curricula of the different departments are highly structured and
allow for only limited flexibility. The conclusion was that such a course cannot be only a bottom-up effort by a few faculty members but must be matched by administrative support. If departments are interested in expanding interdisciplinary courses, it might be useful to establish common times for collaboration in the departmental schedules.

From an administrative perspective, it seems unlikely that such a high faculty-to-student ratio can be maintained. However, although the course can be conducted mainly by one instructor it is critical to have input from faculty of all disciplines. Students will work better together if they see that faculty work together as well.

4  Outlook

The studio will be repeated in the spring semester of 2010 with the following modifications:

• Since students and faculty concluded that the project was too large, a program roughly half the size will be used.
• As the project will be smaller in scale, each team will have the opportunity to collectively develop a design based on a common program and site rather than use the prototype design approach.
• Updating and editing of the BIM Wiki website will become a course requirement thus helping build up knowledge and support for future Collaborative BIM Studios in and outside the University.
• Teams will be required to develop a BIM execution plan early in the semester to assist in defining their design and analysis workflow, software requirements, and information exchanges.
• Given the limited time of one semester and the students’ BIM and team approach learning curve, it remains a challenge to balance creative design, questions of collaboration, and the exploration of the capabilities of BIM software. Through discussion sessions, students’ awareness must be established that digital models are representations of only particular aspects of a building design. Models are not the whole and complex reality, but means of collaborative design and construction to produce meaningful and liveable spaces. BIM and simulation can facilitate the design processes of analysis and synthesis, and interdisciplinary collaboration can reinforce the iterative process of testing ideas.

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References


