Environmentally Friendly Architectural Design Studio: A Studio Based Case Study
ปฏิบัติการออกแบบสถาปัตยกรรมที่เป็นมิตรกับสิ่งแวดล้อม: กรณีศึกษาจากรายวิชาสตูดิโอพิเศษ

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Abstract

The introduction of environmental design strategies into an architectural design studio is not always an easy task. An experimental design studio at the Faculty of Architecture, Naresuan University, Phitsanulok encouraged a group of 18 students to design a relatively environmentally friendly office building. The experimental studio reported here was one of studios in the Special Topics in Architectural Design Studio course, which allowed students to choose a subject of their interest. The studio's learning strategies focused on the use of simple but tangible environmental evaluation activities, such as discussions and workshops, to gauge the possible health and environmental effects of each design, including its estimated rainwater run-off and solar efficiency. Through these strategies, the students were able to evaluate the impacts of their design to the natural environment. The process of measuring and acknowledging these impacts served as a tool for the students to better themselves by developing lower impact designs in the next draft. As a result, these strategies were demonstrated to encourage design improvement and served as a useful learning strategy for the teaching of environmentally friendly design in an architectural studio.

บทคัดย่อ

การสนับสนุนให้นิสิตประยุกต์ทฤษฎีแนวทางการออกแบบเพื่อสิ่งแวดล้อมอย่างเป็นรูปธรรมลงในผลงานการออกแบบในรายวิชาการออกแบบสถาปัตยกรรมนั้นมักไม่ได้รับการตอบสนองจากนิสิตเท่าที่ควร เนื่องจากเหตุผลหลายประการจากสาเหตุดังกล่าวคณะสถาปัตยกรรมศาสตร์ มหาวิทยาลัยนเรศวร จึงได้ทดลองจัดรายวิชาออกแบบสถาปัตยกรรมในรูปแบบของสตูดิโอหัวข้อพิเศษ ซึ่งเป็นการจัดการเรียนการสอนในหัวข้อตามที่นิสิตให้ความสนใจ และในรายวิชาดังกล่าวได้มีนิสิตจำนวน 18 คนที่แสดงความจำนงที่จะศึกษาทางด้านการออกแบบเพื่อสิ่งแวดล้อม โดยศึกษาผ่านโครงการอาคารสำนักงาน สตูดิโอดังกล่าวได้เน้นการศึกษาในเชิงการเปรียบเทียบผลกระทบของอาคารทั้งทางด้านสุขภาพและสิ่งแวดล้อมในรูปแบบที่เข้าใจง่ายและเห็นผลที่เป็นรูปธรรมชัดเจนผ่านกิจกรรมหลากหลายรูปแบบ อาทิ การอภิปรายการประมาณการปริมาณน้ำฝนเหลือทิ้งสู่พื้นที่สาธารณะ และการประมาณการด้านพื้นที่ศักยภาพพลังงานแสงอาทิตย์ที่แตกต่างกัน อันเป็นผลมาจาก

ความแตกต่างและการแก้ปัญหาที่แตกต่างกันทางการออกแบบ ทั้งนี้เพื่อเป็นแรงผลักดันในขั้นตอนการพัฒนาแบบของนิสิต ผลจากการสังเกตพัฒนาการของนิสิตพบว่า นิสิตมีความกระตือรือล้นในการประยุกต์ทฤษฎีการออกแบบเพื่อสิ่งแวดล้อมลงในผลงานการออกแบบของตนมากขึ้นมีความเข้าใจในผลกระทบของอาคารต่อสภาวะแวดล้อมเพิ่มมากขึ้น รวมทั้งมีความพยายามที่จะพัฒนาแบบของตนให้มีระดับผลกระทบต่อสิ่งแวดล้อมน้อยที่สุด ดังนั้นสตูดิโอดังกล่าวจึงเป็นตัวอย่างหนึ่งของเทคนิควิธีการเรียนการสอนแบบสตูดิโอเพื่อการเสริมสร้างพฤติกรรมการออกแบบที่เป็นมิตรต่อสิ่งแวดล้อม

Keywords

Design Studio (ออกแบบสถาปัตยกรรม)
Architectural Education (การศึกษาสถาปัตยกรรม)
Learning Strategy (เทคนิคการเรียนการสอน)
Environmental Design (การออกแบบเพื่อสิ่งแวดล้อม)
Environmental Impacts (ผลกระทบทางสิ่งแวดล้อม)
Sustainable Architecture (สถาปัตยกรรมยั่งยืน)

1. Introduction

It is hard to dispute, in this present era, that the housing and building industries play a leading role in shaping the immediate urban environment. Across the country, in almost every town, new buildings are being constructed at an extraordinary pace. These buildings can cause many effects, social and environmental, and at the heart of the action are the architects responsible for them. Consequently, nurturing a new generation of architects as morally accountable citizens should be the duty of any School of Architecture.

The Department of Architecture, Faculty of Architecture, Naresuan University, located at the fringe of Phitsanulok Province in the lower-northern part of Thailand, realises this responsibility and has recently adopted sustainable architecture as the main component of its Bachelor of Architecture (B. Arch.) curriculum. The new students of the year 2012, the upcoming academic year, will all be under the remit of a sustainability-focused curriculum.

Even before this new curriculum is rolled out, there is already a design studio for the 4th year students called “701417 Special Topic in Architectural Design Studio,” where the students can choose their subject of interest and develop it with the support of their lecturers. This component has proven useful and been continued in the new curriculum. There were six studios available in the last academic year and five this year for the students, including a Sustainable Architecture Studio in both years.

This paper aims to share the experience of the introduction of environmental design strategies into an architectural design studio.

2. Methodology

As the backgrounds of both authors are in academics, the paper is based on observations and the results of 4th year architectural design projects by 18 students enrolled in the sustainable architecture studio at Naresuan University, Phitsanulok, Thailand. The primary method employed for this study was classroom action research. Students’ attitudes and approach to design strategies were investigated and observed mainly through the process of face-to-face tutoring and their final products, along with additional learning activities, including two seminars and eight workshops in the classroom.

The students had to re-check their final design by completing a simple physical capability estimation (Hengrasmee and Vale, 2009) chart, which revealed the current state of their building in terms of the amount of rainwater run-off created, volume of rainwater run-off absorbed/harvested, solar efficiency area, etc. This study process helps the students to understand the impacts of their design on the environment and may serve as a tool to guide students in designing buildings with less negative effects.

The results are intended to be used for the future improvement of learning methods and activities, and consequently as a means to strengthen sustainable design measures.

3. Environmentally Friendly Design Studio

The project asked students to design an office building for a company with up to 60 employees. All students were to locate their offices at the same site in an urban area of Phitsanulok province. The students were required to choose green products for their company as part of their practice in focusing on pre-design and schematic development. A couple of seminars and workshops about green products and a presentation on the products that the students had chosen were organized early on in the semester. The students selected a product that he/she considered green and then presented to the whole class about the characteristics that qualified it as a green product. Discussions and debates were held during the seminar to share ideas and approaches to the different green products.

Apart from selling green products, the company would also engage in as many green and sustainable activities as possible. These proposed activities were also a part of the students' research and study. A number of workshops were held soon after the students had decided on their products to allow them to share and discuss the activities they were thinking of using in their company. Simultaneously with these workshops and seminars, the students had to develop their preliminary design and discussed it with lecturers during the eight tutorial hours every week. The chosen green products and activities, along with the design concept, acted as the underlying idea for the whole study process.

Halfway through the design development, there were two workshops in which each student had to find ways to integrate all necessary building systems and green technologies, as well as double-check their previous design solutions with the orientation and surroundings. At the end of the workshops, the students were encouraged to compare the physical characteristics of their buildings and its impact on their immediate environment.

A simple physical capability estimation (Hengrasmee and Vale, 2009) was also integrated into the project. The physical capability estimation for such an office building takes into account the impacts of the building on its immediate environment, as well as its ability to achieve a status of greater self-reliance. Sections of paved and unpaved areas were examined to compare them with the average annual rainfall to estimate the volume of run-off water the building discharged into the public drainage system. The amount of rainwater harvested was also compared to the area of gardens and lawns that needed to be watered. The leftover water was then calculated and it was suggested during the seminar that it be used in the toilets or for other gardening purposes.

Rainwater can be viewed positively as a source of water supply as well as a cause of run-off, which is often regarded as a burden to the public treatment facility. The average rainfall in Phitsanulok can be derived from the standard normal rainfall collected over 30 years from 1961-1990 (TMD, n.d.-a.) by the Thai Meteorological Department (TMD), which is used as the standard for the purpose of comparing changes in climate. From Table 1, it can be seen that the normal annual rainfall in Phitsanulok is around 1,300mm each year (TMD, n.d.-b.). This amount of rainfall will be used for the calculation of the potential rainwater harvest as well as the potential run-off water from the building site. Even though the total annual rainfall of the selected area of the investigation (in the northern region of Thailand) is quite high, there are approximately only 123 days with rainfall (TMD, n.d.-c.). This limited period of rainfall means that there would be no need to water plants on those days, but green areas in each site would have to be cared for during the other 242 days of the dry period.

Table 1. Normal rate of monthly rainfall in Phitsanulok.

Months	Rainfall (mm.)	Cumulative
JAN	5.1	5.1
FEB	12.9	18
MAR	30.5	48.5
APR	54.5	103
MAY	178.4	281.4
JUN	178.9	461.2
JUL	187.9	649.1
AUG	256.7	905.8
SEP	230.6	1136.4
OCT	159.3	1295.7
NOV	33.3	1329
DEC	6.6	1335.6

Sunlight can be used as a possible energy source for hot water (if needed) and a potential source of electricity generation from solar power. The data regarding solar radiation in the Phitsanulok area (in MJ/m^2–day) was obtained from the Regional Office of Energy Development and Promotion 9 (n.d.), as shown in Table 2. The solar radiation data was then used for the calculation of the size of Photovoltaic (PV) panels. In this example, both stand-alone and grid-connected systems were examined as well as both types of PV (Mono/polycrystalline and Amorphous silicon), since both types have different area requirements for the same amount of maximum power of the PV panel in kW_p. The estimation of the average area requirement ($m^2/1kW_p$) of different PV types was obtained by using examples from previous installations. Two projects undertaken by the Electric Generating Authority of Thailand (EGAT) in association with the Department of Alternative Energy Development and Efficiency (DEDE) give details about the PV nominal power and installation area (m^2) of an average of around $9m^2/1kW_p$ for a crystalline PV panel, while an amorphous silicon PV panel will need around $15m^2/1kW_p$ (EGAT, 1998; 2004). Then a suitable PV size was calculated from the relationship of the energy available per day (kWh/day), the PV maximum power (kW_p), and the solar radiation (kWh/m^2/day). In terms of a stand-alone system, the minimum rate of solar radiation was used to ensure constant electricity throughout the day (DEDE, 2001), while for the grid-connected system the average rate of solar radiation was used. This is due to the fact that a grid-connected system would help balance the electricity input and output for the office and the grid throughout the year. Using the minimum rate would produce more than enough for most of the year.

Table 2. Monthly solar radiation in Phitsanulok.

Months	MJ/m^2 - day	kWh/m^2 - day
JAN	15.8	4.4
FEB	16.7	4.6
MAR	19	5.3
APR	22.1	6.2
MAY	21.4	5.9
JUN	18.5	5.1
JUL	18	5.0
AUG	17.1	4.7
SEP	17.1	4.8
OCT	18.5	5.1
NOV	17.5	4.9
DEC	16.2	4.5
Average of 5.2 kWh/m^2 - day		

Lastly, both rainwater and solar power were examined against the available land area. For rainwater, all of the area is available for capturing rainfall. The rain that falls onto the roofs of the building (excluding a green roof) may be projected as a potential water supply, while rain falling elsewhere may be viewed as potential run-off. The amount of potential run-off water compared to the potential water supply provides an interesting illustration of the resource waste and other such environmental impacts that a building can cause. Green roofs, green areas or pervious surfaces, in this case, could be viewed as an alternative to hard surfaces, in order to reduce the amount of water run-off. For solar power, only the roof area facing south, the most solar-efficient side in Thailand, was examined for potential electricity generation using PV panels. The ratio between the total area of a roof and the solar efficient areas also suggests a better design practice, if generating electricity should be part of everyone's future. For example, a hipped roof would allow very little solar efficient area for PV panel installation when compares to its total surface area. However, this paper assumes that the total roof area and the solar efficient area of the roof would not be much different for office buildings, in general. This is due to the concrete slab roofs are normally used for this type of building in Thailand. The effect of shading from adjacent buildings may play a bigger role in reducing the solar efficient area of a building in most major cities than the orientation of the roof itself.

4. Examples of Student's Projects

Through a number of seminars and workshops that allowed them to check their design against the immediate environment, the students learnt the weaknesses in their building design and its impact to the natural environment. For example, some of the students aimed to use natural sunlight to light major parts of their design. However, during the workshops, most of these students found that they ended up sealing off the majority of the potentially sun-lit area without realising it through their planning development. Calculations about rainwater, solar power, and the consumption of its supporting system showed most of the students how wasteful their design would be if it was built in reality. Possibilities for changes were discussed during the workshops and the students had the opportunity to attempt to resolve their design problems before the final presentation.

The results from most of the students' final projects were interesting. It is not yet common practice for the students to be able to re-check their design in terms of both its building technology and capacity estimation. Therefore, the students found it to be a useful and interesting learning process. It also helped them to understand about the impacts of their design to the environment and acted as a guideline and an inspiration for them to change their approach.

The student projects selected here are interesting examples by two students who were trying to employ several green technologies into their designs, as well as solve some of the environmental impacts that their buildings created.

In each project, green areas and gardens were emphasised in order to lessen the paved area as well as to provide leisure and relaxation space for users. In terms of solar power, the total area of the roofs and the solar efficient area were examined. In this case the whole area of the south side (the solar efficient area) is equal to the full solar power harvest capacity of a building. During the physical capability estimation workshop, students learnt about the effects of their building and its interaction with the immediate environment. From observation, many students were most surprised at the amount of run-off water their building discharged into the public drainage system. Some of the students managed to respond to this by changing their design from a hard surface to green areas or porous block pavements to reduce the amount of run-off water, as the examples in Figures 1 and 2 show.

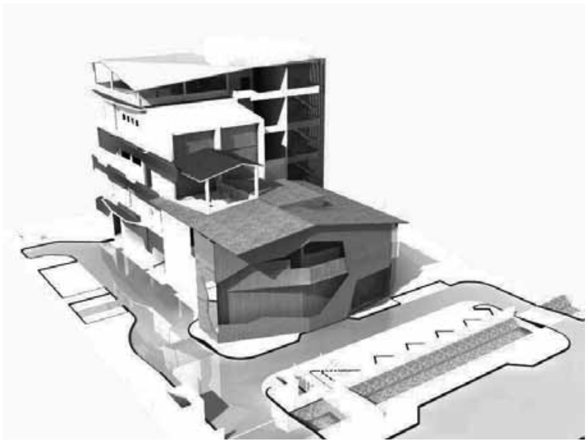

Figure 1. Aroma Charcoal Co. Ltd. By Apinan Utbuawong (4th Year Student), Faculty of Architecture, Naresuan University.

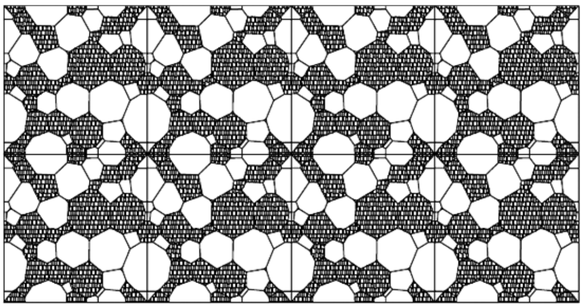

Figure 2. Apinan Utbuawong's idea for porous block pavements to reduce the amount of run-off water for most part of his paved areas.

Table 3. Apinan Utbuawong's Aroma Charcoal Co. Ltd. Physical characteristics.

Physical characteristics	
Aroma Charcoal Co. Ltd. 4^{th} Year Student: ApinanUtbuawong	
Size of land holding	$2700m^2$
Building footprint	$848m^2$
Open area	
- Hard surface/pavement	$588m^2$
- Porous block pavement	$162m^2$
- Green area	$960m^2$
Type of roof	Concrete slab and green roof
Total roof area	$1035m^2$ ($400m^2$ green roof)
Total solar efficient area (on the roof)	$236m^2$

Table 4. Apinan Utbuawong's Aroma Charcoal Co. Ltd. Physical capability estimation.

Physical capability estimation	
Maximum Production Capability Rainwater (Annual rainfall of 1,300mm)	
Water catchment area	
- Total roof area for rainwater catchment	$526m^2$
- Total area of open area	$1710m^2$
Amount of rainwater catchment	
- Rainwater from the roof	$684m^3$/year
- Rainwater on hard surface	$765m^3$/year
- Rainwater on green area/ porous block pavement/ green roof	$1979m^3$/year
Water consumption/ year	
-Water consumption in an office (an estimation of 50l/person/day)	$785m^3$/year
-Water for gardening purpose (an estimation of $1.5l/m^2$/day)	$407m^3$/year
Electricity from solar power (stand-alone system)	
Total solar efficient area (on the roof)	$236m^2$
Mono/polycrystalline	26.2kWp
(average of $9m^2$/1kWp)	115.4kWh/day
Amorphous silicon	15.7kWp
(average of $15m^2$/ 1kWp)	69.3kWh/day
Electricity from solar power (grid-connected system)	
Mono/polycrystalline	26.2kWp
(average of $9m^2$/ 1kWp)	136.2kWh/day
Amorphous silicon	15.7kWp
(average of $15m^2$/ 1kWp)	81.6kWh/day

However, as previously mentioned in the methodology section, there are only 123 days of rainfall in Phitsanulok. Therefore, from the examples of the student projects, using more green areas, such as gardens, green roofs, green walls, and pervious surfaces will in turn require more watering for up to 242 days a year. This led some students to research plant types that used less water or explore potential greywater reuse. These experiments provided students with a productive problem-based learning process in the design studio, as well as reinforced their ongoing studies.

Figure 3. Mountable Cutlery Co. Ltd. By Suthee Pakdeewong (4th Year Student), Faculty of Architecture, Naresuan University.

In both cases the building footprints are similar, but with different designs that result in different roof areas and ground surfaces. These characteristics lead in turn to varying environmental impacts. For example, more hard surfaces mean more potential run-off water, while more green areas and green roofs mean more potential to absorb storm water. In both cases, the amount of rainwater harvested from the roof is assumed to satisfy the requirements of the gardens, green areas, and green roofs. There will be some left for the use of flushing toilets as well. The capability estimation serves as a tool to check the impacts of the building on the environment and acts as a reminder of the possible results of a design. For example, if both students design an office building without using the porous block pavement in their design, but rather the usual concrete slab or other hard surface, both buildings would create 2,744 m^3 and 2,099 m^3 of run-off water/ year respectively, which would go into the public drainage system. Even though this paper is over-looking the rate of absorbency of the porous block pavement, this oversight should be acceptable for the estimation. A more accurate calculation would need to take into account several conditions such as underground water, soil types, and types of rainfall,

Table 5. Suthee Pakdeewong's Mountable Cutlery Co. Ltd. Physical characteristics.

Physical characteristics	
Mountable Cutlery Co. Ltd. 4th Year Student: Suthee Pakdeewong	
Size of land holding	2700m^2
Building footprint	888m^2
Open area	
- Hard surface/ pavement	768m^2
- Porous block pavement	393m^2
- Green area	454m^2
Type of roof	Concrete slab and green roof
Total roof area	821m^2 (306m^2 green roof)
Total solar efficient area (on the roof)	392m^2

for instance. Nevertheless, this level of accuracy would make it even harder to introduce the capability estimation as a voluntary procedure for encouraging the creation of more dynamic architecture.

In terms of electricity generation, at present the price of PV in Thailand is still quite high. According to the previous installation by EGAT in association with DEDE, the average cost of PV cells is over 200,000 Baht/1kW_p (EGAT, 1998; 2004). However, the capability estimation is not suggesting that the full potential should be reached immediately, but rather developed over time until the end of the useful life of a building. The numbers of installed PV cells can gradually increase depending on project conditions and available budgets. Additionally, the estimation may actually be more than what it appeared in the student's project if the vertical planes of a building are included in the calculation, especially for electricity generation. Possibilities and examples of a building using vertical planes to generate electricity can be found in Hermannsdörfer, I. & Rüb, C. (2005) and DEDE (2001), as well as in the headquarters of the Electric Generating Authority of Thailand (T 102).

One interesting finding from the student's projects is that many of them tried to reduce the hard surfaces on both their roofs and floors. Although the

Table 6. Suthee Pakdeewong's Mountable Cutlery Co. Ltd. Physical capability estimation.

Physical capability estimation	
Maximum Production Capability	
Rainwater (Annual rainfall of 1,300mm)	
Water catchment area	
- Total roof area for rainwater catchment	515m^2
- Total area of open area	1615m^2
Amount of rainwater catchment	
- Rainwater from the roof	670m^3/year
- Rainwater on hard surface	998m^3/year
- Rainwater on green area/ porous block pavement/ green roof	1101m^3/year
Water consumption/ year	
- Water consumption in an office	
(an estimation of 50l/person/day)	565m^3/year
-Water for gardening purpose (an estimation of 1.5l/m^2/day)	419m^3/year
Electricity from solar power (stand-alone system)	
Total solar efficient area (on the roof)	392m^2
Mono/polycrystalline (average of 9m^2/ 1kWp)	43.5kWp 191.6kWh/day
Amorphous silicon (average of 15m^2/1kWp)	26.1kWp 115kWh/day
Electricity from solar power (grid-connected system)	
Mono/polycrystalline (average of 9m^2/ 1kWp)	43.5kWp 226.2kWh/day
Amorphous silicon (average of 15m^2/ 1kWp)	26.1kWp 143.7kWh/day

change from concrete slab roofs to green roofs in several student projects reduced the available area for PV installation, the change brought about a better use of these normally unutilised spaces. Roof gardens and communal spaces are among the most popular newfound function of these areas. Although green roofs in some projects are not openly accessible for employees to use, these roofs still serve as microclimate modification by lessening built-up heat and reflection into the building's interior. Even though the reduction of the PV installation area may seem significant if electricity generation becomes more necessary, the installation area can be shifted to the elevation of the building as mentioned earlier. It can be seen that some average consumption rates are needed in order to show the general capacity of a building. These data also help students to understand more about their behaviours when they compare themselves to the average rates. It is true that the production of the physical capability estimation only represented a fraction of the project activities: most of the study time was focussed on selecting green products, developing reasonable functional spaces, planning and establishing green activities in the company, and integrating environmental engineering systems as well as green features and technologies. However, this small component played a very important role in showing the students the impacts of their design and its consumption rate on the immediate environment.

At the end of the course, the majority of the students showed much improvement from their first draft in terms of a more environmentally friendly architecture. Most of the students included the idea of natural light, natural ventilation, passive design, rainwater harvest, solar power usage, and the promotion of biodiversity and green areas as major parts of their design. After the final presentation, the students submitted a report on their design with all estimations included. In addition, they were asked to comment on their own design and how else they could improve it. Most of the students were quite open about their mistakes and were eager to give opinions about how it could be re-designed if more time had been given to them. Many students commented about the lack of in-depth knowledge regarding specific technologies and systems in their design. They rather felt insecure about it and hoped to understand more if circumstances allowed. All in all, the students felt that they were connected to the reality of architectural design more than they had ever been with any other studio, and had been encouraged to realise the responsibility of architects to the general public as well as the natural environment. It is true that not all of the projects were successful, but showed a step in the right direction towards the promotion of sustainable architecture. A year later, about half of these students continued their study in the final year with sustainable architecture as the major conceptual theme for their final projects. These students tried to use what they had learnt during their sustainable architecture studio the previous year and adapted it to different contexts. Some of these students even tried using the physical capability estimation chart to show the impact of their building during the final presentation. As a result, the reactions and changes in attitude among the students towards project design, as well as the greater value given to minimising the environmental impacts of their design, even after the course, demonstrate the successful dissemination of environmentally friendly design principles to the architects of the next generation. However, to sustain these valuable insights in practice, the wider architectural community and general public will need to also get involved to make these ideas a reality.

5. Conclusion

From the lecturer's point of view, the course still has room for development, especially in the area of social context, building materials, and construction processes. Even though these issues were discussed and debated in several seminars and workshops, the results as implemented in the final product designs were limited. In the recent course, during the 2010 academic year, more emphasis was put on the material domain. The students had to research about green and locally sourced local materials, which may be beneficial to them when they graduate. Moreover, social aspects were included as a program component. However, the teaching and learning strategies were not always based on real situations, with real programs involving real users. Therefore, the development of the social dimensions will not be an easy task.

It can be seen from this case study that environmentally friendly architectural approaches can be introduced into a design studio. The results from the physical capability estimation in the 4th year design studio show that it is not difficult for an architect to produce them. This is because the calculation is quite straightforward and easy enough for a 4th year student to do with only simple explanation given to them. Hence, it should not be so hard for any architect to perform, and be part of creating a guide for a changing society and a design that can evolve with its users over time. From the observation of the lecturers, the majority of the students were interested in trying to make their design more environmentally friendly. Even though the students' implementation or approach to the issue may still be limited, the studio provides a good starting basis to develop teaching and learning strategies about and for sustainability in the field of architecture. The fact that, among 18 students, several of them continued on the sustainable design track and selected sustainable/green architecture topics as their final-year project (the Bachelor thesis for the 5th year students), it may be hoped that more students will take the same path in the future.

Nonetheless, this paper illustrates the experience of accommodating some aspects of environmental education into an architectural curriculum. The outcomes of the application have proven to be beneficial to the students and it is hoped that it may contribute to the nurturing of a new generation of architects, who will treasure and have greater respect for the natural environment. From the perspective of the lecturers, the outcome of the past year has been very productive, even though there is a lot of room for further development in the future.

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