Education, Design and Practice – Understanding skills in a Complex World

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TECHNICAL SKILLS FOR STUDENTS OF ARCHITECTURE

Authors:

PETE SILVER AND DR. WILL MCLEAN

Institution:

UNIVERSITY OF WESTMINSTER, SCHOOL OF ARCHITECTURE AND CITIES, LONDON

INTRODUCTION

Architects employ science in order to understand the structural and environmental performance of their products, and apply technology in order to assemble them. And although the role of the architect has changed/evolved even within recent history, the relationship between engineering science, construction technology and the design of the built environment has been at the core of architectural practice throughout history. 2000 years ago, Marcus Vitruvius Pollio (80-15 BC) commenced The Ten Books on Architecture with a chapter on "The Education of The Architect", where he states: "The architect should be equipped with knowledge of many branches of study and varied kinds of learning, for it is by this judgement that all work done by the other arts is put to the test". Vitruvius proceeds to explain and differentiate between practice and theory with the need for an architect to have "a thorough knowledge of both".[1]

This paper describes the pedagogic approach of the Technical Studies department at the University of Westminster to the architecture course for degree (B.A.) students. It demonstrates the product of this approach in the form of a small sample of student work over a period of roughly ten years.

TECHNICAL STUDIES

In the context of architectural technology, pedagogy implies the teaching of specific skills. In most schools of architecture the teaching of these skills is known as *Technical Studies*. In the year 2000, Pete Silver and Will McLean were charged – as joint-coordinators – with overseeing Technical Studies at the University of Westminster for the entire School of Architecture from first year Undergraduate through to final year Postgraduate. This gave them the opportunity to re-evaluate how Technical Studies was conceived and delivered for the whole school.

They found that whilst there was a wide range of technical information available, students throughout the course still lacked a basic understanding of many key principles. They realised that Technical Studies was not being taught within the context of architectural design and hence its application to, integration with and indeed its active participation in design thinking was often absent. Historically, the teaching of Technical Studies had been conducted largely by specialists – typically structural or mechanical services engineers – however the authors considered that understanding engineering science and construction technology from a purely scientific context assumed that the student could digest information in abstract (i.e. as distinct from design) whereas the study of architecture, along with the varied backgrounds of architectural students, was not necessarily conducive to such an approach.

They also found that there was no contemporary overview of architectural design within this context. Since the Industrial Revolution, there had been a continual and exponential increase in scientific and technological advances which would have an impact on how architecture could be engineered. What architecture was required to do over the course of the 20th Century was to make sense of the vast and ever-growing number of specialist fields that contributed to its discipline. And whilst this knowledge was available to specialists in publications dedicated to their fields, it was not being absorbed into publications for designers (and specifically for architects) in such a way that it might be readily digested: there was a lack of clarity and uniformity in the way that it was described and presented.

The authors considered that, as in other fields, the organisation and presentation of information were critical to an understanding of the subject, and that this understanding – that was in turn critical to how architects thought about design in relation to science and technology – was missing.

They therefore set about compiling a new knowledge database for architectural technology, while re-designing the teaching, learning and assessment of Technical Studies for the whole School of Architecture at the University of Westminster.

A NEW KNOWLEDGE DATABASE

Underpinning the teaching programme designed by the authors was the compilation and publication of a set of architectural technology textbooks (see Bibliography), and in particular *Introduction to Architectural Technology*, a publication whose aim was to introduce architecture students to the scope of the relationship between design and technology with the specific intention to enable them to integrate their design thinking with appropriate structural and environmental solutions. The book set out to explain the relationships between physical phenomena, materials, building elements and structural types, using simple classification systems and real-world examples. Photographic images were used to familiarise the user with common construction technologies, while historical examples were employed to chart significant moments in the history of architectural engineering. The Contents page was designed as a branching system so that the user could contextualize any topic within the book. Every spread had a topic heading that could be cross-referenced with the contents tree (Fig. 1).

General classifications

Although it was appreciated that for many early building types the structural and climatic enclosures were one and the same (e.g. earth or ice), architectural technologies were divided into the two major headings of Structure & Form and Climate & Shelter (see Figure 1). The section on Structure and Form was subdivided into three main topics: Structural Physics, Structural Elements and Structural Logic, providing a linear progression from the fundamental principles of structural form – materials science, materials technology and structural integrity – through descriptions of the common elements used in the construction of buildings (such as walls, columns, floors and roofs), to how these elements are combined to form different building types, from simple 'post and beam' structures through medieval vaults to aluminium monocoque shells and tensile nets.

The subdivisions in the Climate and Shelter section dealt with two main topics: Human Comfort and Building Performance. Before examining how buildings are constructed in relation to their local environment, it was considered important to establish the thresholds within which the human body is able to sustain life. The first part of this section therefore examined the principles of thermal comfort and its provider, the sun, while the second part considered ways in which the performance of buildings could be designed passively to maintain human comfort.

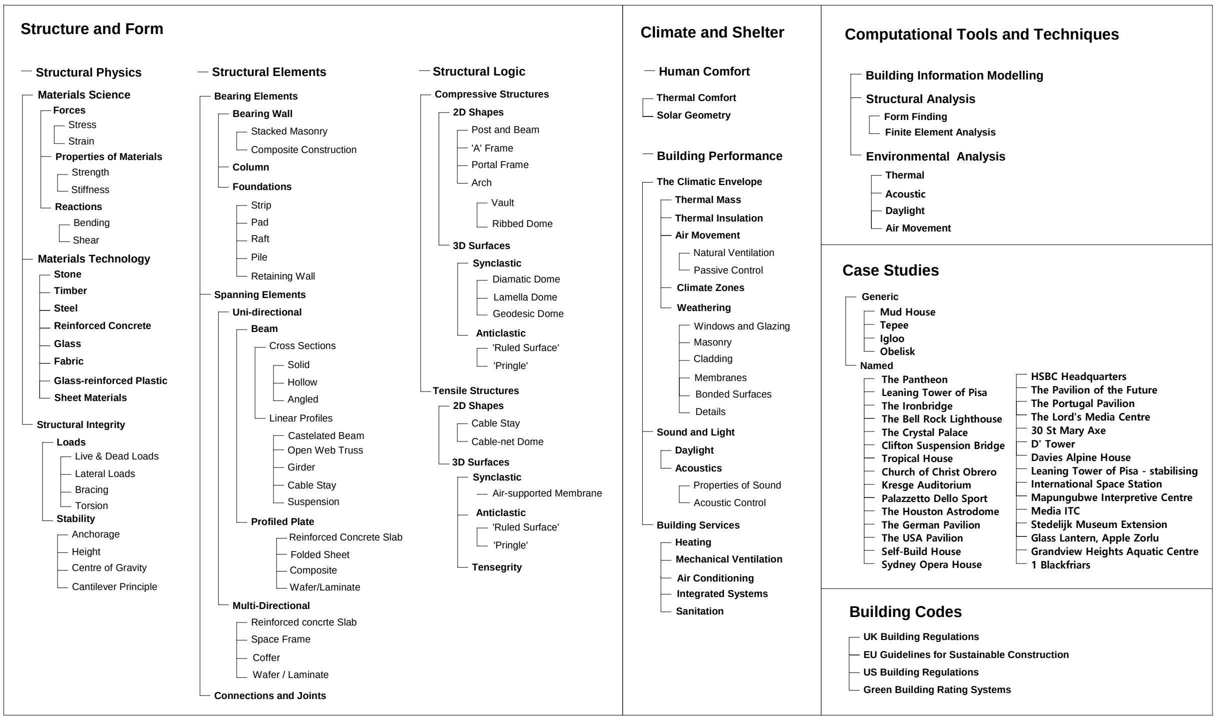

Figure 1. Contents page from Introduction to Architectural Technology (3rd ed,).

Structural taxonomies

The authors designed new taxonomy charts for the section on Structure and Form, demonstrating how to categorise a range of primary structural types, and covering both (mainly) compressive as well as (mainly) tensile structures (Figure 2).

It was considered that whilst engineers classified building types according to physical forces (Heino Engel in *Structure Systems* employed terms such as 'vector-active' and 'section-active'[3]) the key to understanding structural logic for architects was primarily visual – pictorial, hence through geometry and geometric procedures. This morphological taxonomy of structural logic was then designed using two systems: the first involved the application of geometric transformations to a set of primary structural shapes, i.e. to convert (two-dimensional) sections or areas into (three-dimensional) volumes through iterating by extrusion or rotation; the second described classifications for complex double-curved surfaces that could not be understood purely from one or more cross-sections. These were classified as fundamentally synclastic or anticlastic.

Figure 2. Structural taxonomies from Introduction to Architectural Technology (3rd ed,).

THE ACADEMIC PROGRAMME

The following pages are divided into sections that correspond chronologically with the undergraduate technical programme at the UoW School of Architecture during the relevant period, viz.:

- First year / term one: observational exercises
- First year / term two: 1:1 workshop studies
- Second year: small-scale structural design projects
- Third year: environmental design – façade projects

First year / term one: observational exercises

This first year technical courses were designed to introduce students to structural and environmental principles, with the aim of establishing materials technology, construction processes and building physics as integral to architectural design thinking. A dedicated lecture series was based around *Introduction to Architectural Technology* and covered the following topics:

- Structural physics – loads / reactions / structural integrity;
- Structural elements – bearing elements / spanning elements;
- Structural logic – compressive structures / tensile structures;
- Materials technology – timber / concrete / steel / glass / masonry / plastics;
- The passive climatic envelope / cladding and facades / architectural acoustics and daylighting.

Students were assessed through an assignment that required them to demonstrate their awareness of essential structural logic. They selected an existing large-span structure (such as a train station, sports hall, glass house or stadium) and make in-situ, annotated sketches in order to represent its overall structural composition, its principle structural elements, and how these functioned to resist loads (i.e. primarily in tension or compression). Students were encouraged to consider drawing structures as if they were producing a life drawing: It was presumed that structural form was best understood by studying and observing it with the same intensity and attention to detail as if sketching a bowl of fruit, a body, or a face. Students were also obliged to annotate their sketches as the lecture series progressed and they were able to identify the material composition, construction elements and general typology of the structures that they were observing.

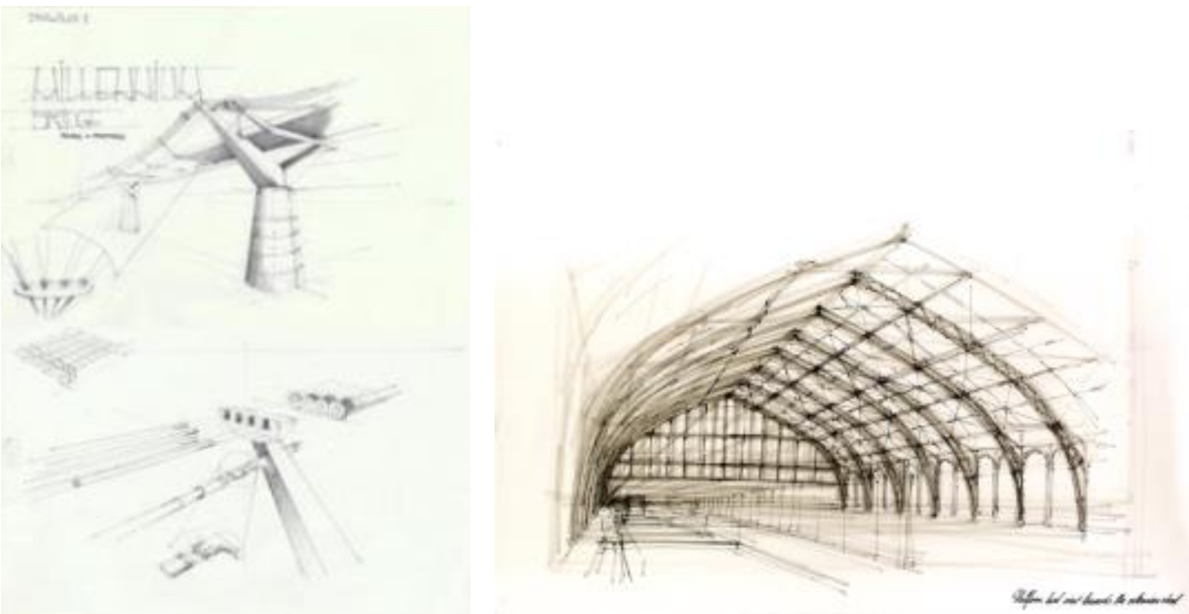

Figure 3. First year observational exercise.

First year / term two: 1:1 workshop studies

The second technical assignment for first year students was planned as a practical project. The aim was to develop an understanding of structural design through a hands-on exercise that would involve the students in exploring the properties and characteristics of materials and learning to use the workshop and fabrication technologies available to them.

Load-testing

To this end, students were challenged to solve straightforward structural problems. Each year at a 'show-and-tell' event every project was presented, load-tested and analysed. As well as meeting the criteria described in the briefs, each piece was evaluated according to its structural logic, its lightness and efficiency, the innovative use of materials, craftsmanship and detail. In none of the briefs was there an imperative for the objects to be demountable or deployable and yet students often chose this route (this could have been for purely pragmatic reasons, i.e. ease of transportation; nevertheless…). Similarly, a number of objects were designed such that they only achieved their optimum positioning once loaded. Projects included a glass floor, a cantilever and an open-web truss (Figures 4-6).

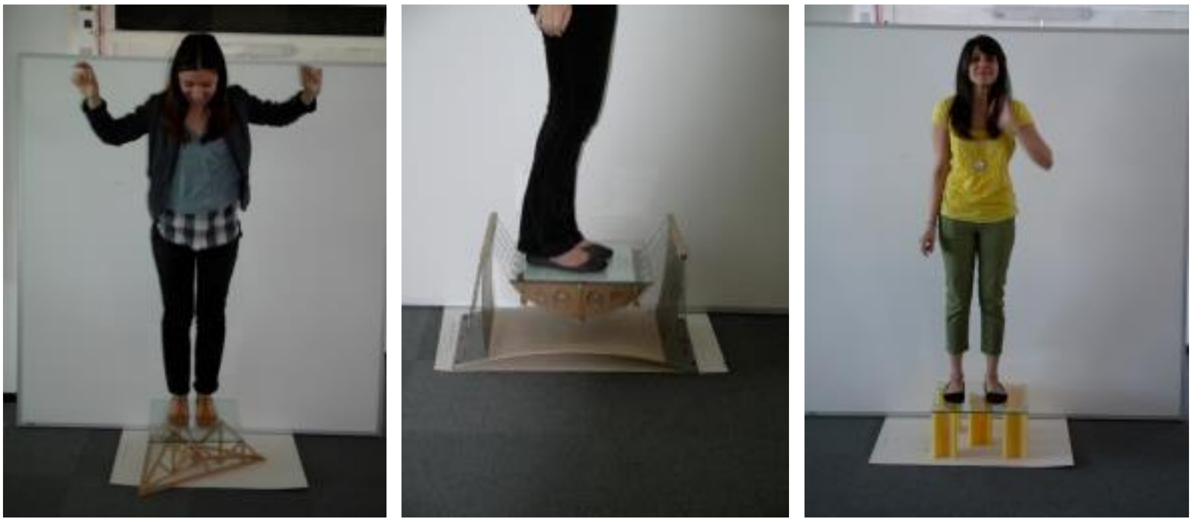

Figure 4. Glass floor project (2008) – Students were asked to design and build a platform that would support their own weight 200mm above the ground; the floor of the platform was float glass – 400mm x 400mm x 6mm.

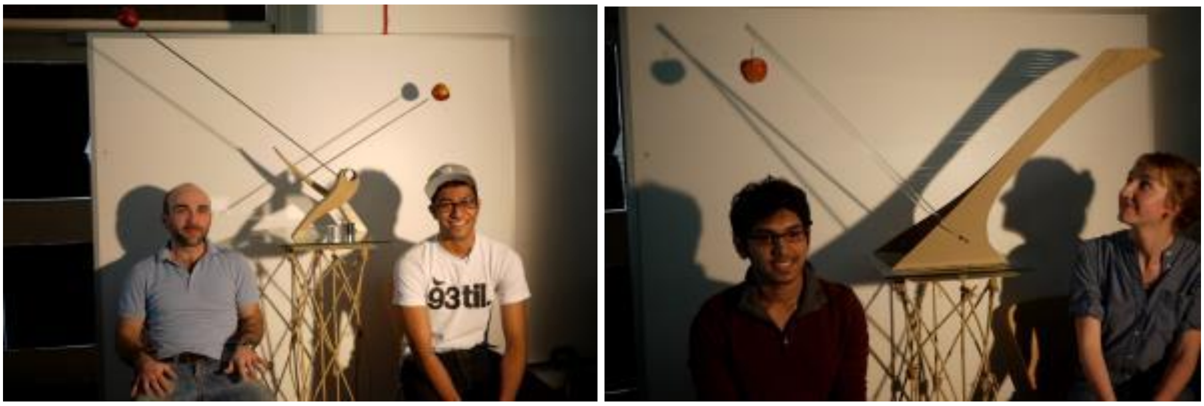

Figure 5. Cantilever (2011) – Students were asked to design and build a structure that could cantilever an apple at a height and distance of 400mm. The footprint should be no more than 400mm x 400mm.

Figure 6. Open-web truss (2013) – Students were asked to design and build a truss that was 1400mm long and 330mm deep that could support a centrally positioned load of 20kg. (The size of the truss was based on the ground floor fenestration of the UoW Marylebone building.)

Second year: structural design

During the second year of their studies, students would embark upon a Technical Studies module whose primary aim was to improve their understanding of construction techniques and processes. The module title was 'Making Architecture' and students received lectures from architectural and engineering practitioners discussing a wide range of projects and how these came to fruition – from inception to realisation.

For their coursework assignments, the Technical Studies team set discreet projects that challenged the students to design a small scale structure. Though not site specific, the structures had to meet certain criteria (e.g. lightness and efficiency) and had to be detailed such that the students were able to produce assembly drawings with all of the key construction materials, principal elements and connection details specified. Projects included a ten metre pedestrian bridge (Figure 7), a bandstand – an outdoor auditorium with a footprint of approx. 25sq metres (Figure 8) and a lookout platform – the *Baywatch* project (Figure 9).

In addition to producing a comprehensive set of working drawings, students were also asked to build a scale model – normally at between 1:10 and 1:20. Students were individually tutored and received further advice at a 'show and tell' day, where many of the visiting lecturers and other consultants were in attendance.


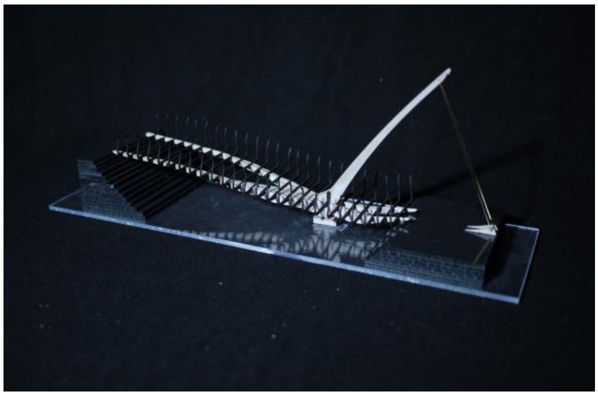

Figure 7. Ten metre pedestrian bridge.

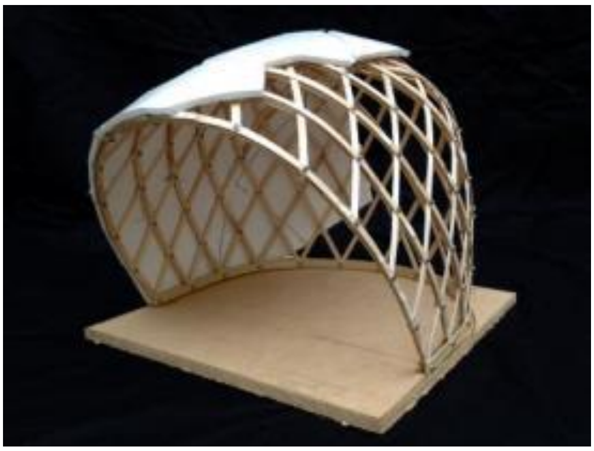


Figure 8. Bandstand.

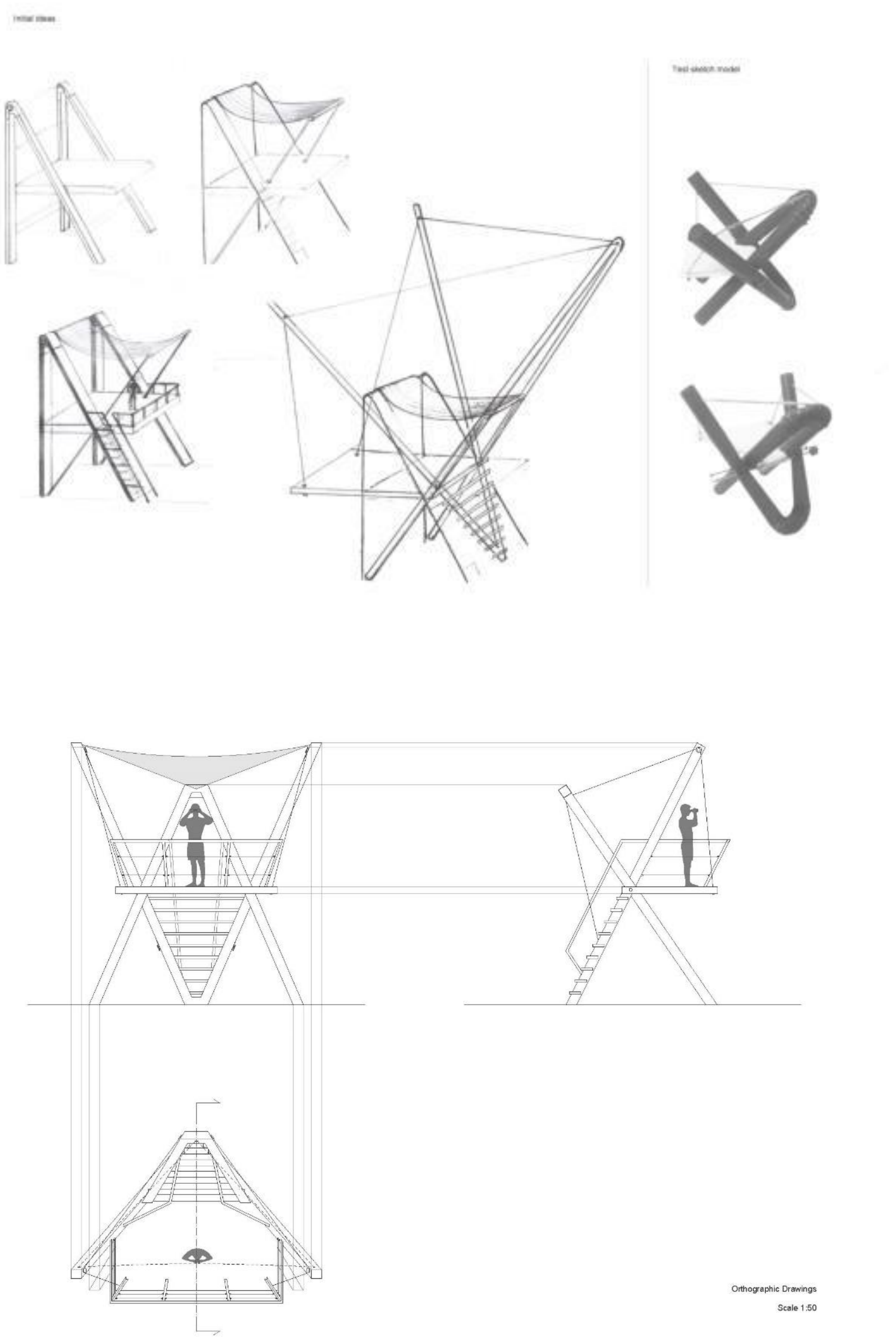

Figure 9. Baywatch project. Marco Catena

Third year: environmental design – façade projects

During the final year of their degree, students engaged with a Technical Studies module whose aim was to improve their understanding of buildings as climatic enclosures / ’envelopes’, as well as to introduce them to analog and digital (software-based) methods for modelling and analysing environmental phenomena. Students received lectures from visiting architectural practitioners and environmental engineers on projects that covered a wide range of both active and passive environmental design strategies.

For their coursework, the Technical Studies team set a discreet exercise that challenged the students to design a façade as a dynamic, environmental interface. The façade, though not site-specific, was likened to infilling a typical brick-vaulted railway arch, where a set of particular environmental conditions had to be considered:

- The façade was South-facing in the Northern hemisphere (or vica versa);
- There was a considerable diurnal temperature change – hot days, cold nights;
- Behind the façade would be a bar/café that required good natural light and ventilation.

The project therefore required students to consider that the façade might need to be dynamic, i.e. may need to adapt in response to the changing environmental conditions. Many students simply couldn’t resist designing a café; others invented their own programme and designed pavilions, greenhouses or entirely new, modular façade systems. Students were individually tutored and received further advice at a ‘show and tell’ day, where many of the visiting lecturers and other specialist consultants were in attendance.

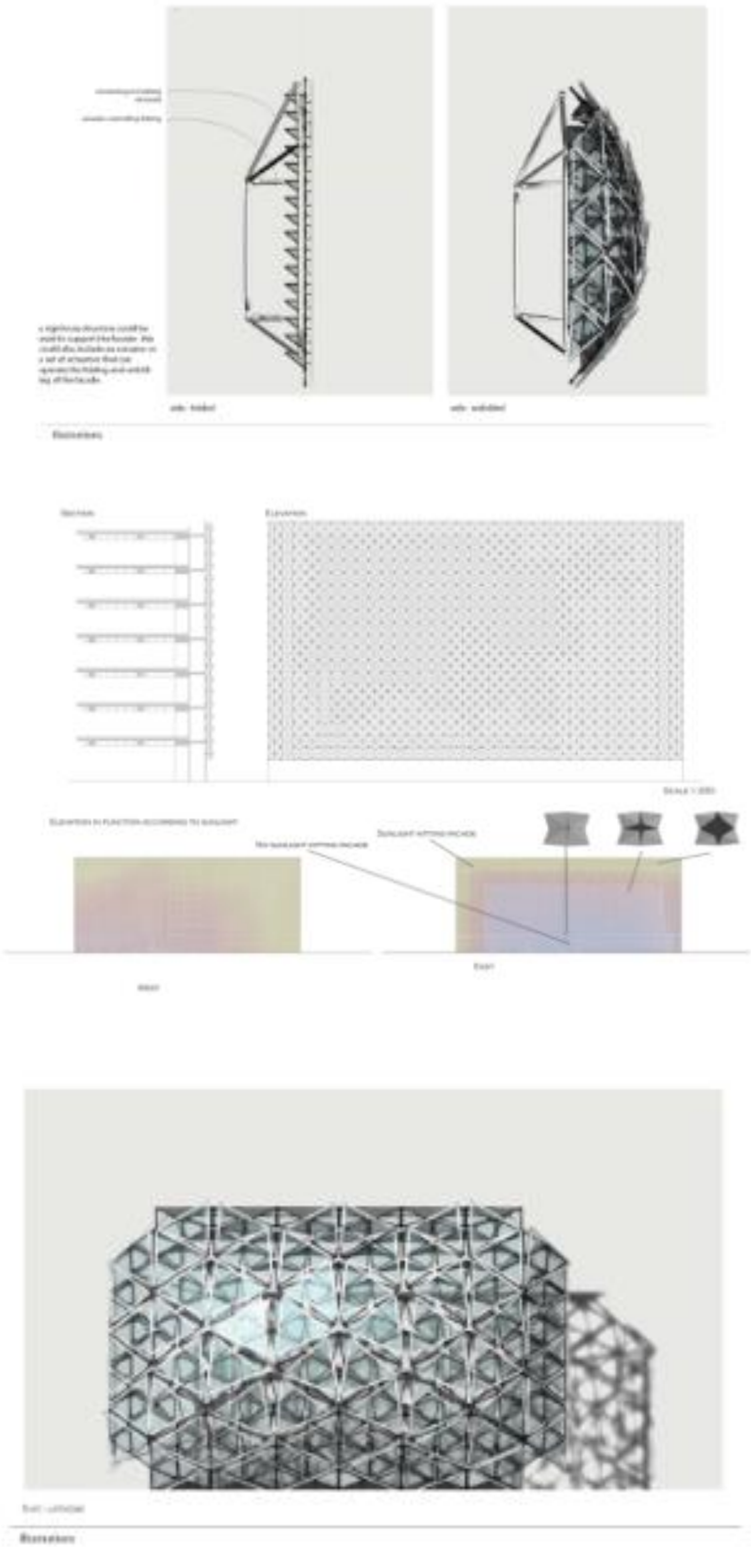

Figure 10. Façade project / Amer Aldour / Origami facade

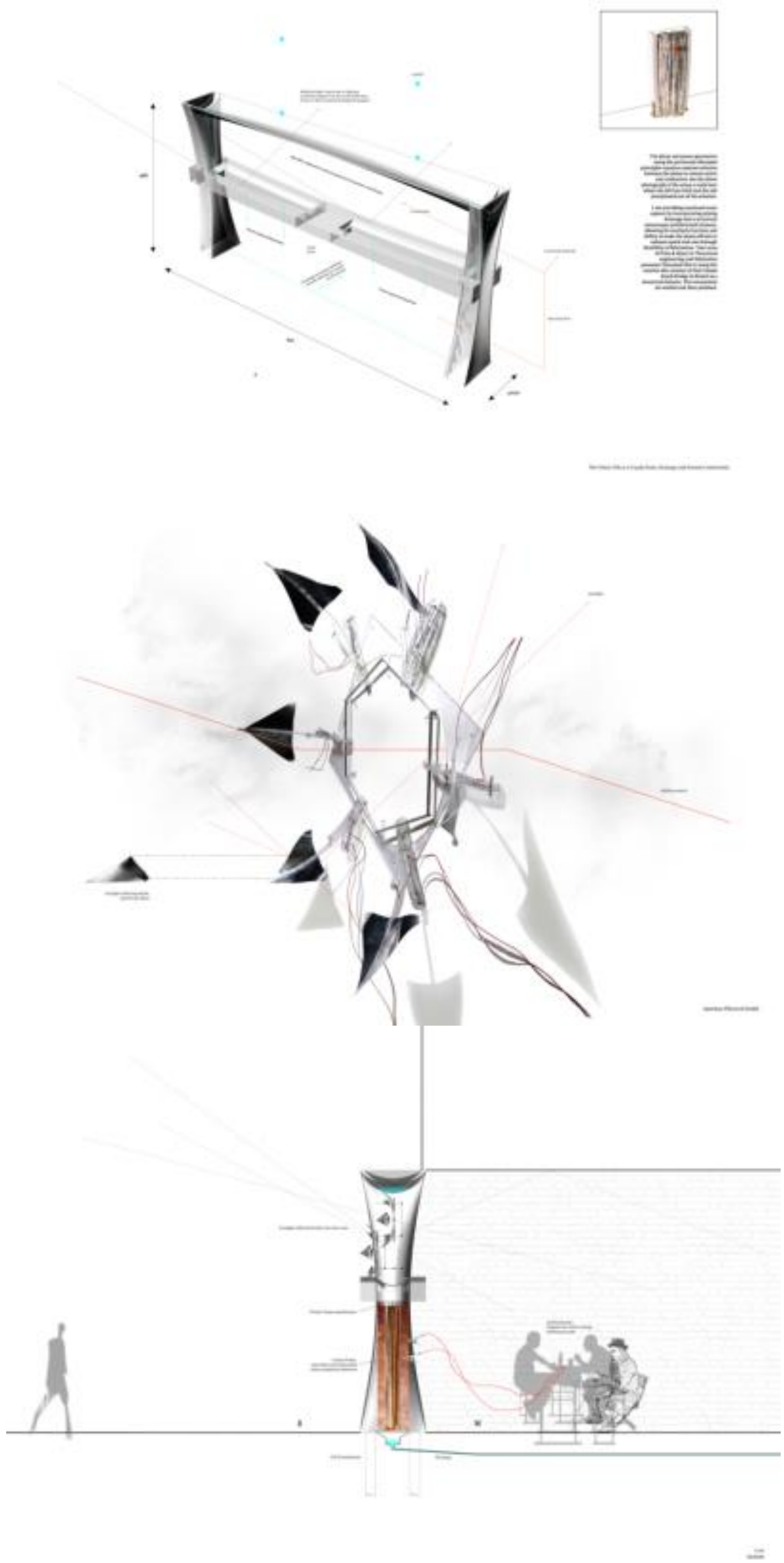

Figure 11. Façade project. Harish Persad / Memory metal skin

IN CONCLUSION

Evidence for the success of the pedagogic approach described in this paper may be found in the work of the students. When encouraged at the outset of their architectural education to produce 'life drawings' of structural form, students developed an appreciation for the built environment akin to that of the human form. This was evidenced by the quality and attention to detail in the sketches. Similarly, when asked to design a 1:1 construct to solve a straightforward structural problem – to resist loads and gravity – students, through prototyping and failure, developed an understanding of the properties of materials and how structures resist forces in tension and compression.

Using appropriate materials and understanding how to fabricate and assemble components was further developed in the second year Making Architecture projects. Here the underlying form of a small scale structure became the basis for its design, emphasizing the symbiotic relationship between design and technology in the built environment. It was often the first time that students had been asked to produce measured, scaled drawings: techniques that enhanced their confidence in the 'buildability' of their projects. This also helped to demystify the technical drawing, so that in their third year projects students were able to employ detailed 'working' drawings to illustrate complex and often dynamic façades.

The range of solutions that students proposed to the technical briefs outlined in this paper is evidence of one of Nature's key lessons – that simple rules will often produce complex outcomes. Inevitably, an academic paper can only provide a 'snapshot' of this evidence, however the volume, range and quality of output has been witnessed over the years by a wide range of visiting lecturers and critics. Alex de Rijke, founding Director of dRMM, states: "The work of the students unselfconsciously demonstrates that it makes no difference how well off you are, of which sex, age or colour. These projects, a paradigm for the principles of architecture and engineering design, reveal the only thing that counts is brains and hands. In the fresh student faces, standing on or beside their first constructions, and in their tense expression of fear, pride or release one can see emerging a lifelong relation to ideas, teamwork, invention, experiment and fabrication, and the relative parameters of success and failure. Between the lines of the deceptively simple briefs are invaluable lessons waiting to test the unsuspecting."

THE AUTHORS

Pete Silver and Dr. Will McLean are teachers and authors. They have co-authored four books on architectural technology that together have been published in nine languages and have sold over 10,000 copies worldwide. Silver is a Senior Lecturer and a Director of the Chartered Practice Architects (CPA) Ltd. McLean is a Principal Lecturer, a Doctor of Philosophy, and is widely published in his own right.

ACKNOWLEDGEMENTS

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Over one thousand students have participated in the technical courses outlined in this paper, and the authors would also like to show their appreciation for the dedication of the students to their technical tasks over the years. The authors hope to be able to publish a full archive of their work in the future.

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