# LEVERAGING TECHNOLOGY:
## With or Without the Buy-In of Your School

Terri Meyer Boake, BES, B.Arch, M.Arch, LEED AP
Associate Professor, Associate Director, School of Architecture, University of Waterloo

The recent Oxford Conference Debate, held as the launch to "50 Years On - Resetting the Agenda for Architectural Education"[1], posed the question, "Would Architecture be better off without Architecture Schools?" Arguing for the question, journalist and editor Peter Buchanan and Architect Jeremy Till, and against, Peter Cook, most famously known for his work in the 1960s with Archigram. As the debate unfolded in front of the International audience, it seemed clear that the problems underlying the presentation of the question hailed from a situation in British Schools of Architecture that placed very little value on practical issues of construction or sustainable design, in deference to a purely Design motivated education. The polarity of position in the UK may be seen to be even wider than in North America, as concerns regarding Carbon reduction and the implementation of protocols into the British codes are more aggressive than in the United States and Canada.

The bottom line defines a gulf that exists between the degree of technological knowledge that is expected from a Professional Architect and the degree to which this is being effectively included in architectural curricula. It is also evident that a further polarity exists within Schools, dividing those who are keenly interested in technological issues from those who do not see these as critical to education, or who believe that this is material that is best learned during one's internship. It would seem that the majority of Schools are under the direction of heads who are less interested in technological issues, making it difficult to integrate technology and environmental concerns into the Design curriculum. The intermediate answer to the solution, which due to global issues and external pressures may eventually resolve itself, may lie in finding means to leverage technology in the curriculum without the buy-in of the School.

In order to begin to reposition technological concerns as key players in a Design centered curriculum, it is important to understand the circumstances that led to its decoupling with the study and practice of Architecture (noting that the practice of Architecture has already begun to incorporate the concerns of sustainable design, carbon, complex detailing and computing technologies/BIM into Design).

### An Historical Overview: The Generation of the Problem

During the Enlightenment, the well rounded "Renaissance Man" ceased to be able to simultaneously address the "art" side of Architecture with the more technical studies of stereotomy, mensuration and physics that were being developed. In the 1700s, building materials became more varied and construction methods more complex. The incorporation of iron, steel and concrete into construction increased design requirements well beyond the capabilities of the Architect as Master Builder. The use of simple materials in tradition based construction gave way to composite assemblies and wicked problems. Historic techniques needed alteration as well as technological validation as potential building failures for larger structures needed to respond to "higher stakes". This accelerated increase in knowledge requirement led to the creation of two separate disciplines – that of the Architect and that of the Engineer. Educational strategies were subsequently divorced, and with rare exception, proceeded to educate the Architect in the Arts, and to rely on the Engineer to validate and calculate the structural implications of their designs.[2] Subsequently, the majority of courses in the area of structural design, mechanical and electrical systems, to this day, are mostly intended to give Architects enough information to speak intelligently to their consulting engineers, but not to undertake – certify and take liability for – the material itself.

Without statistical references, I think it is safe to say that the majority of students who choose a career in Architecture are motivated by more so by their creative skills (interest in Art, English and History), and less by their desire to solve technical issues (referencing courses in Mathematics, Physics and Science). So the decoupling of the disciplines supports the general nature of students to study alongside their strengths.

During the 20th century, with particular reference to Architecture and Architecture Schools that were aligned with the Modern Movement, the International Style, and even Brutalism, the predominant material for design was concrete. Skins were simple. Shapes were straightforwardly geometrical. Most structural elements were hidden beneath gypsum board and other forms of cladding. Energy was cheap and plentiful. The traditional Architect as Prime Consultant in charge of setting out the shape and material palette with the Engineer as validator worked well. Architectural education supported and perpetuated the divide between the disciplines and technology courses were relegated to secondary, and in some cases tertiary parts of the curriculum. Until NAAB and CACB accreditation gained momentum in the 1990s and made this type of knowledge a mandatory part of the Architectural curriculum, schools existed that did not address this material at all.

The history of lamentation by faculty teaching marginalized technical and environmental courses is long. The first ACSA Technology Conference in 1983, which coincided with the launch of Edward Allen's first edition of *Building Construction: Materials and Methods*, saw several hundred faculty members who taught structures, construction and ECS, gather to commiserate. Other groups, such as the Society for Building Science Educators[3], which formed in 1984, began to gather to address the need to share and alter teaching methods as a means to garner increased student interest in courses with environmental themes. The Building Technology Educators Society formed in 2006 (more than 20 years later) for precisely the same reasons.[4] The fact remains that the majority of students who enter professional architectural degree programs do so because of an interest in Design, not Technology[5], making it difficult to garner interest in either increasing or integrating purely technical content.

**LEVERAGING FORCES:**

Where the anti-technology mode of thinking and teaching continued to perpetuate itself through the Post Modern period in the early 1980s, (applying drywall over a structural system did not require much in the way of structural prowess) several key changes have subsequently taken place that put this pedagogical position in question: changes in architectural style (a predominance of exposed structures and complex skins), increased awareness about the need to incorporate environmental criteria, and advances in the application of computing technologies to architecture. These three forces have been able to leverage technology and its associated content in the *practice* of architectural design, if not pervasively in architectural curricula in North America. The only means to mandate change within the School system may well be the criteria imposed by NAAB[6] and CACB[7]. These two bodies respond to pressures from the Profession as to the qualities it expects in graduates. Currently there are changes under study by NAAB that would serve to make the requirements for sustainable design and BIM more rigorous and pervasive.

One of the means to change the way that technology is viewed from within the confines of the Architectural curriculum is to look to the factors that have increased respect and integration in the profession. Looking at the evolution of the products of Design Studio over the last 20 years, it is clear that some of these factors have already become expectations of the Design curriculum.

**Leveraging Technology through Changes in Architectural Style:**
From a purely stylistic perspective, Deconstructivism and High Tech Architecture (and its use of Architecturally Exposed Structural Steel), could not abide by Architects lacking in structural proficiency. Green Tech architecture is requiring a highly expanded ability to incorporate a larger range of technical issues as well as form influencing policies. As students tend to emulate stylistic trends, it is important to draw such examples into the technological curriculum, both as verification that detailing is important, and to dissect such projects for use as teaching tools. Detailed case studies of popular buildings – many of which are more current than the generic examples that can be incorporated into print textbooks – can be used to enrich the curriculum. It is essential to be able to include as many construction images and details into the discussion as possible. Design Studio seldom references generic or non-descript examples.

Fig 1: Foster's Sainsbury Center (1977) and Gehry's Serpentine Pavilion (2008) both require that the Architect understands structure and construction detailing.

**Leveraging Technology through Changes in Environmental Criteria:**
Global issues relating to environmental problems have already changed the way many Architectural practices design. The incorporation of LEED$^{TM}$ and Zero Net Energy practices is becoming the norm. Case studies of exemplary buildings can assist students in comprehending the importance of these issues. Incorporating these guidelines into technical design projects can help the students to begin to integrate the various aspects of this type of technology.

**Leveraging Technology through Computing:**
Where BIM might now be considered to be the current wicked problem of technological integration into the curriculum, the acceptance of the value of 3D modeling and AutoCAD is no longer contested. Students, particularly those exposed to work experience in cooperative education programs while at school, understand the importance of learning digital skills. It can be helpful to create design projects that require students to combine their digital skills with a technological design problem. The use of 3D modeling, for example, can elevate the sense of design in the detailing problem, by requiring the student to also consider presentation skills. The recent acquisition of *Ecotect* by AutoDesk may enable better environmental assessment to be integrated into student projects.

**Leveraging Technology through Accreditation Requirements:**
There has been a steady increase in the technical requirements cited by NAAB and CACB. The Comprehensive Building Design Studio, in particular, requires significant integrated technological development of the studio project. In order for students to be adequately prepared to undertake such a detailed design, skills need to be developed within the courses leading up to this studio, particularly if such technical work tends not to be a part of the

regular studio brief. It is helpful if junior students understand that detailing and structural design exercises will be mandatory as part of this design studio. Showing examples of exemplary CBD projects can assist in the visualization of this type of integrated work in the eyes of junior students.

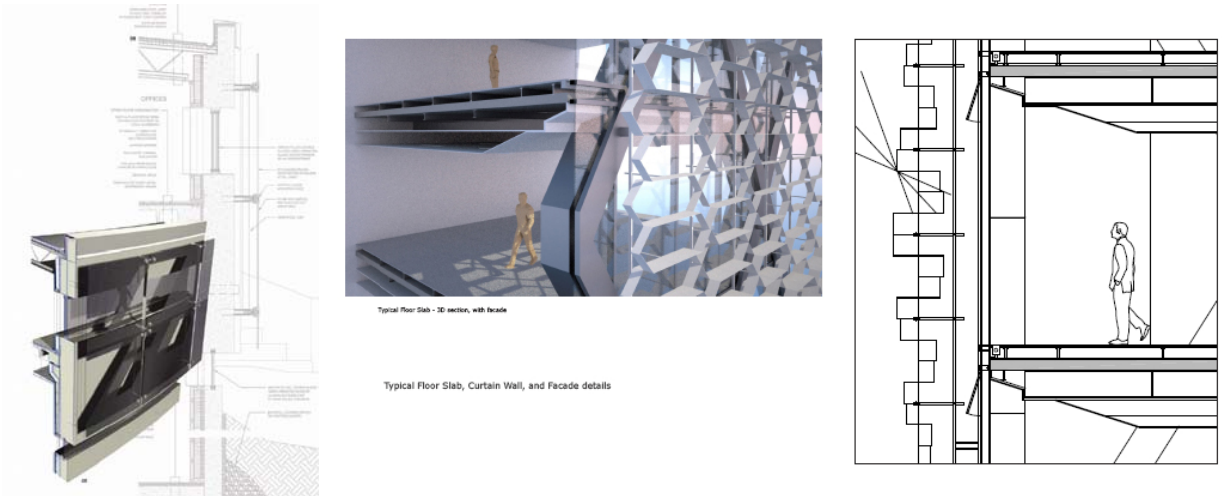


Fig 2: Range of more detailed technological drawings that are an integral part of the Comprehensive Building Design project

**TRANSFORMING TECHNOLOGICAL TEACHING INTO DESIGN TEACHING:**

Given the leverage already provided by influences *outside of the University*, approaches to teaching technical courses may need to evolve from the traditional lecture format, to one which more closely approximates methods used in Design Studio, in order to draw in the interest of both students as well as other faculty from within the academy. Most students that graduate from 4 years of Design Studio experience do so with a demonstrable ability to design and draw buildings. The same cannot be said for the amount of technical or environmental knowledge retained from pure lecture format courses after the same period of time. It is interesting that in spite of earlier protests about the impact of computing requirements on the already stressed curricula, the majority of students do now graduate with a very high level of CAD and 3D modeling skills. These skills, even if taught in core or elective courses outside of Studio, have increased the quality and level of detailed information and exploration within the studio curriculum. The students as well as the Design faculty accept these courses because they have an obvious and direct benefit to the Design Studio.

There may be a multitude of reasons that students do not retain technological material – varying from poor attendance, to interest levels, right to the methods of content delivery and references. Working this problem in reverse, we can speculate that if content delivery were made more engaging, referencing intriguing examples of architecture that make progressive and obvious use of current leading edge technologies, then interest levels would rise, increase attendance and result in a higher level of retention of technological information.

If the divergence of architectural and engineering paths two centuries ago succeeded in decoupling technological material from the Design problem, then one means to re-couple the material would be to look at the continued successes in the teaching of Design, and incorporate this method into technology teaching. That is not to say that most technological subjects need be taught entirely in the Design Studio format – i.e. largely with the absence of extensive lecture content – just that design, being an iterative and integrative process, uses a repetitive methodology that succeeds in reinforcing its lessons, through project based learning, that draws in the innate creativity of students. *Design is project based*.

If technological studies are to become project based, then the scope and direction of these needs must be able to either be managed within the scope of the assigned lecture slot (typically 3 to 4 hours per week), or be conjoined with/become a dedicated Design Studio (typically 15+ hours per week). The latter requires the buy-in of the School and the Design faculty. The former, does not. *Teaching Technology as Design, within the constraints of a lecture format course, becomes the challenge.* Additionally, it is important when using various projects to enhance teaching and learning, to make them as public and high profile as is feasible. This increases students' interesting in making sure that their submissions, if publicly seen, demonstrated and judged, are of high quality.

## PROJECT TYPES, SIZES AND EXAMPLES:

Technological "Design" exercises need not be large in order to engage students in iterative and somewhat experimental work. In fact, there are benefits to tackling technical problems one aspect at a time, in order to isolate the lesson and make it easier to learn, as well as retain and reference through later additive lessons. There are three scales of projects that can be easily incorporated into the lecture restricted time slot: the charrette (3 hour in class design/build); the small project (done outside of class but presented and reviewed within a single class); and, the major term design project (preferably presented and publicly critiqued). The following brief project descriptions illustrate a variety of projects that we have used in Structures, Building Construction, Environmental Design and Digital Design at the School of Architecture at the University of XXX.

### The Technical Charrette:

Design often uses the charrette as a generator of ideas. The charrette is a short, intense design exercise that typically only provides the question to be addressed at the beginning of a defined period of time. This method was used in a first year Building Construction course to define an experimental structural design exercise that was carried out within a three hour class period. The students were required to supply large and small marshmallows, spaghetti, linguine and sewing thread. At the beginning of the charrette they were asked to build a structure, using only these materials. The structure had to include at least one spanning element, a tower and a cantilever. The cantilever was allowed to be assisted by the thread, illustrating the use of tensile forces to remediate insufficiencies in the capabilities of either the material or the design.

Fig 3: The Culinary Charrette

The project was fed by both the lectures on steel construction in the Building Construction course (highlighting the High Tech designs of Foster, Rogers, et all), as well as by a Digital Modeling problem that asked for the students to design and render families of steel joints. The primary issues of tension, compression, and connection design were simultaneously addressed by the charrette and the other core courses. Key case study examples of innovative steel connections were woven through all three aspects of this study. Although the culinary structures may have seemed conceptually simple, they succeeded in addressing key issues of a material (steel) that might have seemed too technically sophisticated to be addressed by junior students in a complex three dimensional form that was able to use actual hinge connections and illustrate deflection. Having the digital design class pull apart the details in rendered form, contributed a higher degree of attention to the aesthetic aspects of the problem than an exploration in a dedicated construction course could have produced.

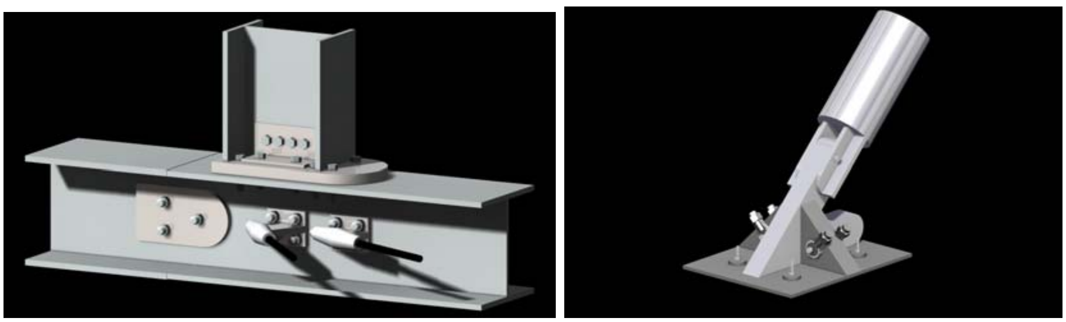

Fig 4: Samples of some of the digitally rendered steel connections from the first year students, completed for their FormZ course

Where the students initially thought the project less than challenging “for a University project”, they soon discovered that the limited capabilities of the materials required innovative thinking. Their previous studio models had been constructed of basswood and white glue, which tend to produce very sturdy, often structurally over designed pieces. The marshmallows acted as true hinge connections (unlike a glued joint), providing for easy rotation. They were forced to use geometry and triangulation to achieve stability. The thinness of the pasta often required that they use multiple strands to create members that were strong enough to act in compression.

The director of the School and a history/theory professor were brought in to judge the projects. Where mere participation ensured that the student would receive a grade of 5/5, placing first, second or third resulted in bonus marks. Maintaining an overt spirit of competition, with academic prizes and public judging increased the importance of the exercise in the minds of the students and served to make faculty and students outside of the course aware of the project. The judging criteria included issues of aesthetics in addition to complying with the inclusion of the required elements.

**Demonstrating Failure can be a Success:**
Design is about visualization. Understanding structural concepts can be difficult without effective visualization. The creation of scale models can assist with this development. Students can appreciate deformation, movement or failure when loads are applied. Catastrophic failures are often the most exciting to watch and hence can lure students into learning more than they might by watching a structure work properly (i.e. not fail). Failure provides the opportunity to carry out a post mortem analysis. As a student I recall creating columns, beams and trusses from balsa wood and taking these to the engineering lab and watching them be crushed. We were scored on the ratio of the weight of our structure to the

load it was able to carry. The element of competition assisted in the students' interest in the project. The Pasta/Marshmallow charrette works with this pedagogy. Students modified their designs to acknowledge the strengths and shortcomings of the materials. The majority of the models collapsed under their self weight, and barely survived to be judged. The relationship between the design, structural principles and the materials was highly evident.

Scaling up and using actual "student" weights to test the structures increases involvement as well as commitment. Our second year structural design class, under the direction of Professor XX, used cardboard and duct tape to design and construct *bridge* elements that were required to span 3.0 meters.[8] The actual shape and form was left entirely up to the discretion of the student team, but was limited by the amount of materials, which was a function of the number of students on each team. Each student was allowed to use a limited number of sheets of corrugated cardboard and one roll of tape. The increase in the number of students per team (their choice) meant that they could pool their resources (the span remained the same), but the bridge was required to support a greater load – i.e. more students. The testing was carried out in the river adjacent to the school. This implied that failure of the member would result in a sudden, frigid dip for the students/load. As the stakes were quite high, the students put significant effort into the design and construction of their structural elements. As the students walked across their structures they could actually feel deflection, torsion and other load induced movements in their structures.

Fig 5: Professor XXX with "live load" students testing the spanning members over the river

Although the bridges were designed and fabricated outside of class time, the testing of the structures was able to be carried out within a three hour time frame, which could easily fit within a lecture period. The use of the river adjacent to the school meant newspaper reporters and some press – a value add for the initiative.

**Demonstrating a Single Principle:**

"Quick and dirty" exercises can be used as short projects that assist in visualizing technical issues. In our introductory environmental design course the students build both a "light box" and a "smoke box" as the means to understand solar geometry and air movement. The hands-on approach takes this lesson away from computer visualizations and graphics and gives them a very tactile experience. They can peer inside the light model and begin to understand penetration, bounce and the quality or problems associated with the light. They handle the smoke machine and can see where the air moves quickly or where dead spots occur. The physical objects are neither time intensive nor expensive to construct.

Making the demonstration aspect of this project fit within the lecture slot was difficult. The class of 72 was divided in half – half doing light boxes and half making smoke boxes. The projects were worked in pairs. This resulted in a set of highly interactive reviews that could be managed within a 3 hour class.

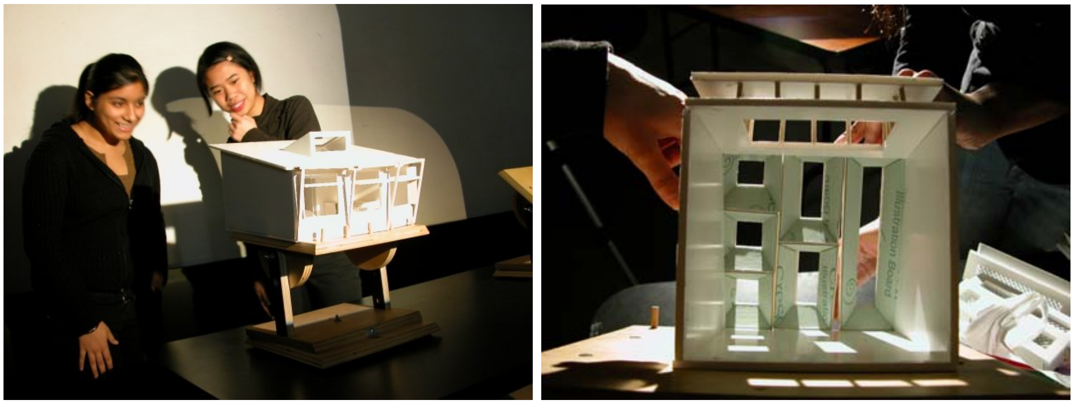


Fig 6: Demonstrating the Lightbox

The light box required the design of a small room that incorporated a declared function (bedroom, dining room, etc.). They had to design for full sun penetration during the winter for heating (cold climate, $43^{o}$N latitude) and complete exclusion for summer cooling. Students designed shading devices, looked at proportioning of the interior dimensions, included light shelves, and begin to appreciate ambiance. The physical models were tested for June 21 and December 21 conditions on two simple heliodons. An overhead projector was used to model the sun (as the source is intense, the rays close to parallel, and required no special procurement) and the bright display in the darkened room, along with the interactivity as the models were rotated and modified, seemed to garner student interest. This particular exercise, because of its immediacy and simplicity, has been used by students in testing models for Design Studio, on their own initiative. They seem to be making models anyway…

Fig 7: The Smokebox

The smoke box required the design of a tectonic space through which theatrical smoke must be forced to visualize air flow. Black foamcore[9] and plexi-glass were used to provide contrast with the white smoke. The models are placed within a plexi-glass box to contain spill over smoke. A fan is used to accelerate the smoke and direct it to the exhaust hood in our wood shop. The session was videotaped, and to limit reflections on the plexi-glass, the students all dressed in black. The students tend to get quite involved in the set up and as this and the light box project are used within first year courses, they tend to gather quite a bit of curiosity as well as experimentation.

**Understanding SCALE:**
Architectural detailing must be one of the most difficult aspects for students to learn. The challenge is to provide students with a project based experience that forces them to understand that the lines that they show on drawings are in fact, materials. When sections and details are drawn at a small scale, it is easy to fudge the solution. When the same section or detail is drawn at full 1:1 scale, this becomes impossible. For the terminal project for their first Building Construction course the students were required to design a small, insulated wood frame building and draw both an axonometric of the structural skeleton (at 1:25 metric) as well as a wall section at full scale. The wall section was not allowed to use cuts to reduce its height. We used a 1.2m wide roll of Kraft paper that could cheaply accommodate drawings in excess of 8m in length.

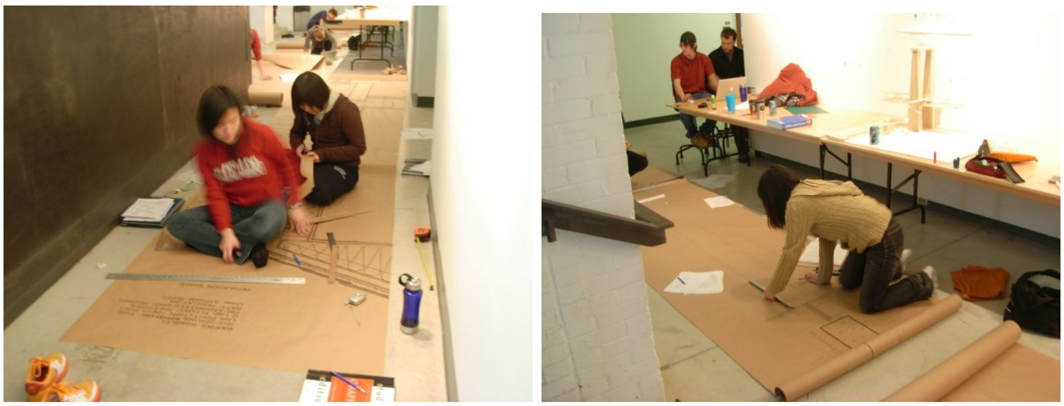

Fig 8: Drawing the full scale wall sections

This project was given for the first time in Fall 2007. It was not specified that straight edges were required to create the line work, but the first group to start decided to hard line their marker work and set a very high standard that the balance of the class followed. This project was done by groups of three students: one for the axonometric and two working on the wall section. They were required to coordinate the design and the detailing of the drawings. This served as their terminal project and was used in lieu of a final examination. Senior students vocalized envy at the project. With 22 drawings of close to 8 meters in length being created on all of the open floor space in the school, the project drew plenty of attention.

Fig 9: Masonry Wall Building Exercise

This same course also gives the students an opportunity to participate in a masonry workshop where they work in teams of 5 to construct 1.2 meter long sections of brick veneer, concrete block cavity walls. The sessions are held at our regional Masonry Training

Center. This field trip requires that extra time be appended to either side of the class time to accommodate the hour bus ride to the site. Full marks are given for participation and bonus marks are awarded for first, second and third prize. The walls are judged by professional masons. The act of building again assists in understanding the placement of materials and the potential differences in precision between drawing and building.

**Full Scale, Real Object, Real Load:**
Where most of the structural exercises have been incorporated into the constraints of a lecture format course, in one instance the entire Structural Design course suite was compressed to allow for the creation of a specialized design build course, while continuing to cover the material required by accreditation. Professor YY, for the terminal structures course, requires that the students design and construct a wood chair. Wood is chosen as it is relatively inexpensive, and easily worked. Our students have had a dedicated Timber Design course prior to this project, which enables them to undertake the calculations.

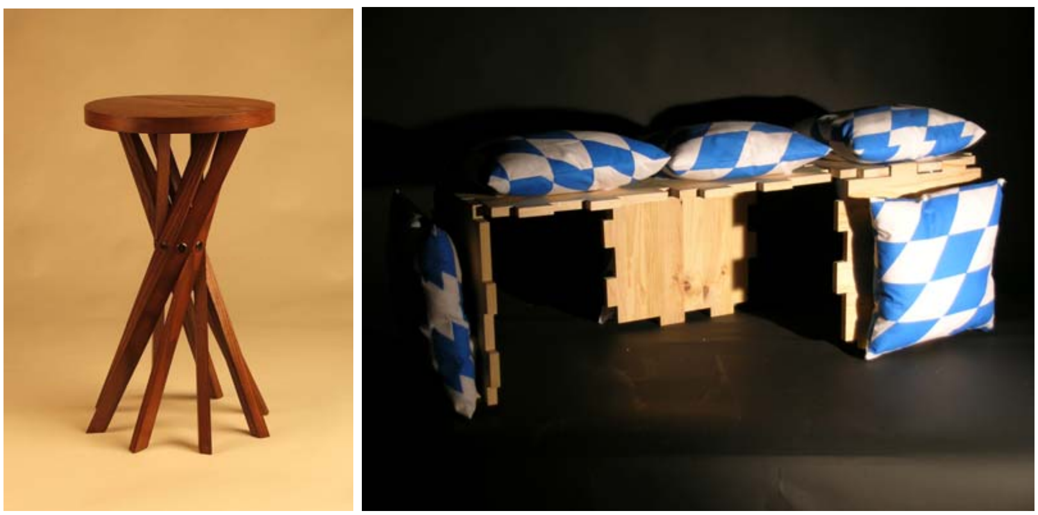

Fig 10: Third year student chairs (Melanie Ross, left, Adam Brady, right)

In this course the design, construction and testing of the object is the primary focus of the work, and the lectures, quizzes and review of Statics and Strength of Materials is tailored to assist the students with completing the chair specific calculations and assessments. This design course, although contained within the technology curriculum, has engaged other faculty members as they are drawn in to assist with the formal reviews of the chairs, as they are assessed not only for their structural merit but also on aspects of their design and aesthetics.

This exercise ensures that students truly understand the ramifications of design decisions as they must attach calculations to the outcome. The variety of chair designs was great – allowing for a range of discussions surrounding material properties as related both to geometry as well as detailing. This course was given for the first time in Fall 2007 and the instructor was surprised at the range of designs attempted, in spite of students understanding that the complexity of the object would require more difficult computations.

**Using Competitions:**
For students to seriously undertake a significant design project that runs parallel to (read, in competition with) Design Studio, there needs to be a major incentive to put extra effort into the work. Using an actual Design Competition has proven to be a major success in getting students to spend the extra time required to create a highly developed *technically proficient*

solution to a problem whose focus is clearly Design. Selecting the right competition is important as it is necessary to find one that reinforces the subject matter being evaluated. It is possible to layer additional requirements on top of the given pro forma – and require students to make a separate additional submission for the course to evaluate specific aspects that are outside of the competition brief. In the case of such a major piece of work, this has been done in lieu of a final exam in the subject. It has typically been weighted at 40% to 50% of the final grade and the students are allowed to work in pairs. We have used a series of competitions as the terminal project for our Building Construction, Digital Design and Environmental Design courses.

The Steel Structures Education Foundation Competition[10] is based on the design of a smaller steel structure (pedestrian bridge, tower, cantilever, tension members) and has been easily handled by first year students upon completing two courses in building construction and one in digital design. The limited scale and complexity of the competition allows students to focus on the development and detailing of a structural system that IS the design element of the project. In this way they are learning that the ability to understand and create innovative as well as functional details feeds directly into the quality of the design of the building. It has been used as a joint requirement with the computing course that has provided instruction in FormZ, Photoshop and InDesign. As a result the finished product has been more comprehensively designed than in previous years where projects were completed without either the incorporation of digital skills or with the intention of submission to a national competition. The attraction of prize money is not lost on the students. Our students win on a regular basis.

The competitions are submitted to two distinct courses with separate grading criteria. This is to avoid problems associated with double counting.


Fig 11: A first year student’s competition entry – final project for both building construction and digital design.

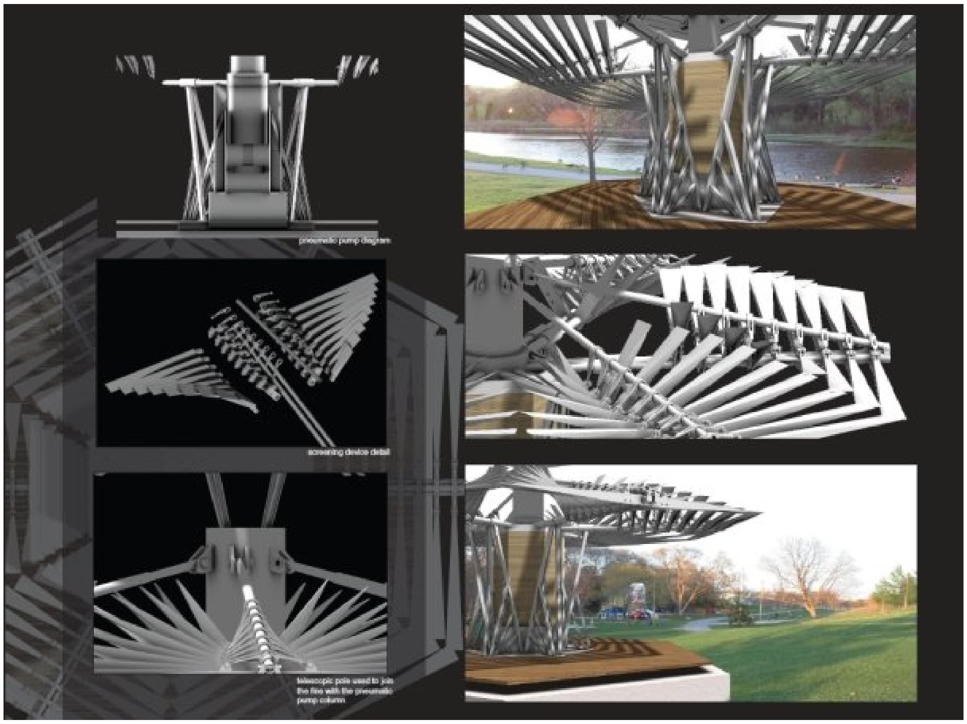


Fig 12: A first year student's competition entry – final project for both building construction and digital design.

This coming year the "Ecohouse Competition"[11] will be used as the terminal project for our second Environmental Design course. The students will work in pairs to design a building that will have to incorporate all of the principles they have learned in two core environmental courses, integrate their knowledge from their two building construction courses, incorporate both LEED™ and carbon calculations, and employ their digital skills to create the diagrams and renderings necessary for the competition boards. Most competitions have format requirements and a limit on the number and size of boards. This also factors in to the learning experience of the student and requires an additional thought layer in terms of designing the overall set of drawings and diagrams in a way that is able to be read in the absence of a public design review. Such projects must be even more complete than might traditionally be pinned up at an end of term studio review.

Past projects have been based on the former Architectural Review "A Writer's Retreat" Competition[12]. Although the competition has not been run on a continuous basis, the brief served as a useful way to create a comprehensive, however focused and limited design of a small ecological building. The bottom line is that it does not take much investigation to find a competition that can easily be adapted for use as a terminal technical/design project and which also leverages the interest and experience of the students. For environmentally based courses, the awareness of global warming has greatly increased the number of competitions comprehensively addressing this theme.

In addition to the lure of prize money, most of the competition winners are published, both on the Internet and in print. The students are very keen to be able to add these projects and citations to their portfolios – representing some of the only technology based work that does get included in their official "design" portfolio.

Using National and International competitions as the vehicle for the terminal technical project in a course sends a clear message to students that Technology IS Design. If approached comprehensively they can serve as good preparation for an eventual Comprehensive Building Design Studio.

**NONE OF THIS WORKS….**

None of this works if the design motivated and modeled projects are not situated in a course or slate of courses that provide excellent foundation and technical reference materials, lessons and case studies. The approach to teaching Technology as Design that is characterized by the aforementioned projects uses these frequent, discrete projects as experiential learning stations, strategically placed within a lecture format course. Each is preceded by introductory and supporting material. With the exception of the major terminal projects whose intention is clearly to replace the traditional final exam, each creates a limited interactive lesson on a very specific topic.

Creating design based exercises that are able to be implemented within a lecture format course, maintains the integrity of the lecture course. That these projects are innovative and potentially quite noticeable or public, allows for the leveraging of the technology curriculum in the eyes of the student, using projects that reflect aspects of technology that the profession has already begin to embrace, and creates the potential for a greater degree of interest, and eventually involvement, of the balance of the curriculum. This does not infer that such a curriculum negates the now divided roles of Architect and Engineer, but does create a positive spin on a higher level of communication between the Architect and Engineer on technical issues. And this begins to address the positive shift that is already happening in the Profession.

**Post Script:**

It would be the intention of the presentation to focus more on explaining and showing the student projects and less on a dissertation of the background material. The limited number of images in the paper makes it more difficult to simply visually show what we have been doing.

**Notes:**

[1] The Oxford Conference Web site: http://www.oxfordconference2008.co.uk/ The position papers of the speakers may be obtained here.
[2] This is covered in great detail in "Architecture and the Crisis of Modern Science" by Alberto Perez-Gomez as well as the "Ecole des Beaux Arts" by Robin Middleton. The shift to pragmatism is also evident in the "Precis de Lecons" by Durand.
[3] SBSE Web site. http://www.sbse.org
[4] BTES Web site. http://www.arch.umd.edu/BTES/
[5] Corcoran, Erin. Masters Thesis. Architecture: Developing a Self Aware Profession for a More Balanced Future. April 2008.
[6] National Architectural Accreditation Board: http://www.naab.org/
[7] Canadian Architectural Certification Board: http://www.cacb-ccca.ca/
[8] This project is largely based on a similar project given by Professor Pat Tripeny at the University of Utah and demonstrated at the Building Technology Educators Symposium in 2006.
[9] A more environmentally friendly replacement material is being sought for the black foamcore. The black color is needed to allow for high contrast visualization.
[10] SSEF Competition Web site: http://www.ssef.ca/competitions/ssef/
[11] Ecohouse Competition Web site: http://www.concretecentre.com/main.asp?page=1740
[12] A Writer's Retreat Competition: http://www.comarchitect.org/award_student_2003.htm