Developing Online Construction Technology Resources in Tectonic Design Education

Jeremy J. Ham\textsuperscript{1}, Marc Aurel Schnabel\textsuperscript{2}, Sambit Datta\textsuperscript{3}
\textsuperscript{1}Deakin University, Australia, \textsuperscript{2}Chinese University of Hong Kong, Hong Kong, \textsuperscript{3}Curtin University, Australia
\texttt{1}www.ab.deakin.edu.au/online, \texttt{2}www.arch.cuhk.edu.hk, \texttt{3}www.curtin.edu.au
\texttt{1}jjham@deakin.edu.au, \texttt{2}marcaurel@cuhk.edu.hk, \texttt{3}sambit.datta@curtin.edu.au

\textbf{Abstract.} We outline issues of importance in relation to tectonic design within the architectural profession and the relationship to architectural education in Australia. Twelve years of research and curriculum development at Deakin University is discussed, involving the creation of online resources and case studies, digitally-integrated projects relating to building construction and design studio education. The ethos behind the Construction Primer of engaging students as ‘amateur researchers’ in a way that ensures ‘that student research work is worth more than course assessment’ forms the pedagogical foundation of much of this work. A model of Socially Networked Construction Technology education has been developed that integrates social networks and the Internet to engage students in tectonic design within and outside the classroom through authentic curricula. Through the use of Virtual Galleries, Blogs, YouTube and social networks, a culture of peer learning and sharing has been developed. Through shared knowledge facilitated through social networks, great potential lies for expanding the synergies between higher order learning and online resource development for design decision support.

\textbf{Keywords.} Construction technology; social network; online learning; design decision support.

TECTONIC DESIGN

\textit{Tectonic design and the architectural profession}

According to Bernard Tschumi we are in a stage of history where ‘the architect becomes more and more distant from the forces that govern the production of buildings today’ (Tschumi 1995). These dissociations have led to the increase in generalist and the ‘sloughing off constituent skill areas, which (have) subsequently become professions in their own right’ (Cuff 1991). Although \textit{design} continues throughout the process, the majority of the architects’ work is based on the need to translate design concepts into real buildings and conversely, the need to understand how real built environments can inform design. Understandings of tectonic design principles are required to ensure buildings meet performance requirements, remain weatherproof, support loads and cope with movement and degradation of integrity. Indeed, a major cause of litigation between clients and architects is the failure of buildings due to ‘design shortcomings, particularly in the area of detailing’ because architects did not spend enough time checking technical issues’ (Caulfield 1990). Architects have a responsibility to society as professionals to obtain and maintain the knowledge required to address tectonic design as a core competency.
Tectonic mastery occurs when dedicated architects incorporate highly developed understandings of tectonics into the craft of architecture, independently of practice size, design approach or building size. The notion of tectonics as employed by Frampton (Frampton, 1995) places architecture within the craft of construction, arguing that modern architecture is as much about structure and construction as it is about space and abstract form. Much like the master composer, the architect as tectonic master must strive for virtuosity (McGilvray 1992).

**Tectonic design in architectural education**

The conscious cultivation of the tectonic tradition in architectural education is of critical importance as the primary means of developing the skills and attitudes of future practitioners. The development of appropriate “repertoires of knowledge” and skills is undertaken through a succession of design projects and technical courses throughout the architectural programme governed by accrediting bodies.

Although all registered architecture courses are obliged to meet the required standards for registration, the methods and the degree to which they prepare graduates for practice may be variable. Studies in Australia (Caulfield 1990) and America (Vasquez de Velasco 2002) have found that architecture graduates are often deficient in their knowledge of building construction. Deficiency in this important aspect of education is put down to ‘the insufficient technical undergraduate training of architects’ (Caulfield 1990). Although most courses dedicate a significant proportion of their course to building construction and other technical subjects (Padamsee 1991), the method of separating technical and design education may not be the optimum. As Abel states, ‘all of the factors have to be brought together somehow in the design process. That is of course where the design studio plays its part and where students are supposed to synthesise all of his specialist teachers’ different kinds of expertise’ (Abel 1995).

The integration of aspects of tectonic design into the design studio provides opportunities for the consideration of building construction as a design issue. Tectonics, when taught in subjects outside the domain of design may lead to competency in problem solving, ‘through the selection, from available means, one of the best (systems) suited to established ends’ (Schön 1983).

In order to address the concerns raised by Caulfield (1990) and Vasquez de Velasco (2002), and anecdotally by local practitioners, there are significant opportunities for design educators to further learn from the unique environment of the design studio. The translation from developing building construction knowledge to tectonic design knowledge may address more fully the requirements of competency for practice, and may help form the next generation of tectonic masters. This may occur through the integration of tectonic design into the design studio, or by integrating unique elements of the design studio into building construction subjects.

**THE EVOLUTION OF TECTONIC DESIGN EDUCATION AT DEAKIN UNIVERSITY**

The teaching of tectonic design and construction technology has evolved over the last twelve years at Deakin University across a range of units. Major impetus in the area was triggered by the 2000–2002 Deakin University- Adelaide University nationally-funded (CUTSD) teaching and learning grant entitled ‘Reflective Making: Higher Order Learning in Early Tertiary Architectural Education’. This project enabled the creation of curriculum and resources to support design education that involved early inclusion of reflection-in-action, road inclusion of designing construction in architectural design and the ability to adapt computer-aided design and related computer systems within a design process” (Radford et. al. 1999). Digital ‘Games’, and ‘Digital Projects’ were introduced into units in design and technology, resulting in the submission by students of thousands of digital files, including web pages, PowerPoint shows, movies and digital images relating to building construction (Challis 2002, Ham et. al 2002, Ham 2003).

Primary to this project was the building, by students, of an online virtual Gallery site (www.
ab.deakin.edu.au/online), which hosted a large number of online resources, student projects and images. The a+b/online Virtual gallery was used ‘by students primarily as an online gallery of student work for peer review and benchmarking and as an information source on construction technology for design projects. For staff, the Virtual Gallery served as a repository of student work for assessment, for inspiration, comparison and benchmarking, to assist in the ongoing development of academic programs and as evidence of high-quality output for several University and national teaching excellence awards’ (Ham, 2008).

Online resources include the Construction Primer (CP), initially developed at University of Wellington as an ‘online resource that looks at all aspects of building construction information. The resource contains an array of information varying from generic interactive 3D descriptions of how buildings go together, the standards and building control laws that regulate the built environment, and access to the professional bodies and manufacturer’s databases that influence practice’ (Burry et. al 2000). Digital content is created as part of project work in construction technology units, wherein students undertake research into construction elements, submit work for assessment and retain the work initially in print form, then online for reference and use in design decision support in students design projects.

The founding ethos of the CP, of *enacting students as amateur researchers* in a way that *ensures that student research work is worth more than course assessment* (Burry et. al. 1995) formed a profound influence on the development of tectonic design teaching at Deakin University and has formed the pedagogical basis of much of the work outlined below— even though the implementation differs greatly across a wide variety of projects.

The Deakin University Woolstores Multimedia Case Study (WMCS) was developed in 2001 as an online case study of a University campus converted adaptively reused from wool storage buildings. The WMCS was designed ‘as a case-based primer for the study of design and construction technology, as a structured case-study container for the addition of student digital construction projects and to benchmark student digital construction projects. The online case study utilizes 3D CAD models and multimedia in concert with physical connection with the actual building to generate holistic understandings of the transition of an idea to a constructed reality (Ham et. al 2002). Through second year construction technology projects interfacing directly with the WMCS, digital media was been utilized to unlock the construction knowledge embodied within the case study building, with deeper understandings of construction technology achieved through direct proximity to the building itself.

Furthering the idea that University campus itself can provide excellent case studies for complex, integrated buildings, the Learning Constructs case study of Deakin University’s Building T was hosted online and used as a learning resource for tectonic design education. This case study, developed primarily for construction management students, brought together a range of video interviews with stakeholders, documentation drawings, images of construction process and other multimedia resources. This case study was fully integrated into the construction curriculum in an authentic learning environment (Challis and Langston 2003). The Construction Primer, Woolstores Multimedia Case Study and Learning Constructs form the core of online resources hosted on the Virtual Gallery site.

Significant further developments in online tectonic design teaching have evolved in conjunction with case study and resource creation since 2001. Direct integration between design and construction technology units was achieved through the ‘Discovering Construction through Architecture’ project (2001–2005). This curriculum achieved direct integration between construction management and architectural design units through the selection of architecture students’ digital design projects for teams of construction managers acting in a role-play environment as developers charged with realising the design intent.
Developer teams used web-authoring software (Dreamweaver and Flash) to develop websites hosted on a School server that recorded the research and development process, including construction detailing in 3D CAD and 1:1 model form, flow charts, risk analysis and constructability analysis. The programme was an exemplar of a way in which IT may be used to facilitate integration between units in a practicum based on role-play, with ‘significant peer learning opportunities provided through collaborative work, peer review and online websites’ (Ham 2002).

1:1 Modelling has been integrated into the design studio at Deakin University as a means for architecture students to understand relationships between design conceptualisation and making, and between physical and digital modelling (Newton and Burry 2001). Through design ‘Games’, students firstly composed a piece of music or soundscape, then designed a “Music Room” that related to the composition in some way. Projects were selected and developed into full-scale in teams of ten over a two week period. ‘Games, digital project and 1:1 construction projects work together to reinforce the integration of music and architecture within an authentic learning environment (Ham 2005). The full-scale Music rooms, destined for destruction following their exhibition on-campus, were retained virtually in the a+b/online Virtual Gallery.

1:1, Or real-scale construction was determined to provide the ultimate learning experience for architecture students in relation to the development of tectonic knowledge in the design studio. Learning outcomes for physical models, drawings (CAD and manual) and 3D CAD, although valuable tools in the development of design through the stages of design (limited mainly to schematic and design development within the studio context), did not compare to the value of learning experiences inherent in 1:1 construction (Ham 2010a).

With the advent of the Web 2.0 technologies of blogs, YouTube and social networks around 2004, further opportunities arose to teach tectonic design in ways that lowered the ‘overhead’ on both staff and students. Ham and Dawson (2004) and Ham (2008) discuss problems of technical literacy, management and infrastructure that limit the development of online resource creation in design and construction technology. Ham (2010) also discusses the limitations of University-based LMS, and the need to ‘work outside the system’ where appropriate to achieve learning outcomes. The ‘overheads’ of requiring students to learn web-authoring programmes in order to create digital projects that are then posted online, as well as the management of digital information were found to be major limitations in the expansion of the www.ab.deakin.edu.au/online site.

The answer to these problems was the engagement in blogs for students to post their work, reflect on the process and outcome of design projects, encourage peer learning and review and for design decision support hosted on the Virtual Gallery site. The a+b/online site still serves as the primary link age point for the blogs, however all digital information is hosted off-site. Through password-controlled access to their www.blogspot.com site, students have full control to either delete work or retain the project online after assessment, thus solving issues of ownership and permissions.

The result of twelve years of development is the vast range of online resources that have been created by students, for use by students in design decision support for design studio projects.

**THE SOCIAL NETWORKED CONSTRUCTION TECHNOLOGY UNIT (SNCT)**

The SNCT comprises a logical formation of the evolving streams of 1:1 construction and resource creation for design decision support within the ethos of the Construction Primer. These streams were brought together within a social network through engagement in online blogs, YouTube™ and Facebook™ (FB) (Schnabel and Ham 2011). Social networks were used as a means of engaging students in construction education socially outside of the limitations of the University’s LMS, which include the development of silos of knowledge, lost opportunities for students to engage with each other and
industry sources and limited sharing of resources for design decision support (Ham 2010).

The SNCT was developed in the second year construction Technology unit, SRT251 from 2009. This unit, core to both Bachelor of Design (architecture) and Bachelor of Construction Management students, is centred on the development of understandings of long span, low rise, commercial and industrial construction technologies in concrete, timber and steel. The unit combined theoretical studies of building construction and structures, learning through student-led research projects and the hands-on making and breaking of beams and trusses.

The unit comprised a twelve week series of 2 hour lectures on building construction and building structures with weekly tutorials and workshops, taught to a cohort of 152. Assessment was through two projects worth 25% each and a three hour examination worth 50%. Whereas the examination is based on the theory-driven lecture series, the two projects are designed to engage students in authentic learning connected to ‘real world’ construction technologies and processes and the physical process of making in construction. These distinct learning approaches are designed to complement each other, allowing students with different learning styles opportunities to engage in the subject.

‘Making and breaking’ blogs
Project 1 required teams of ten students to competitively construct a beam or truss structure that will span 4800mm, with a maximum structural envelope of 4800 x 600 high x 150 wide using 4 sheets 6mm plywood and 20 linear metres of 70x35 MGP10 pine. Students designed and built a variety of structures-trusses, fabricated beams and stressed skin structures in their teams, the challenge being enhanced by the limited material set available. Structures were tested using a point load compression-testing rig. Students were required initiate and develop blogs hosted on www.tumblr.com which was linked to the Virtual Gallery site. Weekly posts utilised multimedia including text, images and YouTube videos to record the process of design, development and testing of the structures, and also to monitor the activities of team members for assessment. This project was founded on the integration of physical making at 1:1 scale for the learning of structures- encompassing the complete experience of thinking, theorizing, designing, making and breaking, followed by reflection, to calibrate students’ structural intuition.

Outcomes for the project were widely variable-with groups variably constructing structures that were completely incompetently designed and fabricated to those that demonstrated complete tectonic mastery. The ‘winning’ group fabricated a laminated stressed skin plywood beam-truss that remained unbroken at 27kPa, whilst other structures failed at only 1-2kPa.

The project design allowed equal learning opportunities through both success and failure. The initial learning experience of building a 1:1 structure was reinforced by further self-directed learning through comparing make and break outcomes online in the blogs, thus completing the cycle of learning through the addition of ‘reflection-on-action’ (Schön 1983).

Youtube construction videos
Project 2 furthered the agenda of authentic learning through the engagement of students in the ‘real world’ of construction technology outside of the university environment. Students were required to form groups of three, then visit buildings under construction and research three construction assemblies or processes. Students variably obtained working drawings, interviewed engineers, architects and construction managers and undertook background research into theoretical aspects of the case study buildings.

Research information was then compiled in the form of a ten minute video, utilising sound and music, video, still images and voice over (as well as humour) to communicate their research in a way that to overcame the traditional ‘dryness’ of the construction technology topic matter. Outcomes for this project were typical of the wide range inherent in any
large cohort of students, ranging from basic presentations to interesting and informative, professional quality construction case studies.

Projects were uploaded by students to YouTube with embed links emailed to the unit chair as the formal means of submission for assessment. From these 50 digital submissions, a Virtual Gallery page was created for purposes of use as a shared learning resource. As the list of construction assemblies and processes closely matched the course content, these videos made the perfect resource for revision for the examination, which was worth 50% of the unit marks.

The model for this project realises the core ethos of the Construction Primer. The vast resources and energy of the cohort of 152 students was used to gather a large amount of up-to-date and highly relevant information based on case studies of over 40 buildings in the area. The importance for students of this resource is realised in both the immediate need for study material for the examination, but also as a student-created resource for design decision support within the studio.

**Facebook as learning management system**

The two projects for the SNCT outlined above, are contingent on the use of a FB group as the substitute for the University’s LMS. The key to the SNCT is the foundation within the real world of construction technology (on the job site and in the workshop) but within a parallel environment of the social network. FB operated as the interface between students and staff and formed a core facilitator of the peer learning principles behind the unit.

The FB group was used by students to communicate ‘out of hours’ with staff to enhance and clarify project information and to answer questions directly. Significant peer-to-peer learning occurred within the group when students answered questions posted by others, with some students forming offshoot FB groups to facilitate their project work. The Blogs and YouTube sites were linked to the FB group and individual exemplars posted to the FB wall to reinforce key points in the course. Activity within this group generally underwent the stages of ‘induction’, ‘socialisation’ and ‘maturity’ outlined in Ham and Schnabel (2012), with an intense period of use during the final week and the revision period prior to the examination, where the need for information increased.

**The pedagogy of the social networked construction technology unit (SNCT)**

We refer to research undertaken in Ham and Schnabel (2012), wherein key attributes of the Social Network Virtual Design Studio (SNVDS) were outlined. These attributes are core to both the SNVDS and the SNCT.

**The nomadic device generation**

Architecture and Construction Management students in this cohort are approaching a state of ‘nomadic ubiquity’ (Attali, 2006), where optical fibre, Wi-Fi, 3G and 4G mobile technologies are used in conjunction with a range of nomadic devices such as Smartphone, tablet- and laptop-computers. Online sources such as FB, MySpace, Twitter, Skype and the various Google Apps enable unprecedented connectivity (Schnabel and Ham 2010). Potentially, students were able to take in information for both examination revision and to assist in tectonic design within their studio projects anywhere they had access to a Smart Phone, tablet device and 3G or wireless networks. This attribute of the SNCT holds enormous potential for the future of construction technology and other elements of design education and professional interactions (Howe and Schnabel 2012).

**Facilitating social engagement**

Social engagement occurred in the SNCT across a wide spectrum, including face-to-face social interactions in group work, tutorials, engagement with industry personnel in the case study and contact with the unit chair and tutors. Parallel social engagement occurred in the FB group, in YouTube through comments on videos and in interactions in the Tumblr sites. These interactions reinforce the Barkhuus and Tashiro (2010) finding that students’ use of FB
facilitated a variety of student-to-student interactions, including ‘casual interaction online, leading to casual interaction offline’. The SNCT enabled the Network Generation an appropriately wide variety of channels to learn in a way that responded to their learning needs (Oblinger and Oblinger 2005).

**From collective to social intelligence**

Collective intelligence in architectural design invites anyone to contribute to a design process through crowd sourcing even if each of the design processes is individual. In the case of the SNCT, Web 2.0 technologies are used to enable students to become participants: engaging in discussion forums, creating their own social and knowledge networks, taking part in polls and building communities and portals of knowledge. This provides opportunities for information to be shared among social groups, extending beyond the traditional construction technology unit setting, allowing for opportunities for collective intelligence to rise. This enabled through the social networks, the next step along the social and collaborative interaction, in which knowledge is generated and collected lays the collective social intelligence.

**Flat hierarchies**

The SNCT unit is founded on Alison King’s prediction that future educators must undertake the transition from being ‘the sage on the stage to the guide on the side’ (King 1993). In the SNCT, students themselves are a primary source of articulate and intelligent information on construction technology, in addition to material provided by the unit chair in lectures. The founding ethos of the Construction Primer, where the students are transformed from passive learners to amateur researchers actively contributing to the construction of knowledge is contingent on educators encouraging the flattening of hierarchies. By flattening hierarchies in this way, we argue that students engage in project work in a way that supersedes the immediate needs for assessment. This results in outcome potentials that are greater than traditional construction educational models.

**CONCLUSION**

The need to embrace tectonics in combination with digital technologies presents several opportunities for rethinking the role of construction units in architectural education. We have outlined the development of a model of “Socially Networked Construction Technology” education that integrates the freely available technologies of the social networks and the Internet. This is founded on twelve years of educational development and research in the establishment of online resources and the creation of authentic learning curricula. We find that in order to engage students in tectonic design within and outside the design studio, authentic curricula can be developed that allows students access to the real world of construction technology whilst utilising digital media and the Internet to enhance the process. Through the use of Virtual Galleries, Blogs, YouTube and social networks, the ethos that students can become amateur researchers, and complete project work for more than just assessment can be realised. Through shared knowledge facilitated through social networks, great potential lies for expanding the synergies between higher order learning and online resource development for design decision support.

**REFERENCES**


