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Architectural science and student-centred learning

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Abstract: The curricula of architectural schools consist of various types of teaching as design studios and supporting subjects, contextual/technology oriented design studios, or integration of these topics to design studio teaching. The present paper reviews insights from the theoretical literature on research into students' learning experiences. Deep and surface learning approaches are discussed, as well as the student-centred learning approach in design studios. The paper also aims to present and discuss the experience gained through the authors' teaching practice, especially through student engagement in learning. During the past decade, technology and science units have been carried out harmoniously with the design studio, providing an opportunity to support the design process, taking some pressure off the workload of the design project by providing solutions to some of the technical issues separately, yet in synchronization. Exercises and assignments have been organized in the form of hands-on applications or by the use of computer software, in accordance with the design project criteria. In this way, students see, touch, feel, or try to experiment various solutions.

Conference theme: built environment education
Keywords: teaching and learning, architectural science education, hands-on exercises, design studio

INTRODUCTION

The aim of architecture is to improve the quality of life and environment. The objective of architectural education is to provide an educational experience for the next generation that will be responsible for planning, designing, constructing, and maintaining the physical environment. Traditionally, success in architectural design has usually been regarded to be equivalent to successful aesthetic and functional qualities. However, the early decades of the twentieth century saw some radical changes in design approaches due to industrialisation and technological advancements forcing these issues to be crucially considered in architectural design. This in turn, required the designer to be more knowledgeable in technical and technological matters.

The International Technology Education Association (ITEA) defines technology as human innovation in action which involves the generation of knowledge and process for developing systems to solve problems and extend human capabilities (Douglass, 1998). While we are all surrounded by technology, with an ever growing emphasis on designing for climate, energy conservation, sustainability, and healthy buildings, it becomes vital for designers to understand the basic principles of architectural sciences and appreciate their importance more than ever. Furthermore, the responsibility for achieving an optimum outcome for any project lies with each and every member of a design team.

The present paper aims to share and discuss insight gained through the experience of the authors especially through the process of student-centred learning. The students have been engaged by the hands-on experiments that they carry out in technology and science lectures and the integration of architectural science topics into the design studio by applying these exercises to their design projects. These experiments and exercises consist of heliodon, artificial sky, computer software, various measuring appliances, and workshops that have been included in the curricula throughout the years. The active engagement promoted through student-centred learning helps the students to learn and achieve the results by themselves guided by lecturers and tutors. The authors believe that this approach enhances student learning, helps them to apply the information gained to design, and gives them a better chance to remember later on.

1. BACKGROUND

1.1. Student learning experience

The student-centred learning approach in design studios deals with the way individual students can build knowledge through the visual senses, and learn through designing. This approach focuses on the goals, tasks, skills, expectations and interests of the student, including continuous learning through socialization, the evolving culture of the environment, and the rapid changes in technology (Branham, 1999).

Design teaching is concerned with the fact that students learn best when they are involved in solving a design problem by themselves and motivated to seek out new knowledge and skills for it. Another important fact mentioned by Rhem (1995), related to the sense of ownership in learning, is that students do prefer exploring and constructing knowledge themselves rather than listening to a static lecture and reading textbooks (Branham, 1999). In design studios, learner activity and ‘learning by doing’ are constantly fostered by connecting this activity with abstract concepts.

The motivational context is in itself very important, and Csikszentmihalyi (2002) presents two approaches to boost the motivation to learn. The first one is to provide a clear statement of the advantages and disadvantages expected from the subject. This approach aligns with Ponton et al. (2005), who state that clearly defined and understandable goals and outcome expectancies are crucial tools to motivate student engagement.

Csikszentmihalyi’s second approach (2002) is to make students aware of how much fun learning can be. He points out the fact that students have serious motivational problems discouraging them to invest energy in learning, in other words, disengaging them. He also claims that, if educators were devoting more energy on stimulating the students' enjoyment of learning rather than spending it in conveying information, they could achieve much better results. Jerram (2002) shares the same opinion, and considers motivation as one of the key issue in teaching and learning.

Moreover, learning effectively happens when students are motivated and able to engage in a constructive activity, embracing a deep approach to learning. Facilitating a good dialogue between staff and students and among students is an effective way to initiate this engagement (Biggs, 1999). Furthermore, encouraging the exchange of ideas among peers is listed among Rhem’s (1995) strategies for facilitating deep approaches to learning. Two other strategies mentioned by Rhem include the creation of a motivational context in which students are given a sense of ownership in the process which helps them feel more in control of their time and their contribution; and the connection of new concepts with students’ prior experience and existing knowledge.

As opposed to deep learning, Rhem (1995) points out that a surface approach to learning transpires when there is too much learning material to cover in the curriculum; relatively high class contact hours; lack of opportunity to pursue subjects in depth; lack of choice over subjects; and a lack of choice over the method of study; and on top of all, a threatening and anxiety provoking assessment system.

1.2. Self directed learning

Self-directed learning, an important aspect of university education, has a long history and is defined by Brookfield (1995) as taking control of one’s own learning. Furthermore, it is essential to the goals of student-centred and lifelong learning, and implies setting learning goals, locating appropriate resources, deciding the learning method(s) to use and self-evaluating one’s own progress. Similarly, Knowles (1975) believes that self-directed learning is a teaching strategy that encourages students to take responsibility for their own learning. Knowles (2002) gives a list of the life long skills required in order to be able to take responsibility of one’s own learning (see Figure 1). He states that students can develop these skills by themselves and agrees with Csikszentmihalyi (2002) that they need serious motivation in order to do so.

Biggs (2003) argues that what needs to be taught is the way to learn; to find new information; to apply it and evaluate its importance. According to him, students should be sequentially equipped with generic study skills; then with content-specific study skills allowing them to organize and conceptualize knowledge in their own discipline; and finally with metacognitive learning skills allowing students to reconceptualise the discourse. Brookfield (1998), on the other hand, believes that social networks and peer support play a role in the educational and emotional development of students.

1. develop and nourish curiosity
2. perceive themselves objectively and accept feedback and criticism about their own performance non-defensively
3. diagnose their own learning needs
4. formulate learning objectives in terms that describe performance outcomes
5. identify human, material, and experiential resources for accomplishing a wide range of learning objectives
6. design a plan of strategies for making use of appropriate learning resources effectively
7. carry out a learning plan systematically and sequentially
8. collect evidence of the accomplishment of learning objectives and have it validated through performance

Source: (Knowles, 2002)

Figure 1: Tasks related to the life long skills of self-directed learners.

2. TECHNOLOGY AND ARCHITECTURAL EDUCATION

As Banerjee and De Graff (1996) state about architectural education,

> the concept is that of a symphony where the overriding single purpose is to produce good music, which is possible only if there is complete integration of all individual instruments in the orchestra.

Similarly, in a design educational perspective, the single purpose is to focus on design excellence. In order to improve the quality of design and in an attempt to bring the benefits of technology, the integration of architectural science within the curricula of design education can be traced back to the 1950s. This was the time when the Science Committee set up by RIBA initiated the recommendation of an increase in research and science teaching (Cowan, 2004; Hawkes, 1996).

Architectural Science comprises a number of issues such as structures, construction, and environmental science. Environmental science includes climate studies, solar control, sound and noise control, and lighting. The objectives of the architectural science stream in architectural education are to encourage students to manipulate the technical knowledge of different scientific considerations into their design projects, and to fulfil functional, social, and aesthetic criteria in order to achieve better architectural solutions. Furthermore, following theoretical discussions on the scientific aspects, attention is given to the comprehensive examination of building concepts, elements and design patterns in order to provide safe, comfortable, and healthy conditions inside the designed space.

The lack of integration of architectural science in architectural design is one of the causes of inappropriate design, misuse, and lack of care in application. This becomes one of the causes for environmental problems such as diminishing resources and air / land / noise / light pollution, which in turn have negative effects on the lives of human beings and animals as well as nature.

Today, though not widely adhered to internationally, the approach to the integration of architectural science to the curricula varies among architectural schools. One approach is to have design studios and technological subjects separately but running in parallel. In this way technological issues are inserted within architectural education through lectures and seminars. However, although the integration of supporting subjects into design studios becomes essential, this usually somewhat lags behind. Students usually seem to overlook or disconnect the application of the knowledge they gained for their projects during the design process unless specifically requested in the course outline. They are far too busy dealing with the more glamorous and complex activity of designing. A second approach is to run technology oriented design studios. In these design studios students learn about technological issues in terms of the design context; however, other design issues frequently suffer. Within the past few decades, integration of architectural science knowledge into the domain of architectural design studio's has been of growing concern and importance, particularly with the accelerating global imperatives of energy crisis, environmental pollution, and climate change. Addressing this emerging responsibility by integrating architectural science teaching criteria into the objectives of architectural studio projects has given way to a third approach.

In the authors' teaching experience these three approaches have been applied at various times and in various combinations. For example, the building physics content is now integrated into the curricula with the conception that students are designers. While Technology and Science stream units have been carried out in the form of separate streams, they have usually been kept in harmony with the Design Studio, where possible. In doing so, related hands-on experiments and exercises have been designed to encourage student-centred learning. Keeping the stream in harmony with the design studio has also provided an opportunity to support the design process. This alleviates some pressure off the design project work-load by solving the technical issues separately, yet in synchronization. The second approach, running technology oriented studios with technology being the driving force, has been carried out more recently and will be analysed and discussed in a future study. In the third approach, architectural science has been integrated into design studios in various ways and in different scales over time.

3. ARCHITECTURAL SCIENCE EDUCATION

Architectural science can be efficiently supported with theoretical and practical tools. The widespread use of computers originated the conception of software for structural, acoustical, lighting, and thermal analysis of the built environment, allowing the development of a good part of the theoretical tools alongside charts, graphs, rules-of-thumb etc. Rational use of software tools help to improve the quality of the design and eases students' comprehension. Practical tools such as case studies, pilot projects, monitoring studies, and lab experiments give support for the design process, providing experience to the designer. As Unay and Atimtay (1999) point out even sites damaged by disasters can be the biggest and most educational laboratory that can possibly exist.

The literature and past experience shows that less theory and more hands-on applications and computer based studies are essential for students' engagement and learning (Hutchinson and Demirbilek, 2005). Many design students are either reluctant, or lacking the time and energy to work with mathematical calculations or learn through research and reading. Some of the students also seem to have a tendency to overlook the integration of this knowledge into design unless specifically requested in their design brief. Usually formal, spatial, and theoretical aspects of design take priority. Student feedback received over the years indicates that they learn the technical subjects more easily and are more willing to apply those to their design projects at the University and their practice. Some extracts from former students´ emails and student replies to the question 'Aspects which are done well and which should be continued' in the Student Evaluation of Teaching forms and of the Units show the students' appreciation of these experiments and exercises. This is illustrated by the following QUT student comments: *"I feel I remember / understand more from an exercise then test."; "[Exercises] allowed us to immediately put what we had learnt in the lectures to practice"; and "The unit continued from what was done last year. This feeling that we are building up our knowledge and skills is good."*

In their feedback comments, in alignment with Csikszentmihalyi's (2002) and Jerram's (2002) statements on the fun aspects of learning, students also used words like: *"I really enjoyed this unit… it was also fun", "… midterm [exercise] assessment is valuable and motivating", "Role play was very effective and fun way to learn about HVAC" and "I enjoyed the semester a lot"* to describe their enjoyment and motivation.

3.1. Hands-on experiments, exercises

In accordance with University policy, every QUT and UNSW course aim to develop graduates who are able to demonstrate the ability to work independently and collaboratively, including being a cooperative and productive team member or leader (QUT MOPP, 2005; UNSW L. & T. Unit, 2003). Group work, including teamwork, is used to develop interactive working techniques or to introduce a social dimension to student learning (QUT MOPP, 2005). Hence, students are asked to form their groups composed of various members, in order to do some of their research or experiments, and to prepare their reports in the form of teamwork. In this way, they not only learn from each other while carrying out the experiments, analysing the outcomes, and writing their reports but also keep in touch socially and build their network (see Figure 2).

Source: (Author 2004-2007)

Figure 2: Some groups of students carrying out various exercises in teams.

The big task of environmental control and design with climate is broken into smaller tasks of designing shading devices, analysing and improving the thermal performance of a building by testing various design options and material choice, experimenting with the effects of material surface characteristics that might affect the thermal performance of buildings, designing openings for obtaining necessary daylighting levels and distribution as well as improving spatial quality, attempting to design building services. Exercises and assignments have been organized in the form of hands-on applications and role-plays or by the use of computer software, where possible, in accordance with the design project criteria. Consequently, students see, touch, feel, or try to experiment with various solutions in accordance with Confucius's saying *I hear and I forget, I see and I remember, I do and I understand* (see Figure 3).

In their feedback comments about learning by doing, QUT students expressed the following: "*I experimented in first person what I was studying and I understood not only how things work but also why they work like that. In this way I am not going to forget it in future.*"; "*I have calculated and designed a typical shading structure for a school [at work]. I wanted to thank you for teaching me. Please find an attached photo. The design was very simple, but the calculation of the shading structure is actually working. How exciting!!!*"; "*I find the exercises quite beneficial; especially the environmental exercises that link directly to design. I preferred the extra log book exercise over the test for environment as I feel I remember/understand more from an exercise then test.*"; "*The hands-on way of learning was good & cemented ideas covered in lectures*"; and "*[the] Interaction [of technology and science unit] with the design studio was best aspect of the design studio this semester.*"

Source: (Author 2007)

Figure 3: A student measuring the lighting levels and taking the photographs of a space for analysing various daylighting options.

A few of these hands-on exercises are summarized below.

Shading devices

Students learn from the bioclimatic chart exercise and through personal experience that depending on latitude and climatic region building interiors regions benefit from solar radiation in wintertime whereas the same interiors, unless protected from the severe effects of solar radiation, may be quite uncomfortable in summer.

Hence, some exercises are set to help the students to understand how shading devices work, design shading devices integrated to design studio, understand the difference between openings facing different orientations, find an optimum solution for varying conditions, integrate shading devices in facades of buildings, and discuss materials and application from ESD point of view by using Eco-specifier. Among these exercises **observation of existing shading devices** to understand how they function**, designing shading devices**, and **analysing them by the help of computer software and heliodon** can be mentioned. These exercises, in return, help students to design their own shading devices for Architectural Design projects.

While designing the shading devices, students are expected to keep in mind that this is part of the design process, incorporating technology and science. The following student feedback clearly indicates that they have learnt from these exercises and they have understood that this is a design tool: " *I have calculated and designed a typical shading structure for a school [at work]. … the shading structure is actually working. How exciting!!!"; "[The heliodon] gave a good perspective on shading devices, and allowed for trial and error testing different options. … the work we did here was a great practical application of our designs."; and "The materials covered in the environmental section are pretty interesting and useful, especially the topic of shading device. I think this is one of the most useful thing I learnt in this semester. …[it] should be kept & continued."*

Colour

This is a small set of exercises that seek to develop an understanding of how solar and thermal radiation affects the built environment. It allows students to be aware of the importance of planning and designing for colour and material, which is especially valid for sunny climates. The diverse materials used in the set have a variety of surface colours, finishes, and textures. Students learn to use thermocouple meters for measuring the surface temperature of various surface colour and texture under sun and heat.

Daylighting

Students are asked to carry out experiments by measuring the lighting levels in various exercises and undertake a project applying analysis techniques to discover the effects of natural lighting on an interior space using 3 dimensional models. The aim of the exercises on daylighting is to help students to reinforce an understanding of the basic concepts of natural lighting in interior spaces, and to analyse the effect of various openings on indoor natural lighting conditions (see Figure 3). These exercises include **daylighting performance observation**, which aims to see the variation of daylighting levels coming through various openings according to the distance away from the opening; **analysing the spatial quality and its integration to design studio**, which requires the students to investigate and analyse the issues of natural light in a key space of their project in design studio by using a 3 dimensional model in the studio, outdoors, and in the artificial sky laboratory by testing various apertures for walls and/or roof and measuring the variation in light distribution.

3.2. Integration of architectural science into design studio:
At QUT, design studio leaders and architectural science experts have collaborated towards the integration of building science criteria into measurable qualities of architectural design in various semesters. In particular, imperatives of optimum orientation, good natural ventilation and solar control have been identified as design criteria to be observed and assessed in student projects. This has occurred particularly in the second or third year of the curriculum, as part of the formulative semesters of a student's education, and likely to have a fundamental impact on the learner. Although each group of students have their tutor for the whole semester or project, an architectural science expert also spends time with the students, discussing the environmental design criteria and providing desk critiques. Some words from the students' feedback on the integration of architectural science into design studio are as follows: *"Having both practical work & theory lectures is good."*; *"Diverse use of tools – computers, heliodon, analytical/empirical methods –all prove something."; and "I know I will remember this phase of my life for many years to come."*

More recently, a similar but slightly different approach has been experimented a number of times. Technology and science topics have been incorporated to the studio design brief in a structured way. One of the design studio coordinators developed an approach with an objective to broaden the base from which design can emanate through an emphasis on the design process. By acknowledging that there exists a multiplicity of solutions to any given problem, the process aims to avoid the narrowness of the singular conceptual dimension and works instead towards a situation whereby design solutions are achieved through the recognition of divergent criteria. The process examines three primary criteria; *Spatial Thinking* (spatial relationships - circulation - context / adjacencies / functionality); *Formal Thinking* (form / expression / aesthetics / composition; and *Logical Thinking* (systematic - logistics / building performance / climatic filter (light / ventilation) / materials / structural resolution/ technology / resources). The possibilities and constraints of these domains are tested over three weekly design workshops that contribute towards an understanding of how these separate modes need to be integrated to achieve a comprehensive design outcome.

Collaboration of the students with an architectural science expert, the expertise of whom provided guidance for them to develop logical thinking, has assisted the improvement of the projects. The outcomes of such design studios have been very positive and this is evidenced through student design projects that demonstrate architectural science as an integral attribute of sustainable architectural solutions *(*Sanders, 2007).

CONCLUSION

Gradual integration of practical applications into architectural science teaching through exercises have enhanced the authors' methods of teaching in academia from theory-only to combination of theory with practice, for the last decade. This in turn improved the active commitment and success of the students through their engagement in class. Although it is very hard to document the evidence of student learning, a few examples can still be given. One such example is that, before the inclusion of the colour exercises into the curriculum, information on the effects of colour and material on thermal performance was provided through lectures and text books with the help of the absorbance, emmittance, and reflectance tables. Assessment via essay and/or multiple choice exams would give quite successful results on average indicating that students had learnt the importance of choosing the surface colour/characteristics and go for the most appropriate one once asked. However, this would rarely be the case during the review of design studio projects, as only a handful of students were ending up thinking about appropriate colours for the climatic region they were designing for. This situation has been reversed after the application of above mentioned colour exercises, resulting in a larger portion of students considering the choice of material and colour from climate point of view in their design projects.

Similarly, although the stream contained detailed lectures on daylighting and students have been successful at the end-of-semester exams for many years, after the gradual inclusion of the hands-on daylighting exercises into teaching, students benefited more from active learning. The activities of actually measuring the lighting levels indoors, analysing the variation, converting the results to graphs themselves, and then discussing the outcomes with their team members have been much more useful than seeing charts produced by others. After carrying out 3 dimensional model exercises, the location and dimensions of apertures in design projects tend to be better designed. Students usually give more importance to indoor illumination levels and to the quality of light and sometimes to the creation of mood; all getting a step ahead of aesthetic concerns of facades. Folio review members often notice the difference, and can appreciate the integration of technical aspects into the design projects.

Such anecdotal observations and feedback from students, studio tutors, and folio review members lead the authors to agree with Knowles's (1975), Rhem's (1995), Brookfield's (1995), and Branham's (1999) ideas related to the sense of ownership in learning, students' preference to explore and construct knowledge themselves, and the stimulation of students' enjoyment of learning; as well as Rhem's (1995) statement on encouraging exchange of ideas and collaboration among peers; and Csikszentmihalyi's (2002) and Jerram's (2002) acceptance of motivation as a key issue to improve student engagement. Student feedback received over the years shows a clear indication that they now learn these technical subjects more easily and are more willing to apply that knowledge to their design projects at the University and latter, in their practice.

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