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TEACHING TIMBER TECHNOLOGY TO ARCHITECTURE STUDENTS: REAL BUILDINGS AND DIGITAL TECHNOLOGIES

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ABSTRACT: There are various reasons why architecture students should be involved in both the design and construction of small but full-size buildings. The projects described in this paper engage students in the full range of issues in the realization of a well-resolved design vision, from beginning the client relationship through to the completion of a small 10sq.m building on site. The projects benefit all involved, providing not just educational outcomes for the students, but useful facilities for community organizations. The paper describes the Timber Technology course at the School of Architecture and Planning, University of Auckland, where students design and construct shelters for schools. The shelters’ timber parts are typically made by digitally controlled machinery. Different modes of learning are involved, including structural theory, design and construction. The paper examines how Multiple Intelligence Theory by Dr Howard Gardner of Harvard University explains the various learning experiences received by the students.

KEYWORDS: Teaching Timber Technologies Architecture Students, Education Theory

1 INTRODUCTION

Until 2012, the School of Architecture and Planning’s Timber Technology seminar course at the University of Auckland had focused each semester on the construction of a student-designed structure, typically around 10sq.m. This achieved the key course goals of exposing 4th year students to ways of building in timber and giving construction experience. In 2012 the course was reconfigured such that the group of 20 students assisted with the construction of a design produced by a 5th year thesis student. The project was an aesthetically and technologically innovative design that stretched the capacity of the School’s CNC technology and workshops. This course structure was retained, and in subsequent years further structures have been built, and the reconfigured course is now firmly established at the School, with 4th and 5th year students working together to realize innovative timber designs.

This paper discusses the many issues raised by the new course structure - student experience, peer-to-peer learning, community engagement, and the encouragement of technological innovation.

The housing research programmes by the Edfab group, which includes both students and academics, is also introduced. The aim of the Edfab research is to introduce digital fabrication to the existing analogue processes to create a balance that can aid the construction of domestic buildings which are affordable without compromising quality.

Finally in this paper, the experience of teaching students construction is examined in relation to the education theories of Prof Howard Gardner of Harvard University and those of the famous American architect Frank Lloyd Wright who ran a school for architecture students.

2 THE TIMBER TECHNOLOGY COURSE

Since 2003 Senior Lecturer John Chapman has been running a Timber Technology seminar course in the first year of the Master of Architecture (Professional) program at the School of Architecture and Planning (SoAP) at the University of Auckland. The course combined small group, seminar-style learning, with hands-on experience of fabrication in the workshop. Following an introduction to various timber technologies, students were asked to prepare designs for a timber structure, 10 sq.m. in plan area, which they then presented to the group. Aspects of one or more of these designs were then quickly developed and documented by Chapman for construction in the second part of the course. These teacher-designed structures – emergency dwellings, a bandstand, and so on - were then fabricated by students in SoAP’s extensive workshops and erected in the SoAP

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courtyard at the end of each semester. The funding for the material used in these projects was provided by sponsors in the construction industry. These projects achieved the key course goals - providing students with exposure to the possibilities of timber structures, as well as “real world” experience of construction.

2.1 COURSE EXPANSION IN 2012

In 2012, the Timber Technology course underwent significant expansion due to two factors. One was that Andrew Barrie, Professor of Design at SoAP, began to supervise the students who designed the constructions. The other was that the student constructions became community-based projects, shelters for schools in underprivileged areas.

Initially, Andrew Barrie was approached by Onehunga Primary School (OPS) for help with a design problem: OPS lacked a clearly defined pedestrian entrance, resulting in children and parents walking and waiting on a driveway at the front of the School at drop-off and pick-up time. OPS’ hope was that a pro bono project by architecture students could create a stronger street presence, and also ensure safety by separating pedestrian traffic from adjacent vehicles. Barrie approached Melanie Pau, a high-achieving student who took the OPS project on as the focus of her final-year MArch(Prof) thesis.

The project would have all the complexities of a real project – indeed it was a real project. Pau needed to link abstract architectural intentions to town planning issues, the client brief, construction methodologies, durability questions, and budget constraints. Pau’s designed her entranceway to exploit a loophole in the New Zealand Building Code. The project was to be located on ‘designated land’ and therefore required an application for an Outline Plan of Works (equivalent to a Resource Consent) be submitted to Council. However, if the structure remained under 10m² in plan, it would be exempt from the need to apply for Building Consent [4] [5]. Taking on this size constraint allowed more freedom in the design of the entranceway and removed potential difficulties and delays associated with lengthy consent processes with the nine-month-long thesis program.

OPS had just enough funding to provide materials for the structure, but relied on SoAP to provide the expertise and labor for the design and construction of the project. In the previous year (2011), Pau had been a student in the Timber Technology seminar course, and recognized the potential to integrate her thesis project with the seminar course in a way that benefitted both. The course was quickly restructured, with Chapman providing engineering know-how for the structure and Pau acting as a de-facto tutor for the seminar course. For the construction portion of the seminar, the students worked in the workshops under Pau’s direction on her thesis structure.

![Figure 1: Melanie Pau, Food for Thought, Onehunga Primary School, 2012](image)

The project presented the students with an exemplar of concept-to-construction design thinking. Dozens of sheets of plywood were cut on the CNC machinery, laminated together by the seminar students in the workshops to produce 50 elements.

A rigorous series of 1:1 prototypes were built to refine buildability and ensure ease of assembly. To help overcome their inexperience, the students are encouraged to prototype all assemblies and joints with 1:5 scale models followed by 1:1 physical mock-ups. The prototyping is an important step within the design and construction processes allowing students to become familiar with digital technology and to test out their ideas. It also prevents expensive mistakes. It has been noted by Professor Michael Stacey that architects and engineers enjoy physical testing, as it can ensure a reasonable level of confidence before final construction takes place [1]. While it took a month to prepare the structure’s plywood members, this rigorous testing of detailing and fabrication meant that it took only 12 hours for the group of students to assemble the structure.
Pau wrote, “The Entranceway was designed and constructed to benefit two communities – to educate and inspire the community of Onehunga Primary, and to develop the skills of the student volunteers who built it.” [2] As well as providing OPS with much needed facilities at minimal cost, the project provided Timber Technology students with an engaging and rewarding workshop experience. Through this course, students learnt to understand material properties, innovate within limited budgets, and to communicate and collaborate with their peers. The new course structure resulted in a number of innovations for the School: it created a new model for the construction of student projects which are of long-term benefit to the community; it created connections between year levels which aid the sharing and accumulation of knowledge, with ideas and experience being developed and passed down through the student cohort; it provided first-hand experience of full-scale project management. Perhaps most importantly, it pushed the level of design and technological engagement to a much higher level

2.2 ONGOING PROJECTS

Beyond benefitting OPS and the students constructing the structure, the project has had longer-term benefits. Pau’s project was very well received by the OPS, and they subsequently requested the construction of further structures. Pau’s Outline Plan of Works application had included spaces for two further 10m² structures, and in 2013 two students – Sam Wood and Yusef Patel – completed these structures as part of the their own MArch(Prof) theses, following the model established by Pau. In 2014 it was concluded that there was not scope for further structures at OPS. However, Henderson High School, who had heard about the OPS projects, stepped forward to request structures as part of a rejuvenation of its grounds. Two shelter structures – by Zhengbang Liu and Patricia Balbas – were completed at Henderson High in 2014, and a further two in 2015 by Charlotte Farquharson and Louie Tong. The integration of the timber technology seminar with thesis projects is now firmly established at SoAP.

With the exception of one project, the students’ choice has been assemblages of CNC-cut plywood parts. Like the inventors of WikiHouse, students view plywood as a versatile product that performs both structurally and aesthetically.

The advent of personal computing and other electronic devices has provided the younger students with a view of the world that is radically differently to previous generations. This substantial shift in thinking allows them to usher in a technological and social change to challenge the way architecture is practiced [3]. There is a growing trend for architectural graduates to take part in digital fabrication [4]. Many tertiary institutions such as the University of Westminster and London Metropolitan University provide design-build studios. Impressive results have allowed them to take part in Nevada’s Burning Man Festival and the Solar Decathlon Competition [5].

Theories of structure are taught within the lecture
environment. At SoAP we have observed that effective tutorials where the students make small constructions to test this theory can reinforce learning in a satisfying way. For example, when students are given a beam and a set of weights, and then asked to calculate the theoretical beam deflection. A satisfying ‘circuit’ is completed in their minds when they load the beam and the resulting deflection is comparable with the theoretical deflection. Thus, the students have learnt the same material in two distinctly different processes and environments. It appears that student understanding is enhanced when there is more than one type of learning involved.

The projects developed through the integrated seminar-thesis structure have received a number of international and national awards. Melanie Pau’s project received the 2013 Bentley Systems’ Scott Lofgren Student Design Awards, an international award for innovative engineering, and was Highly Commended at the 2012 Cavalier Bremworth Unbuilt Architecture Awards. Similarly, the pair of shelters by Wood and Patel won the 2014 Bentley Systems’ Scott Lofgren Student Design Awards. Pau’s entranceway, as well as Wood and Patel’s shelters, were awarded Gold Pins in the Designers Institute of New Zealand’s Best Awards. Three of the projects, those by Pau, Wood/Patel, and Liu, have been finalists in the NZ Wood Timber Design Awards. The projects have also been published in national design magazines, websites, and newspapers.

3 OTHER STUDENT WORK AND THE EDFAB RESEARCH GROUP

Another design and workshop-based course at the SoAP is called Material Fabrication. Fourth year architecture students are asked to individually produce a piece of furniture, joinery or other approved object. There is an emphasis on producing items of lightness and efficiency.
Yusef Patel, presently a PhD candidate, was a student in the 2012 Timber Technology course and in 2013 designed a shelter for Onehunga Primary School. Currently, he is re-thinking timber house construction, replacing timber stick framing with assemblages of plywood parts. He is also part of a larger research group called Edfab (Environmental Digital Fabrication) which includes five academics. Other undergraduate and postgraduate students temporarily join in to assist with the Edfab projects. To date, the EdFab group has completed a 12m² sleep-out to Passivhaus standards made of close-fitting CNC cut plywood components that fit together similar to those of a jigsaw puzzle.

Early innovator Larry Sass from Massachusetts Institute of Technology researched how digital technologies and plywood could be used to solve housing problems through digital fabrication [6]. In 2008, at the ‘Home Delivery’ exhibit at Museum of Modern Art (MoMA) he presented the Instant House. The project identifies how plywood is an extremely dynamic material with the ability to be an effective medium for production of easy-to-handle structural and ornamental components. Sass notes that the only ingredients and tools that are required are plywood, a CNC router, a rubber mallet, a crowbar and a computer. There is a major problem for housing affordability in New Zealand, especially for young adults. The edFab research will try to discover if it is possible to design a house construction system that can be largely built by people who are relatively competent but not trained builders? Self-build activities will include framing, installing insulation and linings, painting and decorating. Areas where professional help will still be necessary include building permits, drawings preparation, electrical and plumbing.

3.1 THE EDFAB RESEARCH GROUP

The benefits of a cross disciplinary team is evident in the Edfab projects. The team is comprised of students and lecturers from the University of Auckland who have expertise in different facets within the design/build
process. Their proficiencies range from spatial design, passive house design principles, production methodologies, engineering principles and client-led development. Improvements occur with each full scale prototype iteration. Efforts are made to use less material, improve liveability and optimise manufacturing and assembly. Prototyping, hand drawing, diagrams, scaled 3D modelling are the mediums used to explain, debate and resolve conflict between the parties.

For the first Edfab project, a large amount of time was spent in the physical processes of assembling prototypes. This prompted a rethinking in which a series of digitally produced components were replace with ‘off the shelf’ Laminated Veneer Lumber members. The resulting Edfab 2.0 construction system was a lot more efficient through the reduction of construction material and time needed for the manufacturing and assembling processes. It is ironic that by slightly increasing analogue and decreasing the digital, there was an ultimate increase in efficiency in the overall process. This goes to show the downsides of lurching to one side of the analogue-digital spectrum, no matter which side. The optimal position is one which balances both sets of technologies. Another benefit of the EdFab 2.0 iteration was simplification that allowed basic hand-held carpentry tools and participation by people without fully developed carpentry skills. The goal of the EdFab research is to introduce digital fabrication to the existing analogue processes to create a balance which can aid the construction of affordable domestic buildings without compromising quality.

4 COMBINING TEACHING RESEARCH AND ARCHITECTURAL PRACTICE

Beyond integrating the teaching of design with courses on construction technology, the project has created a nexus of teaching, research, and architectural practice – referred to by some as the ‘Holy Grail’ of academic life. Seminar students gain valuable experience by supporting projects by thesis students, whose work feeds in to the research and professional agendas of the academic staff involved. These projects have, for example, served as structural research for full-scale commissions such as Andrew Barrie’s Oxford Terrace Baptist Church project. The explicit linking of research to construction meets a much desired but difficult-to-achieve goal for the University – research projects that create direct community benefit.

5 MULTIPLE INTELLIGENCE THEORIES

5.1 HOWARD GARDNER

This paper examines educational theories that are concerned with teaching a topic from various viewpoints to improve student learning. ‘Multiple Intelligences Theory’ by Prof. Howard Gardner of Harvard University postulates that there are at least seven identifiable types of intelligence. These types are relatively distinct from each other but they rarely operate completely independently of each other [7]. He considers that tertiary institutions recognise only one area of intelligence that he terms ‘unitary intelligence’ and is the basis of IQ testing. Gardner’s describes his seven intelligences as Linguistic, Logical-mathematical, Musical, Bodily-kinesthetic, Spatial, Interpersonal, and Intrapersonal.

Brief descriptions of Howard Gardner’s intelligence types are:

- **Linguistic intelligence** involves sensitivity to spoken and written language, and the capacity to use language to accomplish certain goals.

- **Logical-mathematical intelligence** consists of the capacity to analyze problems logically, carry out...
mathematical operations, and investigate issues scientifically.

**Musical intelligence** involves skill in the performance, composition, and appreciation of musical patterns and rhythms.

**Bodily-kinesthetic intelligence** entails the potential of using one’s whole body or parts of the body to solve problems, to coordinate bodily movements. Howard Gardner sees mental and physical activity as related.

**Spatial intelligence** involves the potential to recognize and use the patterns of wide space and more confined areas.

**Interpersonal intelligence** is concerned with the capacity to understand the intentions and motivations of other people. It allows people to work effectively with others.

**Intrapersonal intelligence** entails the capacity to understand oneself, to appreciate one’s feelings, fears and motivations. It involves the ability to use such information to regulate our lives.

When the Timber Technology students work together and successfully accomplish all the project stages, from receiving the client’s brief to delivering a completed building, with the exception of ‘musical, all of the above intelligence types will have been applied. The table below lists Gardner’s various intelligence types and how they operate in completing a ‘shelter for school’ construction project.

**Table 1: ‘Multiple Intelligence’ types relating to students designing and building school shelters**

<table>
<thead>
<tr>
<th>Intelligence Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal-Linguistic</td>
<td>Communicating within construction groups to achieve outcomes; helping and teaching others</td>
</tr>
<tr>
<td>Mathematical-Logical</td>
<td>Deducing member geometries and structural member sizing to ensure sufficient strength and stiffness</td>
</tr>
<tr>
<td>Musical</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>Spatial</td>
<td>Shelter location on site and design; completing construction drawings</td>
</tr>
<tr>
<td>Bodily-Kinesthetic</td>
<td>The students as builders; making, assembling and finishing</td>
</tr>
<tr>
<td>Interpersonal</td>
<td>Listening and accommodating others to form a coordinated and functioning construction group</td>
</tr>
<tr>
<td>Intrapersonal</td>
<td>Thinking ‘off-site’ about achieving design and construction</td>
</tr>
</tbody>
</table>

After the completion of the 2015 class, the students were asked to reflect on their experiences of the course and to fill out the brief questionnaire below.

**Table 2: Student responses to questions re the 2015 Timber Technology Course**

<table>
<thead>
<tr>
<th>QUESTION</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have you experienced working with wood construction before?</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>Have you been involved with large, 1-to-1 scale construction projects?</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Through this course, did you have an experience working with others?</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>Do you feel the course helped you in achieving learning outcomes?</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>During each construction session, did you understand what was expected from you?</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>Was each construction session well organised the workload was evenly distributed amongst all the students</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>How well prepared were student leaders were before each session?</td>
<td>8</td>
<td>2</td>
</tr>
</tbody>
</table>

Ten out of the class of twenty replied and of those, approximately 80% considered that they had an experience that contributed to their learning in a well organised environment.

**5.2 FRANK LLOYD WRIGHT AND ‘LEARNING BY DOING’**

Frank Lloyd Wright was possibly the most influential architect of the 20th century. Mies van der Rohe, another famous 20th century designer said after meeting Wright’s work the first time at the 1910 Berlin exhibition, ‘After this first encounter, we followed the development of this man with eager hearts. We watched with astonishment the exuberant unfolding of the gifts of one of who had been endowed by nature with the most splendid talents. In his undiminished power he resembles a giant tree in a wide landscape, which, year after year, ever attains a more noble crown.’ [8]

Wright and his wife, Olgivanna Lloyd Wright, started a school for architecture students in 1932. Initially there was a role of around thirty students that eventually grew to double that size. He called his group of students the Taliesin Fellowship. Taliesen is the name of the farming property in Wisconsin that was established by Wright’s forebears and where he grew up. The Wrights circulated a prospectus in 1931 outlining their intention to form a school at Taliesin in Spring Green, Wisconsin with the concept of “Learn by Doing”. The prospectus included a broad list of student activities including ‘…music, painting, sculpture, drama…motion, philosophy…Mr
Wright emphasized the importance of integrating work and constant contact with nature and growth. Apprentices [the architecture students] were to live and work in buildings they had constructed or renovated… [9]

![Figure 14: Students at Taliesin learning about masonry by constructing a pier, 1933 [13]](image)

Wright only briefly attended tertiary education which was at the University of Wisconsin. He soon left for Chicago where he learnt the profession of architecture. It is perhaps the above experiences which explain why Frank Lloyd Wright strongly supported the traditional training of architects in the apprentice system. In his own practice, he was welcoming of both men and women apprentices.

The pupils’ activities at Taliesin were in three parts. These were students learning

- Architecture design and detailing
- All aspects of building construction
- Building maintenance and farming

It is easy to see that the students’ involvement with building construction and maintenance would inform their architecture design and detailing. The reason for farming is less obvious but it was for growing the food for the occupants of Taliesen. However, Wright may have considered this activity as being helpful to the students, perhaps in respecting nature.

It is interesting to note that many of the above student disciplines taught by Wright encourage the development of virtually all of Gardner’s types of intelligence. In this way the Wrights and Gardner are in agreement. The Wrights considered an all-round education was helpful to the architecture students within their care - development in all areas makes for a better whole.

6 CONCLUSIONS

There are various reasons why architecture students should be involved in both the design and construction of small sized but full-size community based projects. The projects engage students in the full range of issues in the realization of a well-resolved design vision, including: client relationship, site considerations, design brief, design development, budgeting, construction detail development, material selection, design documents, using tools, automated machine operation, construction, finishes, foundations, transporting and site placement. The projects benefit all involved, providing not just educational outcomes for the students, but useful facilities for community organizations.

At the School of Architecture and Planning, University of Auckland, the students in the Timber Technology course ‘learn by doing’ when they design and construct shelters for school children. The shelters protect the pupils from sun and rain. The architecture students, when working directly with building materials learn the capabilities and limitations of the materials. In their professional lives, architects write specifications and frequently supervise construction works. By carrying out small but real design-construction projects, students gain a deeper appreciation of the activities of the workers in the building industry. Community projects also help students understand the role of the architect and how he/she helps society and the built environment.

Howard Gardner’s ‘Multiple Intelligence Theory’ explains why teaching a topic from a variety of viewpoints leads to increased student understanding and satisfaction. ‘Multiple Intelligence Theory’ postulates that there are at least seven identifiable types of intelligence which are relatively separate to each other but they rarely operate completely independently of each other A very famous architect, Frank Lloyd Wright ran a successful school of architecture based on the principles of ‘learning by doing’. At this school the students were involved almost equally in both architecture design and building construction. Wright was assisted by his wife, Olgivanna Lloyd Wright, and they considered an all-round education was helpful to the architecture students within their care - development in all areas makes for a better whole.

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