Daylighting design in the architectural design studio

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ABSTRACT: This paper discusses two different approaches to teaching design and their modes of delivery and reflects upon their successes and failures.

Two small groups of third year design students have been given projects focusing on incorporation of daylighting to architectural design in studios having different design themes. In association with the curriculum, the themes were Digital Tools and Sustainability. Although both studios had the topic of daylighting, the aim and methodology used were different. Digital Tool studio's aim was to teach how to design daylighting by using a digital tool, whereas Sustainability studio aimed at using scale modelling as a tool to learn about daylighting and integrating it into design.

Positive results for providing student learning success within the University context were the students’ chance to learn and practice some new skills – using a new tool for designing; integration of the tutors’ extensive research expertise to their teaching practice; and the students’ construction of their own understanding of knowledge in a student-centred educational environment. This environment created a very positive attitude in the form of exchanging ideas and collaboration among the students of Digital Tools students at the discussion forum. Sustainability group students were enthusiastic about designing and testing various proposals.

Problems that both studios experienced were mainly related to timing. Synchronizing with other groups of their studios and learning of a new skill on top of an already complicated process of design learning were the setbacks.

Conference theme: Architectural
Keywords: daylighting design, design studio, architectural education, architectural science

INTRODUCTION

Entwistle (2002) states that what people learn depends on how it is learnt and why it has to be learnt. Therefore, to improve the design education, addressing the effects of learning environments and the modes of learning on the quality of student learning becomes crucial.

A study by Quinlan, Corkery and Marshall (2007) addresses that students learn best, are motivated and achieve high grades at university when:

- the educational environment is student-centred,
- they are empowered to construct their own understanding of disciplinary knowledge,
- teachers demonstrate their own learning in their teaching practice,
- department, curriculum, resources, teaching practices and assessment tasks are constructively aligned to specified learning outcomes.

The design studio, undeniably the heart of the design education, is an environment that is “different to a traditional classroom from pedagogical, sociological, ideological and epistemological points of view” (Sagun, Demirkan, and Goktepe, 2001). As stated in a report of the AIAS Studio Culture Task Force (Koch et al, 2002), studio learning has many strengths and not so many disciplines have such a direct interaction between academics and students, whereby students receive immediate feedback on their work. During a time when “the world is becoming more complex, boundaries are eroding, information is flowing faster, and globalization is a part of our everyday vocabulary” (Koch et al, 2002, p.2) the studio culture is also being affected and is under change.

Demirbas and Demirkan (2003) consider the role of the design studio with three steps as (a) learn and practice some new skills, (b) learn and practise a new language (graphic and verbal language), and (c) learn to think architecturally. The vital importance of Sustainable Design taking the centre stage and Digital Technologies offering new opportunities for design are undoubtedly changing the design education. Due to the importance of the design process as much as the design product in the studio various teaching and learning methodologies are being sought and applied.
Consequently, within the light of all addressed points, the current paper discusses and compares two different approaches to teaching daylighting design in the design studio—visual (computer modelling) and hands-on (scale models).

1. APPLICATION

In two consecutive semesters, relatively small groups of third year design students have been given projects that are focussed on utilization of daylighting in architecture in two design studios belonging to different design themes—Digital Tools and Sustainability—both of which are within the framework of Architectural Science.

1.1. How it sits in the curriculum

Both groups, having quite a similar year level experience behind them, had been given the basic knowledge on daylighting, artificial lighting and colour in their second year integrated technologies unit, DAB330. They had observational experience by measuring daylighting levels to see the variation of it coming through vertical openings according to the distance away from the openings; had carried out some hands-on exercises to investigate and analyse the issues of natural lighting in a space including room depth, window height, window ratios, window placement, visibility, unilateral/bilateral light, uniformity of daylight distribution, softening brightness contrasts, etc. by the help of scale models (Demirbilek and Demirbilek, 2007).

In their third year design units, both groups have been assigned projects incorporating daylighting into architectural design. Although students were guided to use tools for experimenting to see different options, the aim and methodology used were completely different from each other. In the Digital Tool studio, the main aim was to learn how to use digital tools in the design process for improving design outcomes specially related to daylighting and lighting design. On the other hand, in the Sustainability studio the aim was to learn specifically about daylighting design by using scale modelling for visualization of complicated daylighting designs.

1.2. Digital Tools Design Studio

The project of the Digital Tools Design studio was to design a Design Centre for Queensland at Kangaroo Point. Among various other objectives, the unit expected the students to effectively use digital tools (3D CAD modelling software), to integrate the benefits of digitally enhanced environments into design, as well as to exhibit ability to integrating an intermediate understanding of environmental sustainability and social context into planning and designing of public spaces. In view of the fact that methods to utilise digital tools or to construct digitally enhanced environments are so diversified, it was aimed to have a number of groups trying different methods to achieve the same goal, while keeping the awareness of the approaches taken by other groups. In this way, it was intended for the students to have in-depth knowledge of one chosen method, while staying in a close awareness of other methods.

The theme of one such group was “Illuminated Design”, in which it was aimed to visualize/analyse the effects produced by natural and artificial lighting on a proposed project. In view of the fact that using a 3D model can help to quickly see how the design can be manipulated to affect lighting conditions resulting from shape, orientation and materials used in the project, the unit acknowledged that the designer has the possibility to include light effect and conditions in the design process with better ease compared to traditional methods of design.

Students who chose to take part in this group were shown how to use complex tools with a minimum of knowledge to incorporate light in their design. They were asked to demonstrate how their design can maximise the use of natural light to minimize costly artificial lighting and also to demonstrate how building shape, material choices and artificial lights can combine to achieve specific lighting conditions and effects.

1.3. Sustainability Studio

The Project for the Sustainable design studio involved proposing a 2 or 3 storey mixed use building in South Bank on the site classified as Stanley Cove Redevelopment Project. In this unit emphasis was placed on the exploration and application of concepts of Sustainability in Design. Among other objectives, it aimed to raise the students’ awareness of the current predicament of environment degradation and highlight that an understanding of the interdependence of social, cultural, economic and ecological dimensions at local and global levels is crucial to sustainable design. Students were expected to exhibit an ability to integrate various concepts of sustainability into advanced building designs. To this end a series of workshops that introduced sustainability ethics and discussion on high priority challenges (e.g. global warming, air pollution, etc) and their implications for architecture were organized. Students were encouraged to suggest an ethical framework that would inform their proposal of a holistic environmental brief to drive their building design solutions. In addition, students were introduced to a diverse range of sustainability concepts and systems by lectures and their own research.

The sustainability studio also used a similar theme approach to look at diverse sustainable solutions for buildings in a more in depth manner, while keeping awareness of others’ work. One of those themes was the Daylighting Theme Group.

The main objectives of this group were 1) to create building/spaces that utilizes natural light for illumination during daylight hours for most of the year; 2) to reduce energy consumption used for artificial lighting and air conditioning by achieving naturally illuminated and sun protected spaces; 3) to respond to the physiological needs of people by designing spaces that allow natural light, provide protection from glare and overheating and most importantly provide views; 4) to integrate daylighting strategies to building design; 5) to integrate daylighting solutions with other passive
and active solar technologies; and most importantly 6) to empirically learn about physical properties of natural light and materials.

Within this design theme, students were given the options of looking at daylighting access of the whole building, daylighting design of a particular space or daylighting element as well as finding different ways of allowing natural light into the space such as side lighting, top lighting, or envelop design. They were asked to search for different alternatives and analyse different materials like lenses, reflective materials, transparent materials, or diffusing materials. The exercise aimed at learning about different daylighting strategies and discovering the properties of various materials and their effects on daylighting design.

2. DISCUSSION

The Digital Tools group has utilized a computer modelling tool for the design of daylighting, whereas, the Sustainability Design Theme was led to follow a hands-on scale model experiment approach. Although, neither theme aimed at teaching the tool but targeted the application of the tool to design lighting, these tools had to be taught to the students in class. However, the means of delivery in these two groups have been quite contrasting.

2.1. Modes of delivery

An academic with an architectural background, who has an extensive experience on Digital Communication, Synthetic Environments, and 3D Modelling as a design tool, led the Digital Tools group. The group has gone through a structured weekly teaching and organisation experience. In alignment with the objectives of the unit, the main idea behind the design activities was to use Global Illumination from their chosen software for assessing the quality of light in the proposed design and to evolve the design based on the quality of light. In order to do this, they needed to construct the design in 3D. Roughly, half of the class used ARCHICAD and the rest used Autodesk Viz.

Sustainability group leader, also with an architectural background, has a research and teaching focus on daylighting and is experienced in using scale models for daylighting analysis. The studio was not organized in a strict sense but scale model making was taught in class and literature on physical models for daylighting analysis was assigned to be read (Bodart et al., 2007, Moore, 1991, Bodart et al., 2006). During the semester students were encouraged to “experiment” with the materials in the workshops to empirically learn about physical properties of natural light and material properties and effects (eg. transparency, reflectivity, refraction etc), then to apply this new knowledge to create innovative daylighting solutions for lighting spaces and finally to qualitatively assess their performance for different times of the year.

2.2. Designing Stage and Timing problems

Both studios experienced some management and timing problems as they both have been experimented and offered first time in its current form. Being one of 6 or 7 groups of the whole studio meant some considerations of time management for synchronizing with others. Digital tools group could not initiate the use of the software till week 4 due to the synchronization with other groups. Sustainability group students also spend the initial 5 weeks period deciding on an environmental brief and what to propose for the site in sync with the parallel running studios. Concerned that the time left would not be sufficient to learn about daylighting and application into design, the daylighting group leader had planned to initiate the daylighting process at this stage with the daylighting group. However, the site studies have been just completed and the students had not started the building design yet. Hence, practically daylighting studies have been initiated on a generic space rather than daylighting leading the building design. This timing setback, in conjunction with teaching and learning of a new skill on top of the design process caused a late start for initiating the incorporation of daylighting into design.

The digital studio students have spent a long time learning the software prior to design stage that did not leave sufficient time to them for designing. Those using Archicad found that the software was good at 3D modelling, providing sophisticated models while the lighting functions were more complex and the end results were not so sophisticated. Once the modelling was over, it was too late for the students to experiment with various options. The groups who used Viz, on the other hand, found that the program offers basic modelling, ease of use, and higher quality in lighting. The models produced were rough but provided the opportunity to play with changing the form of buildings and openings to experiment with the lighting effects, which could be visualized after rendering.

As the unit progressed through the semester the different groups experienced a range of technical problems linked to their choice of software and their lack of knowledge. It was recommended to use Autodesk Viz for both 3D modelling and lighting simulation and only a few students had expertise with this software; the group of students who chose to use Viz exclusively found that 3D modelling of rough shapes was easy and provided sufficient approximation for a design study, they did however found the following difficulties:

- To see the effect of lighting on the different design alterations, it is necessary to render; a process that calculate the effect of light, shadows and reflections based on the objects shape, location and texture and while that process is reasonably fast on simple objects, the time it takes before a result can be analysed is still substantial and increasing with the complexity of the project.

- In order to compare and analyse the different solutions, each render has to be saved and the images then need to be printed or displayed on a screen side by side; this process does not permit to experiment with a large number of iterations as designer would normally do.
• Day lighting is not always sufficient to illuminate internal spaces and students started including artificial lighting in their 3D model. This is not an easy process and it requires more knowledge than the students had. Mistakes in that area meant that often the rendering time grew out of proportion with images taking hours to render; occasionally the light setting was so wrong that no result would display.

The Gallery foyer aims to create a space both reflective of the river environment and vision of the Centre through promoting innovative design concepts and enticing audience participation through feelings of wonder. Through the incorporation of an abundance of natural light filtered into the building, an intense, grand spatial quality is advocated as an initiation to the journey about to be taken which will endeavour to impress and showcase the complexities and innovations of design and its future trends.

Curved interior walls with openings displaying various thicknesses provide a sense of movement and energetic flow enhanced through the use of large windows which reflect the interior space to create an amazing environment.

Further experimentation with material surface treatments and the resultant effects natural light delivers, has led to the inclusion of a polished granite tile floor and matt, stucco walls reflected to create a seemingly large space.

ITERATIONS

Light Shelves & Awnings  Window Size & Placement

Source: (Joanne Blaszczyk 2008)
Source: (Nathan Monti-Bice 2008)

Figure 1: Examples of Digital Tools student work

The group who had chosen to use Archicad did so because one member of the group had experience with modelling using Archicad. However, because Archicad does not use global illumination, testing of lighting condition had to be done outside of Archicad. The students chose to export the 3D model as a dxf format and to re-import in Autodesk Viz to perform the lighting simulation. The following problems were encountered:

• Objects lose their identity during the transfer creating the need to re-apply each texture.
• Applying textures proved to be time consuming because the very large number of objects created by Archicad had to be selected graphically because the objects name could not be identify from a list.
• Due to the exhaustive level of detail, the Archicad models produced tend to be large which means that each render takes a long time. Students reported having to wait for more than an hour before a result was displayed.
• Any alteration had to be done to the Archicad model and the entire process had to be repeated for each one.
Both groups, in the digital studio group, reported frustration at the wasted time waiting for the computer to produce any result instead of designing. As the students did not have much chance for seeking innovative solutions, the final designs ended up in more simplistic forms, dealing more with the quality of lighting in spaces rather than designing and testing a wide variety of options.

In contrast, for the sustainability group, learning how to work with scale models, was not time consuming. They were encouraged to use a trial and error approach, and to experiment with different ideas; however, students in general struggled with this idea of experimentation and freedom. They found it hard to experiment with various materials and daylighting strategies, and usually accepted the first idea they came up with. In addition, they also struggled with the construction of scale models and workmanship of the models was usually quite poor. Affected by the fact that daylighting studies have been initiated on a generic building some students either completely forgot about daylight driven design and carried away with designing objects such as light pipes or they tried to put two separate things together with no proper integration into space. The final results achieved were tactile; and mainly targeted the apparatus and solutions rather than the quality of space, and generally lacking integration with the building design. Although most designs were quite sophisticated (example of students’ work in Figures 2, 3a and 3b) the focus was on the elements more like industrial design solutions such as light-pipes, rotating skylights, etc; however, a lot of emphasis was put on the device performance, as students could clearly see how their solutions worked.

![Image of scale model design of daylighting devices]

Figure 2: Examples of scale model design of daylighting devices: Student analysis of light pipe solutions.

![Image of daylighting design (sustainable group), integration of daylight/ventilation system for a play space for children]

Figure 3a: Example of daylighting design (sustainable group), integration of daylight/ventilation system for a play space for children.
Figure 3b: Examples of scale model design of daylighting devices: skylight/ventilation system integration for a play space for children.

2.3. Testing

In the digital studio the intention was to use the 3D model as a design tool. The software is very powerful at simulating the visual aspect of daylight and it accomplishes that by calculating the position of sun in relation to the 3D objects and then calculating the shadows and light effects. The user simply chooses a geographical location by clicking on the map and then sets the time and date. The effect becomes visible after rendering the scene. This allows the model to be tested at any time of the year. The limitation the students found was with the power of the computers available, the rendering time was often too long forcing them to wait for long periods of time before they could see the result of any design alteration or change of date or time. They were also asked to test their design at two solstices and equinox at 10:00 am and 3:00 pm and to repeat this for every major design alteration.

In the Sustainability studio, rather than applying a scientific approach, the scale models were used as a design tool. Scale models are very efficient tools for teaching lighting properties to students, who do not have sufficient knowledge of physical properties of materials, to simulate innovative materials (such as laser cut panels, fluorescent panels, lenses, etc). These models display the distribution of daylight within the space exactly as in a full-size room (Bodart, 2006) and do not require any scaling correction. The more accurate the models, the better lighting results are. However, even crude models can be very efficient for lighting analysis (Moore, 1991).

Through the utilization of scale models students were able to gather qualitative information by observation and photographic records. They were asked to test final models under sunny sky conditions for three times of the year (summer and winter solstice and equinox) and different times of the day (morning, midday and afternoon) by employing a Helidon to assess the solution performance under different sun angles (Figure 2).

In addition, due to clear sky conditions present in the project region, testing of the scale models under sunny sky conditions using the heliodon proved to be more advantageous than simulation tools as there have been some difficulties in replicating sub-tropical sky conditions with the software.
2.4. Student Approach and Remarks

When the digital tools group was asked to compare what they have expected from the studio and then what they have experienced, the immediate response was “Never again” as they have struggled with simulation. They indicated that they would begin to designing with hand sketching, do simple modelling and then elaborate by using simulation models for the later stages of design. However, it was interesting to see the exchange of ideas, support and collaboration among the students of this group through web. A remarkable number of students signed on the unit’s website discussion forum, communicating day and night, recommending solutions for others’ problems.

Students working with scale models, on the other hand, enjoyed working with scale models and the studio atmosphere created in the workshop, as students do not usually have the time to work while they are at university. They did, however, complain about timetabling, as the workshop hours were outside of the contact hours for the unit. This subject is given at night time, and workshop hours are during the day. They also complained about the extra time they have to put compared to other students in the Sustainable studio. In general they were enthusiastic about designing their “products” and experienced the joy of discovering daylighting characteristics in application.

Although the initial response was negative, students of both themes provided positive feedback in their written responses such as:

**DIGITAL:**

“The site has been modeled up before the design process was started, giving a more thorough understanding of the site’s properties before design input” (Student Group 2).

Utilization of the software “provides a relatively quick and painless method of using modeling as a means of understanding a design. In a way its more effective then paper based models that require a fair effort to change with the design. Saves starting again. We can experiment with different types of lighting to change the mood and look of the project, without actually building it or using real lights” (Student Group 2).

“By using 3D CAD software we are gaining valuable experience with what is relevant to the direction the profession is currently going and currently using. It gives the architect a better understanding of their design, using a more extensive modeling process” (Student Group 2).

“The technological revolution that allows buildings to be modeled in 3D and images captured with photo like representation is an astounding accomplishment that gives us a thirst for information and desire to learn more about the way this technology can be used to greater enhance building design” (Student Group 3).

“With the modern technologies like 3D rendering programs used extensively in the industry, designers these days have an added insight in to the proposed project allowing them to correct any mistakes before the cost of having them built. This trial and error system should be maximized in the design process to create a design solution which responds to the elements and environment” (Student Group 3).

**SUSTAINABILITY:**

Sustainability Theme students’ comments for the most useful features of the tutorial were: “Workshop was great”, “Working with different materials/ideas of daylighting” and “Informs your design well”.

In general they all agreed or strongly agreed that they were able to understand lighting optical properties by experimenting with scale models and different materials. They also agreed that they could not have achieved the same results using other means like computer simulation, stating that “it would not have driven the design as well as scale models did!” Only one student in the group mentioned that he would have preferred to work with computer simulation tools.

**SUMMARY AND CONCLUDI NG REMARKS**

The paper describes two separate design studio experiences carried out at a Design School in two consecutive semesters. It aims to reflect upon successes and failures of them and to draw some conclusions by comparing these two completely different themes and modes of delivery for teaching design. Their lowest common denominators are 1) being design studios in the same school, 2) teaching to architecture students having quite similar experience levels, and 3) using daylighting design as the means of teaching. Both units had a component of architectural science successfully incorporated into design studio rather than having them in separate silos. Lighting design is taken into consideration earlier in the design process, which very often is not even considered—at least not in the early years of design education.
In the particular case of digital tools studio, the students discovered that utilization of software is a powerful design tool rather than being only a presentation tool. By incorporating daylight in the design process they realized that accessing to 3D model allowed them to access other aspects of design. They also had collaboration by helping each other. For the sustainable studio, the scale modelling approach proved a very effective tool to teach daylighting design to students with basic understanding of lighting physics.

The final projects and reports from both groups are evidence:

1) that students had applied the knowledge gained in a previous core unit, which had covered lighting design, and
2) of student learning. It was expected to improve the design but it improved their approach to design. They have focussed on lighting early in the design process rather than other design criteria.

PROBLEMS AND SOLUTIONS:

These studios were offered first time in their present forms so some managing problems aroused. Main problem of both units was not having sufficient time for improving the designs. Due to the time consuming activities such as preparing their own design brief, site selection analysis, and learning new skills it was challenging to incorporate daylighting into the design studio.

Sustainability studio students more readily caught up the initial time spent on the preparation of design briefs and site analysis. As the scale model tool wasn’t complicated, it was easy to learn, leaving more time spent on learning daylighting and for designing. Their problem was the initiation of daylighting studies on a generic space for speeding up the learning process as this caused some designs ending up apparatus and solutions oriented rather than improving the space quality. Another major problem of this group was changing the design, as it was hard and time consuming to reconstruct a model. On the other hand, once learned, the digital tool was much easier to reconstruct a model compared to scale modelling. However, it was significantly time consuming and hard to learn. Consequently, when the students have found what was missing or not working well in their projects, the semester was over and there was not much time left to reiterate and improve the design.

A clearer and precise design brief could have provided sufficient time for the design process for both studios. The late start problem in the Sustainability group is now rectified and it is expected that an earlier start to the design project will provide a more successful incorporation of daylighting into design this semester. Additionally, a new push for modelling and fabrication in the School of Design implies that students are learning how to use laser cutter machines in the earlier years of the program; and as a result students are able to produce scale models in a fraction of the time allowing for more experimentation.

ACKNOWLEDGEMENT

Authors would like to thank the students of both groups.

REFERENCES


