Chapter 11

Beyond appearances: Integrating environmental performance in architectural design education

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BACKGROUND

In response to concerns of climate change, the growing emphasis on sustainable architecture is matched by a plethora of regulatory codes and rating schemes that mandate or benchmark building environmental performance in many parts of the globe. In Australia, the Education and Sustainability Policies of the Australian Institute of Architects and accreditation processes of the Architects Accreditation Council of Australia (AACA) commit to implementing sustainable design practices across all its endeavours and reinforce the importance of this discipline area. Consequently, the inclusion of environmental studies and architectural science in some form or other within any architectural course has remained largely uncontested despite the pressure to curriculum content from an ever widening scope of professional architectural requirements. Nevertheless, a review of several papers on the pedagogical approaches and outcomes for environmental studies reveal consistent themes surrounding the compartmentalised approach to teaching these subjects in architectural courses, the desire to integrate environmental studies into studio teaching, and the need to make the discipline area more appealing to students (see AIA 2006, Rutherford 2006 and Loftness 2005).

Environmental aspects have traditionally been taught as separate subjects from architectural design in most schools of architecture. Although some examples exist both locally and overseas where integrated environmental science and technology courses operate in a "servant mode" to extend the resolution of the concurrent or previous design project, there is limited evidence of an alternate approach to architectural design studio teaching where the objectives of the discipline are primary drivers *within* the studio. While the value of design studio teaching as a means for encouraging reflection and deeper learning is well documented (see for example Schon 1985, Green & Bonollo 2003), an oft repeated concern is that even when integrated into design studio, building science and technology are perceived and conducted as an add-on project (see Wood, 2006). Austin (2007) argues that integration of design with technologies *"is too much to ask of any student during, or even after, five years of study"* on grounds that the technologies are only half understood and there is a lack of a serious role for "technologists" in the design studio.

This chapter focuses on an architectural design studio titled Environmental Performance that was offered for the first time in Autumn 2008 as part of the new professional Master of Architecture (MArch) program, at the School of Architecture, University of Technology, Sydney. It seeks to highlight inherent opportunities and challenges of the "thematic studio" that by its nature is required to straddle objectives across the specific sub discipline of environmental studies as well as the broader ambitions of creative processes towards architectural design. The adopted approach redirected attention to the design process and outcome and is in contrast to a more traditional view of the architectural studio project as the end in itself. A brief description of the context for the studio, its structure and approach, is followed by a detailed reflection on studio processes and outcomes to distil lessons and implications for improved instruction and pedagogy.

By way of background, courses in the MArch including the studio that is the subject of our discussion build upon the foundations laid in four vertical streams - Architectural Design, Technology and Environmental Studies, History and Theory and Communications in the Bachelor of Arts in Architecture (BA) course. In the BA, the building blocks of environmental studies and architecture science are developed in an introductory subject Architectural Environments and Culture and three detailed subjects Thermal Design and Environmental Control, Lighting Acoustics and Advanced Environmental Control and Built Praxis (applied services). Subject delivery is achieved through lectures, tutorials and computer labs and a culminating assessment task requiring "design synthesis" which is supported with studio based tutorials. With a good coverage of architectural science and environmental studies and its links into concurrent design projects in the first three years of architectural study, it could easily be argued that the fundamentals are "done and dusted" and students will automatically integrate what they have learnt in their designs regardless of their choice of design studio in their final years. However, at UTS, a strong emphasis on modes of practising in architectural design, and an ambition to produce graduates who are able to apply ethical, environmental, cultural, aesthetic and technological considerations in architectural practice (UTS, 2008) is continued by offering two complementary studios namely Environmental Performance and Environmental Sustainability. These form two of a selection of 13 studios from which students complete four studios over their two years of study. Each studio comprises 12 credit points, or half the loading of a full time semester.

The *Environmental Sustainability* studio is concerned with the broader issues of sustainability at the scale of the city and major architectural interventions, whereas the framework for the Environmental Performance studio allows for exploration at the level of design process and decision making, including the use of computational and other tools to generate and assess architectural interventions for their performative capacity. The remit for all studios is to go beyond the fulfilment of a pre-set brief. The studios seek to enhance a critical understanding of architecture as both a discipline with an existing body of knowledge and a set of practices that continuously challenge and add to that body of knowledge. Research is undertaken as a precursor to decision-making, during design and in reflection on design development.

STUDIO STRUCTURE AND PEDAGOCICAL APPROACH

Building Information Modelling (BIM) processes are well documented for their capacity to support effective design development towards optimal building performance while using a shared building model in a collaborative design setting (Plume and Mitchell, 2007). However the true interdisciplinarity (with input from mechanical, structural and construction engineering) that is required to drive the highly specialised software is missing in most academic environments of professional architecture courses. Coupled with the reality of the extent of detailed information needed for the various analyses, and the effort of gaining seamless transfer (interoperability) from one software platform to the other, this often means the benefits of BIM only come into play once a design concept is locked in.

In contrast to an approach where separately developed design concepts are post rationalised or optimised using various performance software results, a key focus of the Environmental Performance studio was the foregrounding of building environmental performance analysis and thinking as a critical driver in the morphogenetic development of design. The studio focused on digital and other analytical methods to gain useful feedback in the early design-stages, where designers remain open to developing and generating a number of design possibilities without being fixated on a predetermined design concept. The iterative process of performative analysis and design development was employed to effect the shift from form-making for purely aesthetic considerations to outcomes evolved through form-finding (after Laiserin 2008).

To aid performative analysis, the studio included the use of ECOTECT®, an environmental analysis tool where the main advantage is its focus on feedback at the earliest stages of the building design process and inherent modelling and analysis capabilities to handle geometry of any size and complexity (Crawley 2008). In addition students were introduced to Evolve 97 which enables evolutionary structural optimization (ESO) of a deliberately oversized structure, through removal of elements under least stress to evolve towards highly optimized shape (Holzer *et al*, 2007).

While the studio addressed the aesthetics of environmental performance and alternate approaches for architectural design, it simultaneously sought to recognise the multi dimensional and trans-disciplinary nature of sustainable design. A critical inclusion from this standpoint was an investigation into bionics - a study of natural systems with the aim to derive design principles, and implications for architecture. A brief outline of studio activities together with selected examples of student projects is provided below. The presented projects depict the range of analytical and modelling approaches and studio outcomes. However a detailed presentation of the performance analysis of individual projects is outside the scope of this chapter.

The studio was structured into three phases, and departed from the traditional mode of studio operation of 6 hours per week on a weekly basis. In addition to a weeklong intensive Investigative Workshop over the mid semester break, the group met for 9 hours every alternate week, or 6 sessions over the semester, with the final crits in the final week of the teaching semester. The studio was carefully designed to ensure alignment between course objectives, content, learning activities and assessment in order to ensure deep learning approaches in students (Ramsden 1992)

The initial Design Process phase (conducted over three biweekly sessions) was designed to get students to rethink their design methodology in the light of multi-objective criteria while developing their analytical, computational and modelling skills. Figure 1 and Figure 2 show aspects of the morphological design development and performative design analysis from the canopy exercise in the light of multi-objective criteria for solar shading and evolutionary structural optimisation.

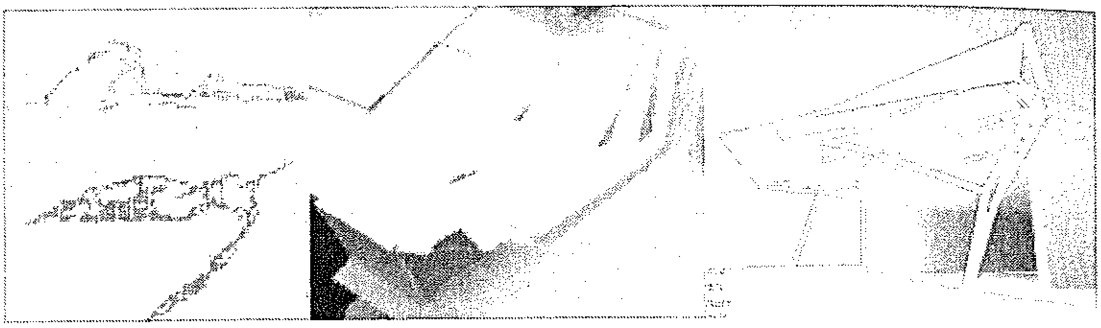

Figure 1. An example of the canopy exercise [Frankie Layson, Ali Naddi, Phillip Meehan]

The brief required development of a canopy that could achieve 100% shading to a north west facade and 3m deep patio during a stipulated time (2-5pm on the summer solstice). It also called for the generation of the structural support system using feedback from evolutionary structural optimisation (ESO) whilst maintaining views, minimising canopy area and material, and allowing unobstructed movement under the canopy. Design development also included physical modelling and testing.

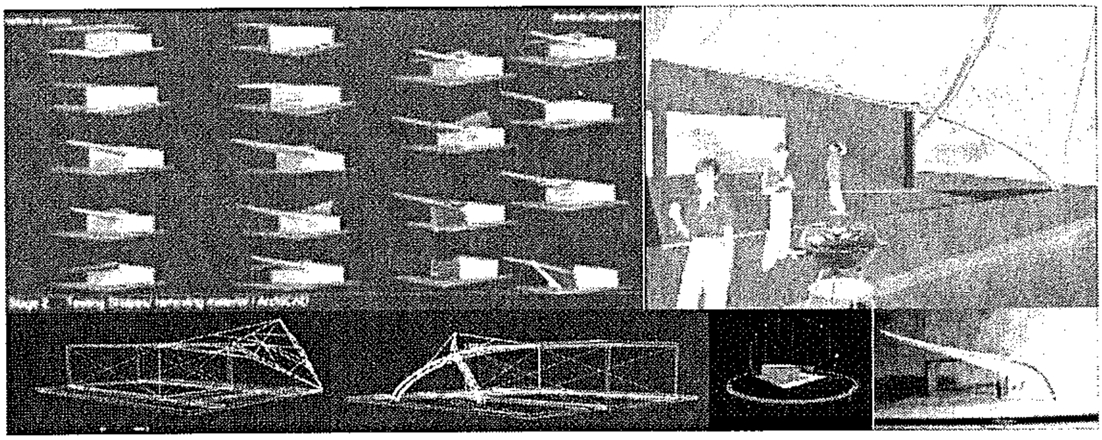

Figure 2. Another example of the canopy exercise [Rebekah Clayton, Hugh Irving, Benjamin Wollen]

Shown here are some of the iterations of environmental performance analysis, morphogentic development and material optimisation from sunshading studies, digital and physical modelling, and evolutionary structural optimisation.

The second exercise in the Design Process phase was the Parametric Screen project. Here students explored parametric principles of associative geometry, and controlled repetion and variation of constituent elements to satisfy criteria for daylighting and thermal performance. This was the students' first introduction to the parametric capabilities of Generative Components® and Explicit History' plugin in RHINO®. Selected outcomes are shown in Figure 3.

The Design Process phase was followed by an Investigative Workshop led by Michael Hensel and Defne Sunguroglu from Ocean North, in association with the two studio leaders. The group was assisted in their botanical studies by Paul Greenfield of CSIRO and Chase Alive. With the emphasis on bionics, students studied selected Australian native plants in relation to their natural habitat and their performative capacity embedded in their morphology and physiology with the aim to derive design principles for architecture. The field work conducted at the Basin area of Ku-ring-gai National Park, focussed on mapping, which was seen as a useful way of documenting and analysing the two way feedback between the selected plant and its environment, and thereby understanding its performative capacity.

Over a two day period, students studied their selected plant and its detailed relationship to its immediate surrounding by mapping a 5 x 5 m quadrant encompassing it. In addition to documenting physical characteristics such as terrain and soil condition, students logged measurements of temperature, humidity, daylight intensity, wind speed and direction over time, and also gained a wider understanding of surrounding area. Additional information on the macro scale was sourced from topographical maps and concurrent Bureau of Meteorology data. In the computational workshop that followed, groups developed a series of spatial and temporal maps ranging from the micro through to macro scale and digital models of relevant plant morphology with accompanying performative analysis and literature study which together served to explicate the context specificity and feedback between the organism and its environment. Students were also required to reflect on implications for architectural design and the scales at which performative principles and criteria might be applied.

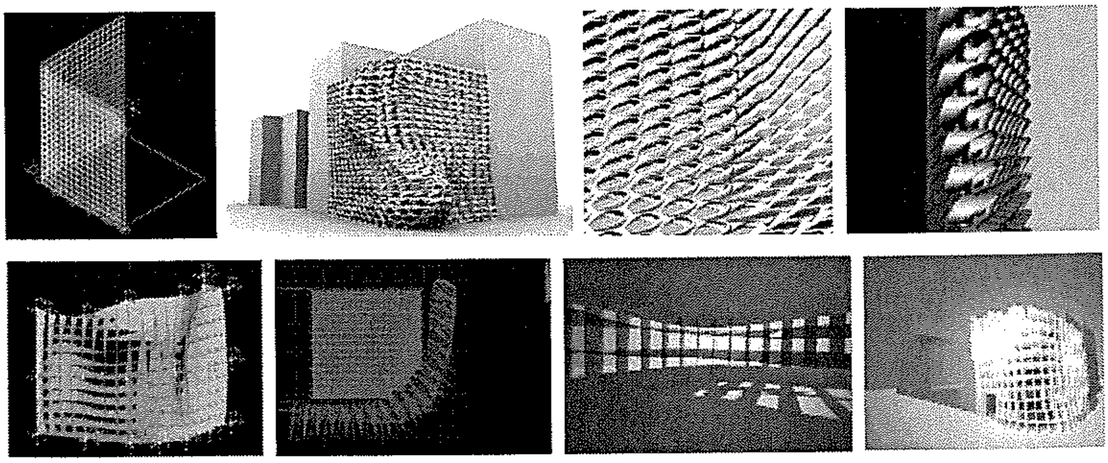

Figure 3. Two examples of the screen exercise using daylight, solar access and solar insolation analysis in conjunction with parametric modelling [Top Row: Jeremy Unger and Pietro Abdo; Bottom Row: Frankie Layson, Ali Naddi, Phillip Meehan]

The project called for the development of an external, screen-like element wrapped around a nondescript "glass box" office buildings to create a feature of interest that could control solar gain, allow for improved daylight distribution to the office plate, reduce the solar loads on the façade yet admit sunshine to lounge areas in winter.

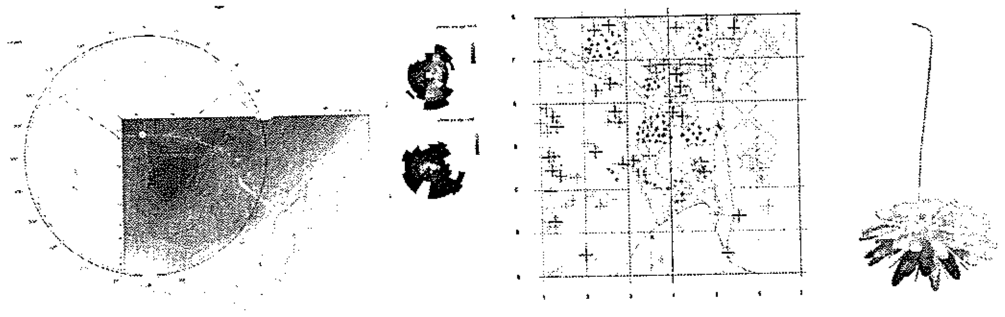

Figure 4. An example of some of the plant morphology studies at macro, meso and micro levels [Chanel Carr, Kevin Bradley and Luke Novotny]

The final phase, Design Synthesis, was staged over the last 3 biweekly sessions. It pulled together the various threads of the studio that had been explored to date through a design project for a small-scale, 'off the grid', ecological research station. The brief was kept simple with a requirement for glare free light, minimum thermal discomfort via an aspirational target of achieving 18 – 28 °C for 95% of the year in the absence of active systems for heating and cooling. Aside from building performance, the project sought inclusion of at least one "broader" and often regenerative environmental criterion such as rainwater harvesting and storage, fire resistance and material sensitivity (embodied energy, recycling reuse and upcycling).

Students were assessed for their design process as well as architectural project exposition and presentation. Significantly, the project required students to consider what design and environmental performance principles could be gleaned from their plant morphology studies for transference to the built artefact while instigating a morphological development of the project in response to the performative criteria. Although it would have been interesting to explore transference of principles in an alternate urban site, it was decided that the hypothetical project continue at the Basin in order to maximise the benefit of the rich data collection, site analysis and mapping developed during the workshop. Some of the outcomes and their approaches are shown in Figure 5 and Figure 6.

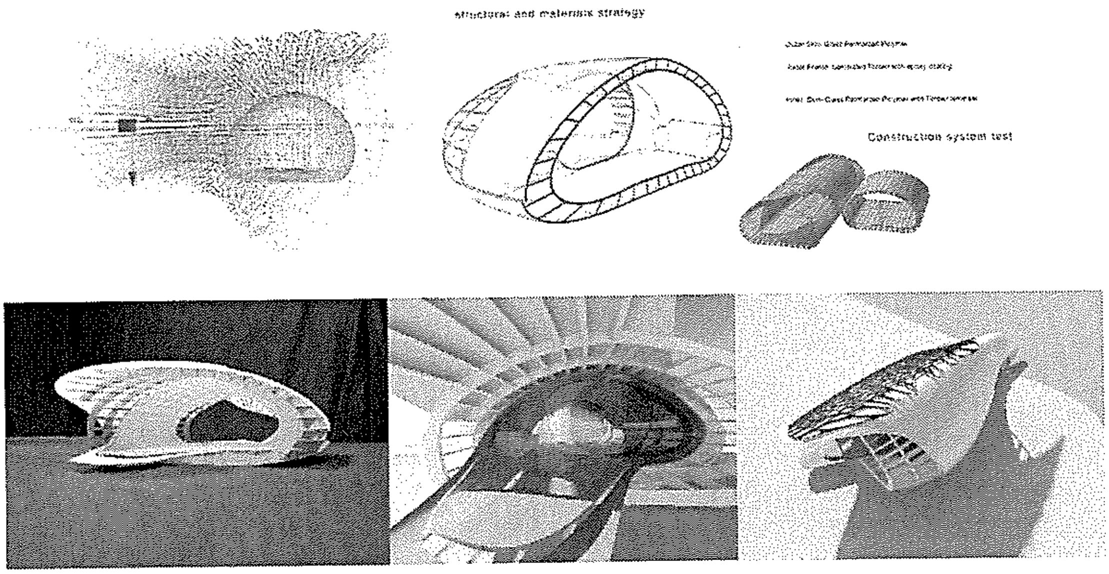

Figure 5. Design development for an ecological research station [Luke Novotny]

The project was developed primarily from a context specific response to environmental and site issues, and included wind studies to modulate form and surface, as well daylight and thermal analysis and an in-depth structural and materials strategy investigated through physical and digital modelling.

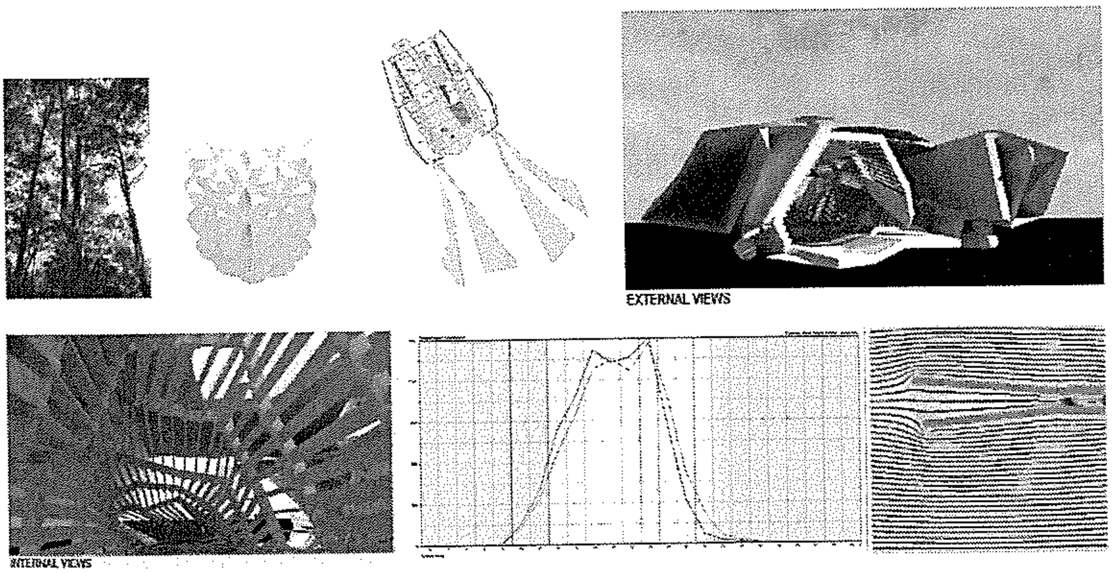

Figure 6. Design development for an ecological research station [Christopher Kelly]

The project was influenced by performative analysis of the casuarina, venturi effect and constriction velocity that triggers seed dispersal, and precedents in architecture to investigate use of prevailing winds for power generation. Simultaneously, the project used daylight and thermal analysis to reconcile the form and employed parametric principles to generate the louver system.

REFLECTION ON STUDIO PROCESS AND OUTCOMES – IMPLICATIONS FOR INNOVATION, INSPIRATION AND INSTRUCTION

Student feedback

The subject rated very well with over 78% selecting Agree or Strongly Agree, and close to 90% selecting Neutral or above for all categories other than resources. A summary is provided in Table 1. The average score for overall quality was 3.74. Rather than mount an argument that the subject would have averaged at above 4.00 (equivalent to Agree) without the three respondents (11%) who were the only ones to choose Disagree or Strongly Disagree on any of the 11 questions, it is more relevant to ascertain the sources of dissatisfaction. Interestingly, two of these respondents returned positive comments about the approach being "very interesting", but recorded dissatisfaction at the bi-weekly contact for the studio. The primary suggestion for improvement raised through open-ended comments across respondents was the need to improve access to software and computer labs as reflected in a mean score of 3.5 for resources. Further implications for resources are discussed later in this chapter.

Comments about the positive aspects of the course included:

"A new way to approach design. The camping trip was a positive" and "The new studios with the masters, allowed for much greater thought provoking environment. This subject is great in that it pushes the use of cutting edge research and technique". A respondent who rated overall quality as 5.0 commented "I enjoyed the intensity and amount of work that had to be produced and the methods by which the work was produced". The same student also noted "I struggled with putting my designs on computer mainly because of a limited knowledge of 3D modelling packages. This year was the first time I was introduced to RHINO. An improvement would be a long term one where the school introduces this to student(s) much earlier". The positive feedback of the subject being thought provoking and interesting is noteworthy. This is particularly significant given aforementioned concerns of a perceived lack of interest in this discipline area and the well established value of thought provoking experiences in developing deep learning approaches. Other aspects of student feedback are discussed in subsequent sections.

A designerly approach to environmental performance

Lawson (2004) observes that "designers work in the solution focus manner that depends heavily upon design gambits based upon recognizing design situations amenable to solving certain problem situations" (p105). He also contends that unless knowledge has been taught in a way that is designerly (after Cross, 1982) they will find it hard to "connect and use the theoretical knowledge when actually designing" (p 105) and notes "that design knowledge depends heavily upon precedent or experience and upon appreciation of the ways things could be, rather than upon rules and theories" (p. 117). In other words, if we as teachers wish to inculcate a sensitivity

Criteria	Mean(sd)	% 4.0 and above	Criteria	Mean(sd)	% 4.0 and above
Subject delivery consistent with objectives	3.81 (0.74)	89%	Teacher - well prepared	3.93 (0.78)	85%
Subject thought provoking	4.04 (0.71)	85%	Teacher - able to explain concepts clearly	3.93 (0.68)	82%
Assessment fair and reasonable	3.85 (0.66)	85%	Teaching of staff	4.00 (0.78)	89%
Appropriate resources for subject	3.50 (0.81)	54%	Tutorials assisted learning	3.81 (0.96)	78%
Constructive feedback received	4.00 (0.68)	86%	Teaching in tutorials	3.77 (0.91)	81%
			Overall satisfaction with quality of Subject	3.74 (0.90)	78%
N=29, n=27. Overall Response Rate = 93% All variables are rated on a 5 point scale where 1=Strongly Disagree, 5 = Strongly Agree					

Table 1. Student feedback indicating percentage of respondents in each category rating agree (4.0) or above

to environmental performance and building science, there is no better way than developing this experientially. In the past when integrating environmental aspects into the design studio, we have had to rely solely on precedents and thumb rules, or on the "say-so" of the expert visiting critic/tutor or testing physical models. Time constraints for the latter mean that only one or two iterations are pursued. The developmental nature of the three phases of the studio, and the co-location of digital design processes and performative design analysis seen here opened the possibility for a more hands-on experience on the part of the student.

In this studio, complexity was not wrought through an onerous brief and programmatic requirement but rather through explicit requirements for integrating an environmentally performative approach to architectural design. This departure from a traditional view of the architectural studio project as the end in itself redirects attention to the design processes and design decisions as well as final outcome. The emphasis on design process in the context of consequent design and environmental outcomes is crucial towards developing the deep learning approaches elaborated by Ramsden (1992), where students do not merely mimic what they perceive to be the right solution or for that matter remain subservient to what is perceived as the correct formulaic mantra or technique. Although all students achieved the basic goals of integrating an environmentally performative approach to architectural design, it was clear that the most successful architectural design outcomes came from those that consistently moved "into and out of their designed space" even as they developed it through their iterative processes, always considering environmental performance, spatial experience and architectural resolution in tandem as they evolved and evaluated their designs.

The aesthetics of environmental performance

An important dimension of preparing students for working in trans-disciplinary contexts was the requirement for students to work and research beyond the traditional domain of architecture, and to engage in a discipline (namely botany and bionics) outside of their comfort zone. While by no means a detailed study in the discipline, feedback from the students was positive. "Some of the plant analysis felt quite strange at first, but very interesting and thought provoking". An early challenge for students was the need to distil performative principles such as differential expansion of materials, modulation of surface area, self shading, fire resistance, wind modulation and water storage rather than simulate formal qualities or even functional analogies (after Aldersey-Williams 2004) of their plant. Simultaneously they had to come to grips with the similarities and differences when moving from a plant to a building as the locus of investigation. The range of different design outcomes reflect the varied starting points from plant morphology, and different emphases students applied to the various performative criteria, where trade-offs occurred, how results were evaluated.

As outlined elsewhere (Holzer 2008), "those students who put a strong initial emphasis on exploring and mapping the imminent environmental and topographical conditions at their site to then relate them to the program appeared to struggle most in the beginning of the exercise, but managed to develop the richest proposals for the morphogenesis of their final project". On the other hand, it was noted that in a bid to satisfy environmental performance criteria, a sizeable number of students had neglected the finer architectural resolution of aspects of their design. Issues included unresolved aspects of entry and approach, and incongruence between the performative language of their designed artefacts and depicted design elements such as openings and furniture. Many students felt that the effective period of five weeks from project introduction to final presentation, with only two contact sessions during that period, was not adequate to take the projects to a level of desired resolution. On reflection, it is considered that a slightly longer lead time for the design synthesis task, and/or weekly studio sessions are needed to provide more frequent opportunity to emphasise successful approaches and discuss issues in emerging designs with students. Such an option would also afford students time to move on to a higher level of architectural resolution once they call a halt to their morphological development.

Moving from computational skills to digital thinking and decision making

There were no software prerequisites set for the course. While most students had used ECOTECT® as part of the BA course, this was the first time they were using the tool outside the context of those subjects. Although advanced 3D modelling software such as RHINO® and 3ds

Max® now form part of the routine suite of tools introduced to first year students at UTS, most students entering the subject this year only had basic CAD skills in ArchiCAD, SketchUp and AutoCAD®. About half the class undertook a 2-day introductory workshop in RHINO® offered separately at the start of the semester. Given this background, the authors were pleasantly surprised by manner in which most students rose to the challenges of learning to use the various computational tools. In the early phase of the studio where students were still developing computational skills, the assessment task called for an individual account and critical reflection on the computational and design development instead of assessing the end outputs at the group presentations in isolation. This move put the emphasis back on design development, evaluation and process rather than an expectation to simply show up with the best design outcome.

In addition to ECOTECT® and Evolve 97 to evaluate environmental and structural performance, a number of students used a Computational Fluid Dynamic software such as ViziFlow and RealFlow, to investigate design modulations in response to air movement in their final project. In the feedback received, students wished they had more time to experiment with the tools, while some requested easier access to computer labs and more training in advanced software such as Generative Components® and Explict History Plug In for RHINO®. Further discussion of tools and modelling exercises used in the studio can be found in another study (Holzer 2008).

Some of the opportunities and challenges of modelling are worth noting here. While students were able to export models to ECOTECT®, they were unable to transfer modified models back into the CAD tools of their choice. Similarly when working with the 2D ESO process, they needed to analyse options for each of the many critical cross sections separately. Students overcame their initial frustration at the lack of a two way transfer across the software by becoming more attuned to the actual results and their implications. The interesting challenge for the students was not to copy results from their separate analyses literally (1:1) into their design, but that they thoughtfully selected and interpreted those most appropriate, and continued designing with those performance-results in mind. This required a shift from a standpoint where environmental and structural considerations were technical add-ons to one where seamless integration was the goal. In addition, the perceived difficulty also reinforced the focus on decision making, which meant that the process could never be one that was simply automated or devoid of authorship.

Developing collaborative approaches – The benefits of group work and buzz of the intensive workshop

To alleviate concerns surrounding software capabilities, students were set up in groups of 3 for two-thirds of the semester. Working in groups enabled students to develop and contribute specialist skills within the team and more importantly benefit from teaching and learning from one another. Potential problems of a lack of ownership of group outputs were managed through carefully structured assessment tasks and by encouraging students to assume quasi-specialist roles within the group. The best aspects of group working and collaboration came to the fore as groups and larger conglomerations worked together to cater for food for all six meals while the class camped at the Basin, in the Ku Ring Gai National Park north of Sydney, where all supplies had to be ferried across to a site with no road access! For a class cohort that had previously not gone on any field trips, the social dimension was significant. The author observed that the experience also engendered a level of generosity whereby the students themselves took the initiative to share and post mutually useful material via the school server. This has the spin off of increasing the quality of the output across the board, but also ensured inclusion of students who might be typically more reticent on this front.

The camping trip and the intensive workshop generated a strong sense of achievement and enthusiasm and was the high point of the subject for many, to the extent that a period of inertia followed when the individual design project was introduced after the two week break. For the students, this was a point of opportunity and challenge to take individual ownership of their work, which they did. Nevertheless as the studio progressed through the third phase of the individual design project, many students continued to benefit from working collaboratively in locating new analysis tools and sharing insights on "how to" across the range of their computational endeavours, while retaining authorship of their design ideas. In the formal feedback received, one respondent commented that they were "Extremely pleased with the intensity of the studios. After returning from the Basin, the students were able to learn from a collaborative environment." The experience in this studio clearly demonstrates the value of effective learning interactions between students whether formal or informal is widely recognised (Biggs 2007).

Implications for staffing, timetabling and resources

In this studio, the positive feedback for teaching quality, tutorials and constructive feedback (Table 1) was reinforced by open ended comments. Students also commented positively about the complementary role played by the two lead tutors. Both had architectural training and a strong interest in sustainability and design process, however one specialised in environmental performance, evaluation and user studies whereas the other had an architectural practice background with a specialist capabilities in digital design, parametric tools and evolutionary structural optimization. This was further augmented with insights into performative design and bionics from the Ocean team and specialist expertise gained from the botanist at the intensive workshop. The mode of team teaching had the benefits for the tutors as well, with productive exchange of ideas and an ability to offer a studio that went beyond the sum of their individual capacities.

It should be noted that thematic studios of this nature require substantial time for planning and coordination of external teaching staff and field trips. Additionally, there is a need for flexibility, both in terms of timetabling to accommodate intensive workshops and movement between studios and labs, as well as in responding to learning outcomes as they develop. In this instance, aspects of the final project were only finalised once the outcomes of the investigative workshop (that highlighted the importance of context specificity was known.

The school is only into its second year of exclusive studio space for the School of Architecture, while computer labs with the dedicated software (130 seats for general access) are shared across the whole Faculty of Design Architecture and Building. Over the semester, many in the studio including those with their own laptops relied strongly on these physical spaces for group working, with the wireless networking capability of the studios, access to software, and fast machines in the labs at university being key drivers. Although students were very appreciative of the additional resourcing via guest tutors, a number of students raised the issue of difficult access to computer labs outside the weekly class bookings, which is also reflected in the lower feedback for resources compared to all other categories in Table 1. As the studios and computer labs in most schools are increasingly occupied for teaching, schools will need to look at options for increasing labs as well as spaces for casual working with access to wireless networking and alternate modes of software licensing for student use on individual laptops to continue to cater for student access and group working.

Integrating sustainability and environmental performance in the architecture curriculum

In respect to the perceived and real disconnect between architectural design and environmental studies discussed in the introductory section, and concerns about the lack of serious role for "technologists" in the design studio Austin (2007), it is our view that the experiences of this studio demonstrate a valid alternate approach. For any successful studio embracing environmental performance and sustainability, the expertise must be intrinsically located within the studio. It is also crucial that the studio objectives has buy in from all design tutors, and that the students see and know that it is being taken seriously at all levels - not only through explicit course objectives and assessment criteria but also in terms of how the issues are naturally part of the day to day concerns of the studio.

While the studio stressed a design-based approach, it must be acknowledged that a thematic studio of this nature requires a sound understanding of basic environmental principles. In this instance, the studio relied heavily on the prior learning in environmental and structural design that had been developed in the BA courses. This enabled time in the studio to be used effectively, without the need for content based lectures. Where further research was required, students were able to initiate this on their own, reinforcing the importance of the foundational material taught in earlier years.

In an environment where there are a number of competing pressures on the curriculum and too much content that needs to be covered, the onus falls on schools of architecture and individual teaching staff to prioritise on the content and detail required. It is therefore necessary to look for opportunities such as those presented in this studio where an integrated approach to architectural design pedagogy and environmental performance not only delivers efficiency but better learning outcomes.

CONCLUSIONS

As current concerns range from effective responses to global warming to the ever widening scope of architectural curriculum content, innovative and integrated teaching approaches such as those discussed here are needed to produce graduates capable of synthesising the array of complex considerations they will confront. In an era of increased reliance on digital tools for performance analysis and evaluation in engineering and construction that could see architectural graduates sidelined to using digital media exclusively for aesthetic considerations of form making, the Environmental Performance studio demonstrates a way of extending design considerations into performative design inspired by nature.

The thematic nature of the selective studios offered at Masters Level meant that students took ownership of their learning right from the start of the studio. Despite initial difficulties in working outside their normal comfort zone, the experiences in this studio show that students will rise to the challenges, particularly if they find themselves in thought provoking environments that encourage innovative approaches and collaboration. Also crucial to the success of such studios is an emphasis on design process and 'decision support' capabilities of performance tools, accompanied by carefully structured assessments and learning activities, as well as school support for resourcing through labs and personnel. While the importance of a foundational curriculum in the areas of science and technology is upheld, there is a clear need for more academic staff capable of teaching across the subject area and as primary design tutors in architectural schools. The positive outcomes and student feedback indicate that that it is possible to bridge the perceived disconnect between architectural design and science/technology, and develop a designerly way of approaching environmental performance. Clearly, the capacity of the discipline area to drive new ways of understanding, and provide inspiration for design application must be pursued through experiential learning in the design studio.

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COMPUTING, COGNITION AND EDUCATION
Recent Research in the Architectural Sciences

Edited by Ning Gu, Michael J. Ostwald and Anthony Williams

Never before in our history has the design and maintenance of the built environment been so contingent on expertise in the architectural sciences. From conceptual modelling and documentation to code-checking and materials manufacturing, a shift has gradually occurred in the building industry away from its craft-based roots, and its manufacturing industry paradigms, and towards a knowledge-based economy. In this environment, where ecological sustainability has focussed the world's attentions on the building industry, there is a heightened need for research to be undertaken in the architectural sciences.

The present book is focussed on these two sub-sets of the architectural sciences – computing and cognition and education. Computational tools and processes govern many applications in architecture and the educational environments where these skills and abilities are learnt are similarly deserving of our attention. This is why the present book draws together the best research on these topics from the Australian and New Zealand Architectural Sciences Association (ANZAScA) that was developed in 2008.

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Introduction

Research in computing, cognition and education: Investing in a knowledge-based economy

Michael J. Ostwald, Anthony Williams and Ning Gu

Never before in our history has the design and maintenance of the built environment been so contingent on expertise in the architectural sciences. From conceptual modelling and documentation to code-checking and materials manufacturing, a shift has gradually occurred in the building industry away from its craft-based roots, and its manufacturing industry paradigms, and towards a knowledge-based economy. In the new knowledge-based economy high-level expertise drives processes of design and construction and specialist knowledge is being valued more than specialist skills. In this environment, where ecological sustainability has focussed the world's attentions on the building industry, there is a heightened need for research to be undertaken in the architectural sciences. Yet, in this twenty-first century world, the old definition of the architectural sciences, as pertaining mostly to building services and material properties, is no longer valid. Today, computational skills drive research and industrial applications across most areas in the architectural sciences and all are increasingly underpinned by educational practices. Moreover, computing itself is not just a tool for supporting other research. The work that began to occur in the 1970s under the auspices of shape grammars, space syntax and algorithmic analysis has lead to the rise of a distinct and vibrant sub-field of the architectural sciences; computation and cognition. This is one of the two sub-fields that are the focus of the present book. The second sub-field has always been part of the architectural sciences in Australasia at least, but around the world it has suffered from a lack of equivalent focus and commitment. This second field of research is concerned with architectural education.

Just as the constituent parts of the architectural sciences have evolved over time, so too has the place of educational research in the architectural knowledge domain. In some parts of the world research into architectural education is focussed in the design and humanities fields, drawing on philosophical models and classical rhetoric to shape discourse in schools of architecture. In Australasia, research in architectural education has typically drawn its methods and practices from the social sciences and from education itself. For this reason research in architectural education has tended to be loosely aligned with the architectural sciences. Regardless of where the boundaries between these complimentary knowledge domains fall, there is a growing focus in professional education on the importance of research. This international development has placed renewed pressure on the architectural community to improve the way in which it prepares graduates for practice in a world where the development and application of knowledge is valued so highly.

The present book is deliberately focussed on these two sub-sets of the architectural sciences – computing and cognition and education – because they have not traditionally been seen as central to the field. Yet, computational tools and processes govern many applications in architecture and the educational environments where these skills and abilities are learnt, applied and critical tested are similarly deserving of our attention. This is why the present book draws together the best research on these topics from the Australian and New Zealand Architectural Sciences Association (ANZAScA) that was developed in 2008 and refined, revised and expanded especially for the present volume.

ANZAScA supports research from national and international scholars that enables advances in architecture, engineering and construction. Whether these developments are in the environmental sustainability of a building, in its design theory, or in the education of future researchers and practitioners, the society in 2008 asserted that science remains a critical component of the built environment as follows.

- Science drives *innovation*; the creation of new ways of understanding materials, processing data, monitoring energy use and increasing efficiency.
- Science provides *inspiration* for design by way of computational methods, form generation, theory development and new forms of inhabitation.
- Science supports *instruction* and pedagogy; it assists in improving approaches to teaching and learning.

This book showcases the outcomes of recent research in computing, cognition and education. The book is structured in two parts, which reflect these major themes and in 15 chapters.

The seven chapters included in Part I present new research into computing and cognition in the architecture sciences. The first of these chapters, by Michael J. Ostwald and Josephine Vaughan, describes an investigation into the fractal dimensions of five house designs by Eileen Gray (a prominent architect working mainly in France between 1922 and 1956) and five by Kazuyo Sejima (a Japanese minimalist architect working internationally today). In this chapter, a computational variation of the box-counting approach is applied to a multi-dimensional review of the houses of two of the Twentieth Century's foremost female architects, Gray and Sejima. The research in this chapter is important because it expands the limited pool of examples of architects who have been analysed using the method. The chapter concludes with a comparison between Gray's and Sejima's results and outcomes from previous research on the fractal dimensions of the domestic architecture of Le Corbusier. Chapter Two, entitled "Surface geometries: Experiments with constrained tessellation" is by Greg Pitts and Sambit Datta. It takes as its starting point the growing popularity of parametric modelling as both a design and fabrication tool and then tests the capacity for such models to produce coherent, bi-directional connectivity between the design, modelling and fabrication processes. Chapter Three, by Ning Gu and Vishal Singh is about a broadly related topic, Building Information Modelling (BIM) and the implications of BIMs for the construction industry. Despite the rapid growth in the capability and availability of BIM tools, industry has been relatively slow to adopt these technologies. Gu and Singh identify that a number of factors inhibit BIM adoption but that most past studies of these barriers have focussed on specific disciplines. In response to this situation, their chapter reports on the findings of an action-oriented research project that is aimed at developing strategies and measures to support improved BIM adoption in industry. In Chapter Four, Dean Ward and Jacqueline McIntosh describe the use of internet chat forums as a means of researching construction innovation practices. They focus their study on on-line discussions concerning a relatively new building prefabrication technology – Structural Insulated Panel systems (SIPs) – and assess the usefulness of Internet forums as a source of valuable and accurate information for construction researchers.

The next three chapters in Part I include studies that develop, validate or evaluate design models or designers' behaviours. Chapter Five, entitled "Knowledge based collaboration for cross-disciplinary architectural design" is by Gianfranco Carrara and Antonio Fioravanti. Their chapter describes a model of cross-disciplinary design, called a *Knowledge based Collaborative Working Environment.* In their chapter they demonstrate a prototype system that has been developed to support high levels of interactivity in collaborative design exchanges. In this interaction they chart the involvement of three "actors"; specialists in the fields of architecture, structural engineering and mechanical engineering. The author of Chapter Six is Paul Murty and the focus of the chapter is an investigation of a range of design and practice paradigms that are associated with learning by conjecture. These paradigms typically do not yet "accommodate conceptualisation, or the processes and experiences that actually lead to the discoveries that elevate designing above ordinary problem solving." In response, Murty proposes a more inclusive model, the *design conjecture cycle,* "illustrating conjecture interacting with exploration, generator and discovery processes." In the following chapter, Leman Figen Gul, Ning Gu and Anthony Williams describe a method to investigate design behaviour in collaborative environments. This chapter, which completes part one and follows from the previous papers about collaborative environments, commences with a comprehensive analysis of a wide variety of newly emerging technologies supporting collaborative design and different modes of design representation. The chapter presents a methodology of a future study to investigate human cognition in different high-bandwidth collaborative environments. The outcomes will lead to a critical understanding of how collaborative design can be facilitated and more particularly, how designers collaborate and interact with external design representations using leading-edge design technologies.

The second half of the book comprises eight chapters that report on research about current pedagogical practice in architecture schools and factors which influence architectural education. The first three chapters of Part II are studies on theories or perceptions in design education. Chapters Eight and Nine contain detailed results of the first Oceania wide analysis of architectural academics' and students' perceptions of a range of topics. The first of these two chapters, both of which are by Michael Ostwald, Anthony Williams and Sascha Fuller, reports on the results of an on-line survey and a series of interviews and focus groups with more than 100 academics about their attitudes towards professional accreditation. The chapter analyses and categorises the responses into a series of themes and broadly differentiates between them on the basis of frequency of response and the relative value they attribute to the accreditation process. The second of these chapters investigates the idea that academic staff believe that students are not motivated by learning but by consumer culture which relates not only to keeping up with the latest technological fads but also to their education. As part of this trend, students expect a certain level of customer satisfaction from their architectural studies but without an associated level of commitment. While staff portray students as technologically savvy and financially independent, students are also perceived as confused by course requirements and unable to think critically. The research reported in this chapter, relates these themes to a broader social and cultural context. Chapter Ten, by Zbigniew Bromberek, considers the advantages of the integrated architectural curriculum and barriers to the implementation of such a system. The chapter reviews the idea of a "total studio" and concludes with a discussion of the both the positives and negatives of the proposed model.

The final five chapters in the book use a series of pedagogical case studies to describe recent developments in architectural and design education. The first of these argues for the importance of integrating environmental performance software modelling in the design studio. In this chapter Leena Thomas "argues for an integrated approach to architectural design education to produce graduates capable of synthesising the array of complex considerations they will confront." The aim of the studio project described in this chapter is to embed environmental thinking into an architectural studio project. In Chapter Twelve, Miranda Anderson considers the specification of sustainable materials and the importance of addressing this practice in architecture schools. Anderson's chapter "has its roots in a pedagogical perspective" concerning "design specification and the importance of addressing such concepts as embodied energy in architectural and interior design education." She argues that in "many cases the continued increase in green building rating and material certification systems can do more harm than good, by creating confusion and/or contributing to a false sense of security for many design students." Chapter Thirteen is entitled "teaching consultancy skills in architecture, addressing the challenge of client design literacy." In this chapter Marc Aurel Schnabel and Evelyn L. C. Howe argue that it "is important for Architecture students to understand that a low level of client design literacy can impede effective communication in practice." Schnabel and Howe demonstrate that by "coupling communication courses in Dentistry and Architecture, students were able to develop consultancy skills suited to professional interaction and public communication with specific target audiences." The penultimate chapter in the book describes a long-term collaborative project wherein a school of architecture was able to support to local youth organisations. Richard Burnham and Robin Green describe this project, known as the "Castle", as a form of micro-dwelling; a mobile, autonomous and minimal domestic structure. In the final chapter, Jerry Jen-Hung Tsai, Xiangyu Wang and Yinghsiu Huang outline a research project involving the protocol analysis of collaborative designs of different scales in real and in virtual environments. In this chapter, design is viewed as a collaborative process wherein professionals communicate with each other for the purpose of achieving a common goal.