Teaching Architecture Technology: Shifts in Subject Matter and Pedagogical Practices From 2006 to 2009

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Is it possible to perfect pedagogy? Perhaps it is more appropriate to suggest that pedagogy, like construction technology evolves gradually in response to advancements in technology, differences in place, culture and the availability of resources, and trends in architectural education. Both subject matter and delivery are relevant to perfecting our pedagogy, because as architectural educators we are responsible for both what we teach and how we teach it. This paper discusses evolving technology subject matter and teaching methods – some tried and true, and some new and innovative – that have emerged in recent years. This paper focuses in particular on the subject matter and teaching practices reported between 2006 and 2009, as demonstrated by the presented papers and keynote speeches of the first two meetings of the Building Technology Educators' Society.

In August 1996, the University of Wisconsin Milwaukee hosted a meeting of Building Technology Educators. Gil Snyder, Associate Professor at UW-Milwaukee, one of the organizers of that meeting, recalled that meeting and described the climate of building technology within architectural education. (Snyder) At that time many architecture programs shied away from technological subjects, focusing more on architectural theory, history, and design. Concurrent to the 1996 conference, Robert Gutman, then a lecturer at Princeton University, wrote in *Architecture.*

> "With most architecture programs specializing in the teaching of design skills, and with all schools—some more than others—emphasizing the historical and theoretical underpinnings of design ideas, the current curriculum actually conveys as smaller fraction of the totality of knowledge and skill required for practice than in any period since professional programs were established." (Gutman)

Subjects such as structures, building construction, and environmental controls were viewed by many students and faculty as necessary evils that one must overcome and pass in order to graduate. As Edward Allen has professed, "by the end of their first year, they know that studio is fascinating and all-important, and that the technical courses are necessary evils that must somehow be endured". (Allen)

Recently, however it would appear that architectural technology has been gaining more relevance within our architectural programs. With new developments in design delivery methods (through Building Information Modeling), new building fabrication and assembly methods (driven by rapid prototyping and robotics), growing interest in making our buildings more sustainable (reinforced by AIA and USGBC, and facilitated by advances in computer simulation techniques), and practice-driven research (such as KieranTimberlake's Research and Development division), building technologies seem to be nudging themselves closer to the center of architectural curricula.

Another reflection of this trend is that during a the late 1980's and 1990's the topic of building tech-

nology was removed from the ACSA National Conference agenda and discussed at secondary ACSA Technology Conferences and workshops. The Technology Conferences were terminated in 2002; however it appears that technology topics have been re-integrated into the ACSA National Conference agenda through solicited paper sessions. This new relevancy of building technology to the design curricula is continuing to evolve. Just as technology develops and changes over time, and is gradually assimilated into standards of practice, so to does our teaching of that technology.

In the August 2009, this paper's two authors, co-hosted the Second Building Technology Educators' Society Conference (BTES_2), titled "Assembling Architecture" at the University of New Mexico. The Building Technology Educators' Society (BTES) is a non-profit corporation that was formed less than two years ago, and brings together researchers, educators, and practitioners with an interest in building construction and architectural structures. The intent of BTES_2 was to build upon earlier themes as established at the Building Technology Educators' Symposium (BTES_1) held in 2006 at the University of Maryland and to identify new directions and developments in the area of building technology and architectural pedagogy.

In this paper we present shifting developments and continuing trends in subject matter and teaching practices within the area of architectural building technology from 2006 to 2009 as demonstrated by the first and second BTES Conferences. Sources include observations based on presentations and submitted draft and final papers from BTES_2 and the published proceedings recollections of presentations from BTES_1. There are a number of differences between the two conferences that are important to note. Because of the variables that existed between BTES_1 and BTES_2, we are not presenting this paper as a scientific or objective study of developments in technology teaching, but instead are offering a more nuanced insight into our understanding of current trajectories of teaching architectural technology.

LOGISTICAL DIFFERENCES BETWEEN BTES_1 AND BTES_2

There were a number of logistical changes that occurred between BTES_1 and BTES_2. We do not believe that any of these had a substantial impact on conference content, but believe they should be noted. First, as with any national, repeating conference there was a venue change from BTES_1 to BTES_2. BTES_1 was held on the East coast at the University of Maryland. Because of the large number of accredited architecture programs in close geographic proximity, representatives from those programs could more easily attend. BTES_2 was held at UNM, the sole accredited program within the state, and co-sponsored by the University of Idaho. Most attendees were from outside of the region—from all of the United States and Canada. Secondly, overall attendance shrank from 64 people in 2006 to 48 in 2009. We believe that the decline of attendance is due in part to geographical isolation of Albuquerque in relative to the sites of other accredited programs, but also to changes in the nation's economic climate—and thus reductions in academic program's budgets. Finally, between 2006 and 2009, the Building Technology Educators' Society was incorporated as a 501(c) 3 corporation and a significant amount of the Society's efforts has been spent in developing and publicizing organizational goals and objectives. The BTES accepted members in August of 2008 and its first officers were elected in November of 2008. The Fall 2009 membership drive is now underway.

DEVELOPMENTS FROM BTES_1 TO BTES_2 WITH POTENTIAL IMPACT

There are two important changes that we believe may have had a larger impact on developments between BTES_1 and BTES_2: the introduction of a specific conference theme and the inclusion of a pre-conference workshop and invited plenary session leaders with areas of expertise in specific areas of technology education.

The "Building Technology Educators' Symposium", (BTES_1) was described it as "a gathering of architectural educators, passionate about teaching and technology". BTES_1 presentations, workshops, and keynote speeches focused on pedagogical approaches to and curricular initiatives for teaching building technology. As the organizers for BTES_2 we believed that it would be important to distinguish this conference from BTES_1 and to perhaps set a precedent for subsequent BTES Conferences by introducing a title and a directed theme.

The title of the 2009 BTES_2 conference was "Assembling Architecture". The conference description as posted on the conference website as part of the call for papers stated:

> "In keeping with the BTES Mission, this year's conference will assemble architectural educators, researchers and practitioners "who are passionate about teaching the technology of building design and construction" to engage in lively discussion and debate. Assembling Architecture hopes to bridge the gap between the theoretical and the practical, providing participants the opportunity explore advancements in technology at the intersection of design, theory, and practice.
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> Significant developments in material science, design and manufacture of building components, innovative building systems, and dynamic structures, require specific knowledge and expertise and are driving design practice. However, one of the emerging challenges in architectural education, research and practice is to promote integrative design through interdisciplinary models of teaching, research and practice. Despite this call to action, many architectural programs remained fractured and collaborative work between technologists, theorists, and designers is undervalued and underrepresented. At the same time, new models for teaching, research, and creative work are required to intersect these contrasting developments." (Assembling Architecture)

Through this call for papers, it was our desire to position building technology more centrally within the architectural curricula, and to mend the past fracturing between building technologies, architectural theorists, and designers. We introduced the ideal of integration as a means to discuss reconnecting these divisions within architectural education and highlighting architecture's trajectory of interdisciplinary practice.

BTES 2 introduced themed plenary sessions and a pre-conference workshop. Annette LeCuyer (University of Buffalo) and Jason Vollen (Rensselaer Polytechnic University and the Center for Architecture, Ecology and Science) to create two plenary sessions: "Concept + Construct" and "Local Complexities: Integrating Technology and Ecology", respectively. The session topics were developed around LeCuyer and Vollen's own research, and included special vetted papers that responded to each topic. For the pre-conference workshop, we invited Francisco Uvina (international lecturer on earthen construction) to lead a hands-on workshop in adobe construction.

As participants in the first BTES Symposium and co-organizers for the second BTES Conference, we noted four distinct developments in the area of building technology education. First, in 2006 we were still discovering the possibilities of the tools of digital fabrication; now in 2009, we have 'mastered' digital fabrication and are now investigating the use of robotics for building assemblage. Secondly, haptic learning continues to be an important pedagogical tool for teaching building technology and includes full scale buildings and components for building assemblage, as well as full-scale objects and test models for architectural structure courses. In 2006, Building Information Modeling (BIM) as a tool and its potential impact in the classroom and in practice was introduced, but in 2009 it appears to have evolved from teaching computer programs into a broader approach to teaching integrated design. Finally, topics in sustainability had been discussed in 2006, but in 2009 became more substantial as a subject and better integrated within the technology courses—leaving the domain of environmental controls and entering areas of building construction and architectural structures.

DIGITAL FABRICATION

In 2006, during the BTES_1, digital fabrication technologies (e.g. laser cutter, 3-dimensional printer, and CNC mills) were the subject of several papers and our impression was that these tools and techniques were becoming an integral part of many academic programs. As the name 'digital fabrication' suggests, these technologies bridge two academic groups of faculty: digital (or computer process) and fabrication (or building technology). Digital faculty are often needed to process the input of virtual programs and models required to interface with the equipment and the building technology faculty are needed to offer applied solutions with the equipment's physical output. Questions emerged about whether these technologies occurred in the realm of digital technology education, building fabrication, or the design studio; or perhaps because school's wood shops were purchasing these new technologies design faculty with competency in digital modeling began to experiment in the classroom.

In 2006 at BTES_1, digital fabrication technologies, and the idea that mass-customized building components of the future would be constructed us-

ing these methods, were widely discussed. Digital fabrication technologies were assumed to be the technologies that would ultimately revolutionize building construction. At the BTES_1 papers that specifically focused on digital fabrication technologies and their applications. For instance Edgar Stach's "Pattern in Architecture: Explorations of the Digital Modeling & Fabrication Lab" explored the digital modeling and fabrication through various student projects. (Stach) As revolutionary as the use of these digital fabrication tools in architectural practice appeared to be 2006, it seems that the CNC, laser cutter and 3-D printers may have been the penultimate step in the technology revolution. At BTES_2, the role of robotics as the next phase in digital fabrication was discussed by Martin Bechthold, Professor of Architectural Technology at Harvard University, in his keynote address, titled "New Catalysts in Architecture", and referenced in other papers including Annette LeCuyer's presentation for her plenary session.

Traditionally robots have been used primarily for welding, however as Bechthold's keynote speech demonstrated, the use of robots in architectural application has been greatly expanding. Because of an increased range in motion and superior tool usage, robots may soon be replacing some of our digital fabrication equipment, such as the CNC mill. In Bechthold's presentation he used photographs and video footage of a robot at Harvard University using a water jet tool to create tapered holes within a piece of marble. (Bechthold) Because of the robot's range of motion, the tapered holes could be cut on both the front and back of the material, without the necessity of material reorientation.

Beyond robot's ability to fabricate building components, robots also have the ability to assemble our building components. With robots' strength, agility, and precision robots can erect portions of our building. This practice of using robots for building assemblage is occurring both within architectural practice and academic research. LeCuyer referenced a 2008 building at the Gantenbein Winery in Switzerland, where robots replaced the highly-skilled mason—inserting a subtle pattern of spheres into a traditional running bond brick pattern. (LeCuyer) Bechthold has been researching using robots within the classroom by having students work with a small, table-mounted robot to stack blocks, similar to built example of the Gantenbein Winery.

In analyzing pedagogical applications of digital technologies, it appears that two different approaches are currently being taken. In one case students in a seminars or lab setting experiment with the new tool – finding things it can do, and working with the digital interface to develop techniques that go beyond conventional applications used in manufacturing. The other approach is that once an instructor develops skills and ideas for application, he/she is able to develop design problems that provide structured support for students to build skills while developing in design solutions that achieve pedagogical goals.

NEW TAKES ON HAPTIC LEARNING

Another common strand that wove through BTES_1 and BTES_2 was the critical role of haptic learning in technology education. In 2006 Deborah Oakley presented a paper titled, "Haptic Structures: The Role of Kinesthetic Experience in Structures Education" (Oakley) , provided an overview of haptic learning applications in structures courses, and five additional papers discussed full-scale, habitable design build projects. In 2009 the topic continues to be discussed; however, new ideas about the methodology and new technologies have expanded boundaries for potential for pedagogical explorations. Interestingly, while no full-scale, completed habitable projects were presented in 2009, the advantages and disadvantages of participation the Solar Decathlon were the topic of dinner and lunch-time discussions.

While the topic remained central to ongoing discussions, new ideas about the methodology and new technologies have expanded the potential pedagogical applications. We find design build at the intersection of digital fabrication and hand's on construction. In his paper, in his paper "The 2to3 Chairs", Frank Jacobus described one of several projects developed for his Furniture Design Studio. Building upon his own experience and the experience of others he challenged students to design and fabricate a child's chair from a 30" x 30" sheet of plywood using the CNC mill—converting two dimensional sheet stock into a 3-dimensional object. (Jacobus) The ability to easily assemble the chairs by hand was key to the problem.

In her paper, "Taking Buildings Down", Erin Moore discusses the idea of end of life planning for all new construction. While Moore's focus was on issues of

sustainable practices (see below) one of the ideas posited was for designing buildings for disassembly at the end of the use period. (Moore) This idea and the paper title, suggest the potential of taking extant buildings down as a pedagogical method of understanding the materials and assembly and the potential for investigations of material re-use in future projects.

In another twist on design-build, Matt Burgermaster developed "an integrated application of digital tools and design-build practices to teaching introductory building technology". (Burgermaster) In this example students created virtual materials such as standard lumber sizes, concrete masonry blocks and bricks and designed specific solutions to design problems using the virtual materials. The students used these tools to test their designs for full-scale mock-ups they would subsequently build. The idea was to link design thinking directly to design making within the context of a building construction class.

INTEGRATED DESIGN

One of our primary observations of the changes in pedagogy between 2006 and 2009 is that of integrated design. In 2006, the terminology 'integrated design' was still relatively new and most of the papers presented at BTES_1 specifically referenced Building Information Modeling (BIM) as a tool for achieving design integration. Joseph Burns of Thornton-Thomasetti Structural Engineers delivered a Keynote Lecture entitled "BIM Applications in Architectural Education". It became a highly discussed topic at the Symposium. At that conference there were also two other related papers: one that discussed taking a systems approach to Building Information Modeling (Livingston), and one that directly addressed the capabilities of using Revit in technology courses (Christenson).

BTES_2 continued to focus on BIM as a tool for pursuing integrated design and we found that the design studio is the place where BIM is used to enable design collaboration. Craig Griffen discussed a BIM lab course that is taken simultaneously with a design studio so software is learned in the lab setting and applied in the studio. (Griffen) A more comprehensive approach was reported in the paper "Craft and Computation: Modeling Integrated Practice in the Academy", about the introduction of BIM and Integrated Practice into the curriculum at the University of Wisconsin, Milwaukee. This funded academic studio "engages students, academics, architects, [MEP] engineers, structural engineers, pre-construction contractors, virtual construction contractors, arts groups, scientists, professional architectural organizations, software specialists, and motion consultants in a collaborative environment designed to simulate model practice in the 21st century." (Snyder, et. al.)

Integration as a way of thinking was so new that the BTES_1 paper sessions were divided into two categories: structures pedagogy and construction pedagogy. In 2009 at BTES_2, there was no clear division between topics. The pervasiveness of integrated design may have been a result of the themes of BTES_2, but it can also be viewed as a reflection of what is happening in practice and in the academy.

In 2009, the words integration and collaboration appeared (or were implied) in numerous papers with topics ranging from curricular structures to community design. In many of the papers the focus was on technical integration, integrated practice, or integrated design. Annette LeCuyer was invited to create a Plenary Session for the BTES_2 Conference. In her session titled "Concept + Construct" she investigated the historic context of design and making (LeCuyer); a beginning design project that worked with local craftspeople (Burgermaster); and a graduate studio that appropriated manufacturing processes for potential architectural application (Gulling). Ryan Smith also reported on a new intensive graduate program he is developing at the University of Utah, School of Architecture: the Integrated Technology in Architecture Program (I_TAP). This new Utah program will move from design through production in collaboration with partner industries. (Smith) This topic of integrated design could also be found outside of the Plenary Session, scattered throughout the general parallel sessions.

For BTES_2, it appears that our teaching of integrated design has changed drastically. In one form or another, building technology is being pulled into the design studio and is transforming how our students think about architectural design. In 2006, we were still figuring out how to integrate technology with design and we were proposing to use BIM as the tool to accomplish this. In 2009, we accepted in-

tegrated design as a premise and continued to look toward BIM as a tool while also investigating new definitions of 'integration'. The definition of Integration has become more broad-based and included fabrication methods in addition to environmental systems, structure, assemblage, and design.

SUSTAINABILITY

The final topic that was addressed more substantially in 2009 than in 2006 is sustainability. We noted a total of 8 papers and presentations that were presented at BTES_2 that addressed issues of sustainability in comparison to only 4 papers presented just three years earlier. As presented at BTES_1, building technology educators were beginning to fold elements of sustainability into their coursework, but overall sustainable issues and their potential pedagogical impact had not be fully investigated.

There were two specific papers at BTES_1, "Green Roof Design Workshop" (Hunsicker et. al.) and "The WSU Solar Decathlon – Design/Build Lessons" (Taylor and Bangs), which exemplify this statement. These papers did include sustainable building components—such as a green roof or a solar house—but sustainability itself was not the focus for these papers. Instead both papers focused more on the process of getting either of the sustainable components built. In his paper titled "Recycled Walls", Paul Zorr had his students design and build a non-load bearing interior partition out of recycled materials, but did not delve into the ecological solutions that the project offered. (Zorr)

Only in one paper that was presented at BTES_1 particularly addressed a broad understanding of sustainability and the built environment: "Ecological Aspects of teaching of Historic Building Technology in and Architectural Preservation Curriculum". (Wasserman) Her paper described the potential ecological impact of historic preservation, but did not address architecture's current design practices. Ecological issues could also be found scattered throughout a few other papers, as a design criteria, however sustainability and architectural technology were not addressed holistically.

Not specifically described within the 2009 BTES_2 Conference Theme (see earlier excerpt), the topic of sustainability was listed under "Additional Questions" and asked: "With today's focus on sustainability, what regional and/ or vernacular technologies are being (re)introduced into architecture?" (Assembling Architecture). Despite what could appear to be an underrepresentation of sustainable issues within the overall conference theme, we asked Jason Vollen to create a plenary session that would integrate issues of ecology with building technology. Vollen's Plenary Session titled "Local Complexities: Integrating Technology and Ecology" examined issues of ecology through technological advancements (Vollen), understanding the micro and macrostructures of living things (Dyson), rethinking our attitudes toward the existing fabric of the built environment (Buccellato), and utilizing better our planet's water resources (Barnhouse).

In addition to the focus of Vollen's Plenary Session, we also noted a number of additional papers that folded sustainable thinking into their subjects and teaching methods. Through different courses Shahin Vassigh and Kenneth MacKay asked their students to investigate the environmental performance of buildings through digital modeling (MacKay) (Vassigh); Justin Miller challenged his students to design a Habitat House that was energy efficient. (Miller) Erin Moore, as stated earlier, investigated the idea of planning of the end of life of all new construction. (Moore)

Through this comparison from 2006 to 2009, it appears that the topic of sustainability has moved out of its traditional association with Environmental Controls courses, and has become more prevalent in our other technology courses (Construction, Materials and Methods, and Studio). It also appears that technology educators are better considering how to integrate sustainable thinking into course content and to apply design-thinking to offer ecological solutions.

CONCLUSION

When investigated in the context of the papers and discussions at two subsequent meetings of Building Technology Educators' Society we find that were several themes that remained constant: the value of haptic learning as a pedagogical tool and the emergence and integration of new technologies by way of digital fabrication. In addition, a broader understanding of design integration and the ever-growing subject of sustainability are evolving in our teaching of building technology.

If we modify the question asked in the call for papers: "is it possible to perfect the pedagogy of architectural technology?" we see that it can better be described as an ongoing process. Comparing the teaching of building technology in 2006 to 2009, we find that instructors new and seasoned continue to search for new ways to engage students in learning and to develop and refine best teaching practices. We are uncertain what the future may hold for the development and continued growth of these architecture technology subjects. Our hope is that they continue to develop and respond to the changing pedagogical climate and that building construction and structures technology will continue their move toward the center of pedagogy and practice, including integration in the design studio.

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McKay, Kenneth S. "Animating the Environmental Performance of Integrated Bldg Systems".

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