International Collaborative Project in Engineering Design Education Between Kanazawa Institute of Technology and Singapore Polytechnic

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Abstract *— This paper reports positive learning outcomes in an international collaborative project in Engineering Design Education between Kanazawa Institute of Technology (KIT) in Japan and Singapore Polytechnic (SP) in Singapore. In 1996, KIT became the first university in Japan to offer courses in Engineering Design. The goals of the courses were to have students not only gain actual engineering design experience through working on real-life projects, but also acquire skills in presenting their results in written and oral reports. Two visiting academic staff from SP attached to KIT from November 2002 to February 2003 studied the Engineering Design II course, under the staff exchange program. SP has implemented an Innovation, Design & Enterprise in Action (IDEA) module since July 2004. As a result, an international collaborative program has started between KIT and SP. In 2003, students' teams at both KIT and SP worked on the same engineering design project, the theme of which was "Roof Top Gardens". Their achievements were unique in their design solutions due to the differences in climate and culture in Japan and Singapore, although all the design teams followed the same engineering design procedure. This collaborative project was a positive experience for both students and faculty members. Furthermore, both groups benefited from a study of the design solutions generated by their foreign counterpart.*

Index Terms *— engineering design, international collaboration project, roof top garden, engineering design process*

Introduction

Kanazawa Institute of Technology (KIT) started its university wide educational reform in 1995. The basic principle behind the reform is to develop students who can learn autonomously. The paradigm shift is from "passive knowledge acquisition and problem solving" to "active problem discovery and wisdom seeking" as shown in Figure 1. The idea was initiated from educational inadequacies up to that time, where instructors crammed knowledge into students [1]. In 1996, KIT started two introductory Engineering Design (ED) courses as a part of the educational reform. The ED courses were devised to allow students to identify and solve open-ended problems in a technical fashion [2].

In most Japanese universities, classes are in session for one hundred and fifty days in a year. It is necessary for KIT instructors to develop good strategies to have the students spend the remaining two hundred and fifteen days in a productive and creative ways that help students to improve their academic performance. Therefore, in 1993, KIT established an innovative facility, "Factory for Dreams and Ideas", ("Yumekobo", which literally means "Thinking Workshop" in Japanese language) [3]. "Yumekobo" is designed to be used by the entire campus population 330 days in a year. "Yumekobo" is fully equipped with the latest machines and tools, and is staffed with highly skilled technicians to support students' learning.

Students are encouraged to build models and prototypes and/or carry out experiment at "Yumekobo" to see if their designs, which are generated in ED courses, are feasible and useful, or find out what needs to be improved.

Two visiting academic staff from the Singapore Polytechnic (SP) attached to KIT under the staff exchange programme from November 2002 to February 2003 taking up Engineering Design II course. SP has implemented new module called "Innovation, Design & Enterprise in Action (IDEA)" [4]. Since then, an international collaboration project in ED Education has started between KIT and SP.

This paper reports positive learning outcomes in the international collaboration project.

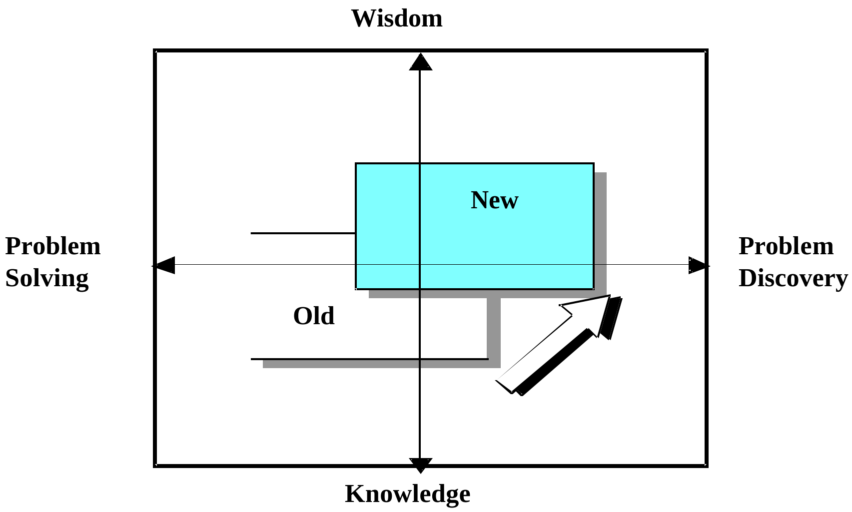

FIGURE 1
PARADIGM SHIFT OF EDUCATIONAL REFORM AT KIT

Introductory Engineering Design Education at KIT

Introductory ED Education consists of two ED courses; ED I and ED II. ED I is taught in the Fall term of the freshman year, and ED II in the Winter term of the sophomore year, respectively. The course objectives of ED I and ED II are distinct and properly coupled in order to achieve a seamless transition as shown in Figure 2. ED courses are characterized by project-based learning in groups. The goals of ED I and ED II are to have students gain actual engineering design experience through working on real-life projects, and to present their results in written and oral reports. Also, this would be their first experience at working in groups. The students are given open-ended problems. In the process, they are expected to learn teamwork skills such as communication skills and leadership. Students choose engineering topics relating to their daily life, identify project, characterize design projects, generate design concepts, evaluate design concepts, select the most promising concept, and design in detail. Students are encouraged to develop distinct and creative design solutions.
The procedures covered in ED I and ED II are:

- To identify project/design opportunities
- To characterize design projects
- To generate design concepts
- To evaluate design concepts and to select the best concept
- To design in detail
- To present results

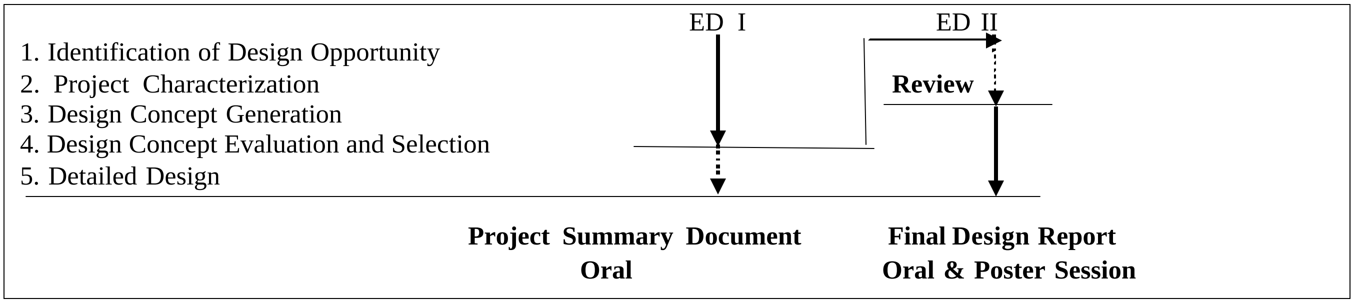

FIGURE 2
FLOW OF ED I AND ED II

Collaboration Project between KIT and SP

Collaboration Project in ED education between KIT and SP started in 2003 when two visiting academic staff from SP stayed at KIT from November 2002 to February 2003 studying the ED course. The collaboration project includes the following activities;

- KIT and SP continue the Staff Exchange Program.
- KIT and SP continue to exchange information and experience of ED education.
- Both students participate in project themes in ED courses by using IT technologies, e.g. e-mail, website and/or video conference.
- Both staff jointly publish conference papers on ED education.

In 2003, a project theme of "Roof Top Gardens" was selected as the first collaborative project between the two instituations. The main goal was to create roof top gardens where people can relax and enjoy themselves. Eight teams at KIT and one team at SP worked on the same project. Nine teams independently worked on different gardens focusing on their themes of interests. Their progress reports and final achievements were exchanged.

Students of Kanazawa Institute of Technology and Singapore Polytechnic

Students of Kanazawa Institute of Technology

Approximately 1,700 sophomore students of KIT have to enrol in ED II course. They were distributed across 50 classes of approximately 34 students per class, according to their varied course of study. The typical KIT sophomore student is 20 years of age and finished high school two years prior to his/her entrance into KIT. He/she has never held technical industrial position and has little to no experience in design. Each class is divided into 5 to 7 teams and each team is composed of 5 to 6 students, depending on the class size. The classes meet during two subsequent 60-minutes lectures on weekly basis for 9 weeks. Additional weekly office-hour meetings are assigned to the student groups for discussion of the team projects and class assignments, and to better monitor the teams' progress and accomplishments. Approximately 320 design teams select their design projects on their own judgement by taking much account of their interests, social needs, majors, etc. The cost incurred is for making a model and is born by them.

Eight teams selected the engineering design project, the theme of which is "Roof Top Gardens". The teams independently worked on different gardens focusing on their themes of interests.

Students of Singapore Polytechnic

Students of Singapore Polytechnic are generally between 17 to 19 years old. They have completed the General Cambridge Ordinary Level Examination in the secondary schools and met the entry requirements before enrolling into the polytechnic education.

All the third year students in SP have to take up a final year students' projects in their respective three-year Diploma course. The aims of the final year students' projects are to provide students an opportunity to apply theoretical and practical knowledge that they have acquired in the courses into a project. In particular, project work provides opportunities for students to:

- carry out brain storming sessions to come up with ideas, and to draw up and achieve a prescribed set of objectives;
- integrate all aspects of knowledge acquired and comprehension from other modules of the course;
- cultivate team spirit and team work through working with team members;
- practice technical skills, quality consciousness and time management;
- develop initiative, creative thinking and innovative ideas;
- plan, organize and write a group project report.

Each group usually consists of not more than three students who have to meet fortnightly and discuss their project with the Project Supervisor.

Although the time for meetings with the Project Supervisor and the time allocated for practical work are written into the student timetable, students are free to work outside these allocated time slots. Students are expected to spend an average of three hours per week on their project. Project work is not "structured". Every project is unique and every problem may have more than one possible solution.

Students of the final year project are given 30 weeks to complete a project and shall be credited as one module in their course. Due to the diverse nature of student project work, a broad marking scheme based on assessment on the following five core skills is used to assess each student individually as well as a group.

- Organization & Planning
- Communication & Co-operation
- Independence & Responsibility
- Ability to work under stress
- Application of knowledge and thought processes

In addition marks are allocated for any new knowledge gained by the students upon completion of the project and for their individual knowledge on the project as a whole.

Students' Activities and Achievements

The purposes of the nine design teams, who tackled with the roof top garden project, are shown in Table 1. Although the project theme is same, the teams independently worked on different gardens focusing on their themes of interests as sown in Table 1.

Purpose of design	Student
Designing a roof top garden and developing a multimedia walkthrough animation video	SP
Designing a roof top garden which utilizes rainwater for spraying water	KIT
Designing a roof top garden and preventing visitors from falling from the garden	KIT
Designing a roof top garden and preventing objects from falling from the garden	KIT
Designing a system of spraying and draining water for an easy maintenance of a roof top garden	KIT
Designing a fence to prevent visitors from falling from the garden and to decorate flower pots	KIT
Designing a sprinkling system utilizing the capillary action	KIT
Designing gardening modules	KIT
Designing an easy and cheap gardening kit	KIT

TABE 1
PURPOSE OF DESIGN

Activities and Achievements of KIT Students

As a typical example of KIT design team, activities and achievements of a team, whose design purpose is "Designing a roof top garden which utilizes rainwater for spraying water", are exhibited below.
The purpose of the KIT design team was to design a roof top garden which can contribute to save energy and to improve green environment. The team studied the possibility of utilizing rainwater for spraying plants on a roof top garden.
First, the team investigated the amount of rainwater in Kanazawa Region [5]. The monthly rainwater recorded in 2003 is shown in Table 2. Second the team carried out experiment to see how much of rainwater will be absorbed by soil of a roof top garden, and how much will be seeped from soil. Lightweight soil of 100 mm thick was packed into a plastic bottle and then water was poured into the bottle in order to measure the rainwater absorption capacity of the soil. The amount of water seeped from the soil was measure at "Yumekobo". It was found that the maximum amount of water absorbed by the soil of roof top garden is approximately 50 mm as shown in Figure 3.
Third, the recoverable rainwater was determined by taking account of both rainwater recorded in Kanazawa and the absorption capacity obtained from the experiment. Total amount of water recoverable annually from rainfall on the roof top garden of 120 square meter amounts 49,593 litter, which corresponds to 42 % of rainfall. The recovered water can be utilized for spraying plants on Roof Top Garden.
Finally, The team designed a Roof Top Garden of 510 square meters (30 m long by 17m wide). A three dimensional model shown in Figure 4 was made to illustrate the layout and its facilities; i.e. fountain, rest pavilion, bench, rainwater recovering system, spraying system, footpaths, trees, lawn ball area and flower garden. The team submitted a poster, a final design report and a three dimensional model.

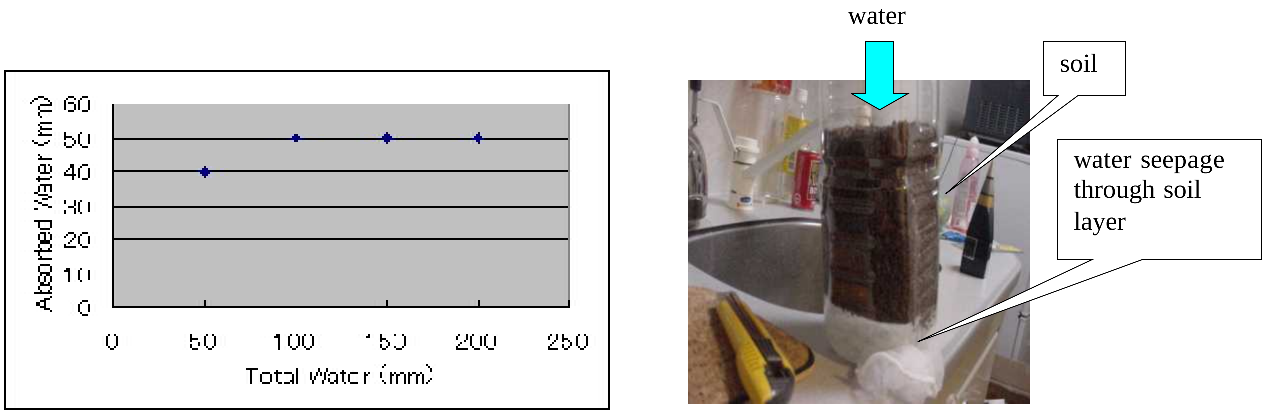

FIGURE 3
MEASUREMENT OF WATER ABSORBED BY SOIL

Month	Rainfall (mm)	Recoverable Rainwater (mm)
April	229	77
May	70	32
June	136	11
July	227	91
August	236	158
September	99	48

TABLE 2
RAINFALL AND RECOVERABLE RAINWATER IN KANAZAWA REGION

FIGURE 4
THREE-DIMENSIONAL MODEL OF A ROOF TOP GARDEN

Activities and Achievements of SP Students

The land usage has been important due to the scarcely land in Singapore over the recent years. The building of Housing & Development Board (HDB) flats is a good example. The flats are built upwards to minimize land usage. Although providing shelter is important, the need to provide a soothing and relaxing environment to cater to Singaporeans hectic lifestyle are not compromised. Therefore most of the HDB includes a neighborhood parks or garden for the residents. Currently these parks and gardens are constructed on the ground level with only a small percentage constructed on the multi-storey carpark rooftop. In order to minimize land usage, local authorities encourage future parks and gardens to be built on the rooftop.

There was only one team in SP working in this collaborative project titled “Proposed Roof Top Garden on Multi-Storey Carparks". The project team consisted of three students pursuing a Diploma in Civil & Structural Engineering course in the School of Design & the Environment. The scopes of the project involve facilities, safety features, maintenance, age group catering, footpaths, entrance access, positioning of facilities, lighting, greenery and shelter.

The project requires clear and structured activities that covering the engineering design process. The process involves design project identification, design project characterisation, design concepts generation, evaluation and selection, and detailed design.

A good design process should provide a framework for managing a design project and help the students in the design team to get a good start for the project by promoting the selection of the right problem to work on. Make orderly progress towards a solution by providing a sequence of activities to be implemented and to achieve a successful end to the project through appropriate implementation of a solution. Students integrated information and techniques that they are mastering in order to develop analytical, applicative, problem-finding and problem-solving abilities. The experience would gave them opportunities to exercise their creativity and hone their leadership skills as they carry out individual and group tasks to make an invaluable contribution to the community.

A set of design specifications for the roof top garden was generated and is shown in Table 3. Students have proposed 12 design alternatives. All the alternatives have been examined with the requirements stated in the design specifications. Feedback from the residents and the Professionals has also been carefully evaluated too. All these activities were important to the project team in order to finalize the design of the proposed roof top garden.

A 1:200 scale model having the dimensions of 55 cm long by 17 cm wide shown in Figure 5, was made to illustrate the layout of the roof top garden. Its facilities include the barbecue pits, fitness corner, flower gallery, gathering area, grandstand for seating with Light Emitting Diode (LED) lights embedded into ground, children playground, chess pavilion with cone shape roof, foot reflexology path linking chess pavilion and lawn ball area.

The project team submitted a poster, a comprehensive detailed report and multimedia animation with walk-through effect of the roof top garden as their achievement in the collaborative project.

The roof top garden on the multi-storey carparks offers many advantages. It reduces the surface temperature by 15 to 20 degree Celsius and lowers the ambient temperature by 1 to 3 degree Celsius. It also shields a roof from harsh weather, absorb carbon dioxide and reduce air pollution. The facilities provided will attract residents of all ages onto the roof. The atmosphere created from the design will help to strengthen the bonds and friendship amongst the multi-racial residents, families and friends.

No.	Design Factors	Objective (Goal)
1	Facilities	Minimum 4 type
2	Safety Features	Parapet wall, railing, fencing at areas where there is a prone to fall over
3	Maintenance	Easy
4	Age Group	Cater for elderly, adults, children
5	Footpath/clearance width	Minimum 1.5m
6	Access	Minimum 4 access points (for split and single level design) and 1 stairway and 2 slopes (for split level design only)
7	Size of gathering area	Cover ¼ - ½ of total area
8	Position of facilities	Minimum of one facility on either side of the garden (for split level design only)
9	Lighting	LED installed either on the pathway or gathering area
10	Greenery	Minimum of ¼ of total area
11	Shelters	Minimum 2 pavilions and provided cover over walkways

TABLE 3
DESIGN SPECIFICATIONS

FIGURE 5
THREE-DIMENSIONAL MODEL OF A ROOF TOP GARDEN

Conclusion

Japan and Singapore are countries whose populations are overflowing their narrow geographical limits. People of both countries are very much concerned about improving green environment and preventing urban heat island effect. Therefore students of KIT and SP tackled with the project theme of roof top garden in order to improve green environment and to provide a relaxing and soothing environment to cater to Japanese and Singaporeans hectic lifestyle.
Important information obtained are listed as follows:

(1) Eight years experience of Engineering Design Education at KIT and the staff exchange programme between the two Institutions have contributed to the successful start of the international collaboration project.
(2) Although student teams of KIT and SP worked on the same project of Roof Top Garden, they independently worked on different gardens focusing on their themes of interests. Their achievements were unique in their design solutions due to the differences in climate and culture in Japan and Singapore.
(3) One of the KIT teams studied the possibility of utilizing rainwater for spraying plants on a roof top garden. After investigating rainwater recorded in Kanazawa Region and carrying out an experiment to see how much of rainwater is absorbed by soil of a roof top garden and how much is recovered, the team designed a roof top garden which utilizes rainwater for spraying plants on a roof top garden.
(4) KIT students are eager to find out the design solutions of Engineering Design course by producing models and carrying out experiments at Yumekobo as outside class activities.
(5) The achievement of the students' project team in Singapore Polytechnic cultivated the creative ideas and innovative solutions. It would definitely enable students to foster out-of-classroom learning and team building. By having a green roof garden can extend the lifespan of the roof by protecting it from harsh weather. Roof garden can also absorb carbon dioxide and reduce air pollution. The roof top garden will be linked directly to the third or fourth floors of the surrounding blocks. In this way, it will become focal points for residents in these blocks.
(6) This collaborative project was a positive experience for both students and faculty members. Furthermore, both groups benefited from a study of the design solutions generated by their foreign counterparts.

REFERENCES

[1] Ishikawa, K., "Principles and Perspectives in Educational Reform at Kanazawa Institute of Technology, Changing Knowledge to Wisdom, *KIT Progress*, Vol. 1, 1996, pp. 5-10

[2] Matsumoto, S., Maekawa, H., Kubo, T., Matsuishi, M., "The Courses of Engineering Design I & II at Kanazawa Institute of Technology", *Journal of Japan Society for Design Engineering*, Vol. 36, No. 8, 2001, pp. 25-31

[3] Hattori, Y., "Education to Stimulate Students Motivation –Activity through The Factory for Dreams and Ideas", *Proceedings of 4th ASME-JSME Joint Fluids Engineering Conference,* 2003

[4] Loo, C. N., Pee, S. H., "Engineering Design Education - Learning Experience at Kanazawa Institute of Technology-", *Excellence in Education and Training Convention 2003, Singapore Polytechnic.*

[5] http://www.data.kishou.go.jp/