Abstract. This paper seeks to question how the academy should position itself in this changing environment of Building Information Modeling (BIM), providing a critical analysis of how digital design education is taught. The pedagogical goals of the digital communication stream at the University of Arizona will be addressed; in part discussing the implementation of relevant software and techniques in appropriate venues in a specific class, stream and the curriculum as a whole.

1. Introduction

With the wide-spread use of smarter and smarter tools containing more and more relevant information we have largely moved past the era of Computer Aided Drafting, where most architects implemented software in a way that did not alter their existing working methodologies (i.e. in two dimensions) to finally embracing Computer Aided Design.

The term Building Information Management (BIM) has become synonymous with this change; the term is used by various authorities to refer to the products of software, the process for collecting and documenting a building, and the use of information in simulation and analysis to enable decisions about design (Eastman, et al. 2008). The more traditional architectural process of Computer Aided Drafting consists of designers abstracting the building into orthogonal, 2-d drawings. The BIM process, which has a history beyond the institutional definition, constructs a virtual building in three and four dimensions and simulates its performance, avoiding the 2-d abstraction steps (Ambrose 2007). This change implies a different design methodology. Dr. Stan Guidera noted in his ACADIA paper, BIM applications in Design Studio, that part of the initial embracement with BIM was its ability to automate many tedious aspects of architectural production, such as schedules, coordination and 2-d production (Guidera 2006). In part the goal was to give more time to architects for the creative design process. Ironically, the reality is that it now just means that less architects are needed. For example, a large tower that previously took a team of 20-30 architects to complete can now often be done by a team of a tenth that size as architectural production work becomes more efficient.

With this paradigm shift in design methodology how can the academy best prepare our students for a profession with rapidly changing technologies, virtual building models and big data? How can we teach our students to use these tools to improve design sensibility rather than employing them just to expedite the process? Emphasizing the importance of design principles and processes is fundamental. Renee Cheng stated at the national AIA Conference that because of this shift, simply applying new tools and processes to old pedagogical and educational paradigms would not be sufficient. The careless introduction of BIM could be
detrimental to design thinking and its central role (Cheng, 2006). Guidera has also noted that the inherent precision of computer–based programs have led to the perception that they are inappropriate in the early design stages (Guidera 2006). This has been exasperated by the use of smarter tools, like BIM and parametric software, which give increasing information and power to those who do not necessarily have a strong foundation in architectural design and materials and methods. Another obstacle is that this new paradigm shift (design-wise) is often not fully acknowledged in the academy. In many schools, digital courses are still viewed as separate courses rather than being integrated throughout the design curriculum.

2. Background

Guidera refers to the “exclusionary” or “tangential” approach to computing in the studio. The exclusionary approach is either non-existent or proscribed, whereas the tangential approach assumes that digital skills have been previously taught or are taught in separate courses. In both cases only a minimal amount of time in studio is typically given to skill development with computation (Guidera, 2006). A superior concept or “digital studio” is organized around the use of digital design; design decisions are made on the screen verses paper. This model is contingent on having faculty with digital expertise or having enough resources to employ assistants or co-teachers with this ability. Digital learning processes can be time consuming, so additional studio outcomes or National Architectural Accreditation Board (NAAB) or other professional accreditation board’s criteria often need to be compromised. These specific NAAB criteria and their apparent lack of knowledge of digital processes is a topic beyond the scope of this paper.

In an era of environmental crisis and complexity, we need holistic, non-reductionist (i.e. complex) design outcomes, but sometimes pedagogically we as educators need to be reductive about a particular design or assignment strategy, as being inclusive of every aspect of computation can be overwhelming to instructors and students, especially at the beginning design stage. There is so much information out there, how do we focus it on what is relevant? Assignments need to limit and strategize over what features are required to be learned and taught. This can be further exasperated at some institutions where the range of student ability is vast. The challenge is to make sure assignments are kept fundamental enough to allow a large range of students to be successful and creative, whilst also ensuring that they are challenging enough to allow the best and brightest to excel.

The following digital methodology applies specifically to the professional undergraduate program at the University of Arizona, where digital communication is one of five streams (including studio), that make up the required curriculum. Currently students learn some basic computer skills in their first-year foundation, with two required three credit lab and lecture classes in the fall of their second and third years respectively. These are large classes containing 60-70 students each. Three years ago the digital communication stream created a digital matrix for the larger school curriculum, to encourage and increase digital use in more and more classes. This included classes which were not specifically designated as digital, as a way to ensure that in the curriculum digital methodologies are becoming pervasive and are no longer seen as just a separate, distinct stream.
3. Digital Methodology

As stated earlier, the digital communication stream comprises of two required support (non-studio) classes. In the first class, students are taught the basics of the Adobe Software Suite, basic rendering, orthogonal 3-d modeling and laser cutting. The following section discusses in more detail the specifics of the second, more advanced class that for the past four years has centered on a precedent analysis. Although the class encourages the digital as a design rather than a production tool, the use of precedents are incorporated to limit the design choices available to students, mainly due to time constraints. Precedents are chosen for their geometrical complexity and/or parametric logic. Most are buildings that have been realized, in part so there is more availability of resources, but also to increase the awareness to students that these geometrical complex buildings are real and are not just contained to the virtual world.

In this particular institution, BIM is often associated with a particular software platform, in this case Revit, an Autodesk BIM platform. Because Revit is a laborious piece of design software, a pedagogical decision was made for students to begin their digital modeling education (in their second year) learning Rhinoceros, a 3-d modeling platform from McNeel that has a much more intuitive interface. Revit is introduced to students in another support course on Materials and Methods, at the same time in their third year as the second design communication class. Early introduction of BIM technologies alone tends to make the weaker or lazier design students gravitate to this one piece of software for ease of production rather than increasing their design ability. This way of thinking and designing usually leads to mediocre results. In contrast students need to be educated that top design firms use multiple platforms as there is not one tool out there that will do everything. These firms are often inventing or scripting programs themselves as they push the limits of platforms and their interoperability. The imperative is for students to become digitally agile if there is an interest in design.

Students begin their second design communication class with advanced rhino skills which enable them to build 3-d models of their selected precedent studies (figure1). During this process lectures and discussion focuses on modeling methodology. Apart from software techniques and geometric logic, emphasis is placed on what should and what should not be modeled, whether surfaces should or should not have a thickness; on how much information is enough to relate to the reality of the built logic. Many students in the early stages of their career, whose knowledge of both time management and construction is minimal, often spend too much time modeling details or parts of their projects that never make it out of their computer into their final studio presentations (assuming traditional methods of representation are used). The amount of detail modeled is important even if models are displayed virtually in the form of interactive environments or animations; on a pragmatic level decreased file sizes allow easier workability.

This approach also reinforces methods of working smarter, not harder. With the widespread introduction of cloud computing for rendering etc. the concept of not modeling or creating more than is necessary for a given task is still relevant to issues of sustainability on multiple levels: relating to how much energy the student is spending, socially and energy-wise. After models are completed these become a tool to test their ability to create 2-d images from their 3-d database (one of the most dominant shifts with 3-d BIM-like packages). In Rhino this is not as automatic as most propriety BIM packages.
This step is important for a couple of reasons; most BIM packages have the ability to create various, sophistications in line-weights and standards, but students need the ability to make presentation quality drawings rather than production drawings. This normally involves interoperability with the Adobe software package. This exercise offers the potential to look at an implicit level of creating information rather than a more explicit level of production i.e. students have the ability to be creative and explore various representation and drawing methodologies too. One particular student, Joseph Di Matteo used his precedent study of Frank Gehry’s Lou Ruvo Center for Brain Health, USA to conceptually create a new type of digital drawing methodology that visually “relates” to the precedent architect’s hand sketches (figure 2).

Another student, Dulce Arambula used this opportunity to incorporate Autodesk’s Ecotect, a software program she had previously learned in her second year to create performative diagrams that “relate” to the acoustic realities of her digital model of Eladio Dieste’s Church of Christ the Worker, Uruguay (figure 3).
After, students are introduced to the concept of parametric modeling; geometric relationships are emphasized which update together in a coordinated way. In this particular course the Rhinoceros plug-in Grasshopper is used. Developed by David Rutten, Grasshopper is not just a stripped down version of BIM. It allows a parametric design dialogue that is not the emphasis of all BIM tools. The interface and logic is different from the students’ previous digital exposures, but offers a more graphic way of engaging students with scripting logic. In this phase of the course students are encouraged to explore various Grasshopper plug-ins. Performative practice models and live digital workflows are demonstrated, with the goal that students will begin to understand that the ability to simulate and use analysis tools for performance in preliminary stages of a design can lead to ways of form-finding verses form-making. Some students used plug-ins as generative, evolutionary modelers to speed up their iterative process. Digital models are also used to create animations and rendered images.

The penultimate process taught is that of digital fabrication. Subtractive (laser cutting and CNC routing) and additive tools (3D printing) are introduced. Laser cutting is a tool that students are already familiar with at this point in the curriculum, so emphasis is placed in using the tool in new ways, including material testing and creative ways to make complex 3-d forms out of 2-d products (a pertinent architectural challenge that relates to the use of paper models at Gehry Partners). Joseph Di Matteo used this design and rationalization process to make a physical model that could move and twist, to begin to show the formal possibilities of using simple, orthogonal 2-d products; showing how ruled surfaces can be relatively complex, especially if there are multiple sheets (figure 4).
Dulce Arambula, the previous mentioned student who had used Ecotect in her initial studies, continued her exploration with research into what she called, ‘Acoustically Responsive Architecture.’ Dulce stated that her idea came from working on her previous parametric model and animation that led to the conclusion that architecture could be more responsive. She used another processing program, in this case VVVV (by the VVVV group), which allowed her to create a live interface and surface from actual pieces of music. This was later transferred to a CNC router to make physical form that related to the sounds (figure 5).

While the exploration of sensory cognition is not directly relevant to this discussion, it is another example of how the digital is becoming more inclusive in an area which had been previously predominantly sight driven. The connection of 3-d models to a physical output is obviously haptic in the sense that there is a materiality (finally) to the virtual process, but incorporating other senses and performance criteria is a design direction that can richen the process and end product.

![Figure 5. Physical model images and drawings relating to sound. (Submission by Dulce Arambula, B.Arch candidate 2015)](image)

Issues of sustainability are also addressed in these fabrication methodologies, all the while relating to real projects and processes. Conceptually, additive CNC methodologies seem greener, but nesting techniques and realizing the opportunity for second generation mold-making steps can obviously alleviate this assumption. Now more realities can be incorporated into the digital model in an easier way than ever before, e.g. materiality and direct links to fabrication: the architect as master (or mistress) builder. Multiple aspects can be tied together in one model; design, analysis, representation, simulation, fabrication, cost-estimating, construction and post-occupancy evaluation data-bases.

Throughout the course there is an emphasis on documenting one’s individual process, which becomes a tool to remember how one actually completed a task successfully and also becomes a useful pedagogical model to show that design and technology are never complete or static, emphasizing the need for students to stay adaptable and aware of their processes in this digital age. Finally, students are encouraged to create a dissemination piece that incorporates all their previous work for the course. Figure 6 shows an example of one student’s final project.

4. Findings

Most design students enjoy the ability to experiment creatively with contemporary techniques and tools. It was not mandatory that there be a conceptual link to each assignment, but the students who developed a conceptual idea over the course of the semester, rather than those
who completed the individual tasks as separate were more engaged, had more advanced
digital tool research and ultimately ended up with a better final product.

Figure 6. Final compiled drawing. (Submission by Joseph Di Matteo, B.Arch. candidate 2015)

This should be encouraged, although focusing too much on design aspects is very time
consuming for most students in the early stages of their career. To assume that support
courses should be completely devoid of design input is unproductive though, practicing
design helps one become a better designer, so the more design opportunities a student
receives the better. Allowing design exercises into support courses also undercuts the
dichotomy that is often present for technical verses design electives; science and art. These
separations are not helping us design more holistic environments and also reinforce the
computer as a production tool rather than a legitimate partner in the design process.

5. Conclusion / Future Directions

Although this course completes the required digital communication classes for the school, it
improves each year as more techniques are pushed down to earlier years. In part, as a result
of the curricular-wide digital matrix, the last few years have seen more courses incorporating
various digital methodologies. When students complete this required course, in the middle of
their professional degree, students have the basic digital methodologies, which they can then
build upon throughout the rest of their education and career. With regards to specific foci for
future incorporation, it is important to begin an interface with Geographic Information
Systems (GIS). Architecture’s traditional discipline boundaries are blurring. If we do not
embrace innovative technologies that are crucial for other disciplines and large-scale works
then we are potentially risking being pushed to the sidelines. There is also an urgent need to
start students in basic programming skills. Many high school science classes are now
incorporating basic Net Logo programming skills so we should not fall behind the curve. In
my four years at this particular institution there has been an increased demand from students
for more “advanced” offerings.

There is only so much that can be taught by faculty in a limited number of courses. Ideally, most studios would be seen as “digital studios” in the future or just completely
integrated. To do this we need to increase faculty skillsets and incorporate more bottom up
opportunities for our best students (we started exemplar student run weekend workshops two
years ago) and incorporate some of the great online open source tools on the web. Students
need to be made aware that they are active participants in their own education process.
Technology is constantly improving so research blogs and help groups, where questions can be posted and answered, are valid pedagogical models. These groups can also lead to a larger sense of a digital community in the academy and beyond.

It is clear that courses and the larger discipline need to have more future overlap and integration if we hope to educate more holistic, environmentally-sensitive future designers. A first step is making our studios more digital with the ability to integrate as many support courses as possible. Like parametric modeling – some early, upfront work in this area will achieve vast pay backs later on. Large universities often have less flexibility with their curricula than smaller, less bureaucratic bodies do. Knowledge of these university and accreditation board’s procedures and protocols, that are often driving curricula, is crucial if changes are going to be made in a more effective way. One has to understand the underlying rules in order to improve the system, realizing that these should not be fixed in stone, but should be questioned and adaptable to keep up with the changing times and technologies.

Acknowledgements

Special thanks to the students whose work I have shown and all those interested in a digital culture in our school. Additional thanks should also be given to my teaching assistants for the fall of 2012, David Kim and Kyle Szostek. I would further like to acknowledge Paulus Musters and Jean-Luc Cuisinier for their support in our materials lab.

References