Abstract

In 1996, Kanazawa Institute of Technology (KIT) became the first university in Japan to offer courses in Engineering Design. Starting in the Fall and Winter quarters, Engineering Design I (EDI) and Engineering Design II (EDII) were taught respectively to approximately two thousand sophomore engineering students. These courses were developed with the assistance of visiting professors from U.S. universities. This paper discusses how the Engineering Design Program at KIT was transferred from one culture to another, how it evolved, and how it is now.

The first revision of the program occurred during the 1998-1999 academic year. A Task Force, which included some foreign professors, was formed to identify problems and needs in Engineering Design Education (EDE), and to develop design specifications for educational materials. The result was course packages for EDI and EDII. These packages included easy-to-use manuals for students and instructors. The course objective of EDI and EDII is distinct and properly coupled in order to achieve a seamless transition from EDI to EDII. A “Project Summary Report” was introduced to achieve this seamless transition.

The second revision of EDE started in 2000. Websites for EDI and EDII were opened for students and instructors to use. The websites contain teaching materials, templates for assignments, past student design projects, a bulletin board for information to students, and a question-and-answer box.

Today, both the face-to-face instruction system and the e-learning system are used. The Engineering Design courses are being taught face-to-face in the classroom, while collaborative communication functions of the e-learning system are being used to help the student teams complete weekly assignments. Since each student spends approximately five hours on each assignment, the collaborative communication functions of the e-learning system are very helpful.

The entire EDE faculty is now Japanese and visiting faculty from other countries comes to KIT to study the Program. A collaboration project is now under way between Singapore Polytechnic and KIT.
1. Introduction
Kanazawa Institute of Technology (KIT) is a private engineering college of approximately seventy five hundred undergraduate students and five hundred graduate students. It is the first university to have introduced engineering design education (EDE) in Japan. This is a part of the effort to reform the Japanese educational system since 1991. The aim of this reform was to promote the integration and application of knowledge-based learning and skill training. It was proposed in order to enhance the creativity of KIT graduates and to cultivate flexibility as engineering professionals.

2. How the Program Started
EDE started in 1996 with the assistance of American professors from Rose-Hulman Institute of Technology, a sister school of KIT, and other US institutions. These professors worked with Japanese professors to develop two courses, Engineering Design I (ED I) and Engineering Design II (ED II). These courses were offered in the Fall term and Winter terms of the sophomore year. Approximately two thousand sophomore students were divided into sixty classes and were taught by EDE faculty and other KIT engineering professors of various disciplines. Each course was taught once a week for two seventy-five minutes period. The terms lasted nine weeks\(^{(1)}\).

While the program began with the assistance of foreign faculty, it was never intended to model it after a design program in any country. The program, from the beginning, was to be uniquely Japanese and serve the needs of Japanese students, and Japanese industry.

The goals of ED I and ED II were 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 were given open-ended problems and were expected to generate design concepts. In the process, they were expected to learn teamwork skills such as communication skills and leadership.

The procedures covered in ED I and ED II were to:
1. identify project/design opportunities,
2. characterize design projects,
3. generate design concepts,
4. evaluate design concepts and to select the best concept,
5. design in detail, and
6. present results.

The courses were taught as originally designed in the 1996-97 and 1997-98 school years. The logistics of offering sixty sections of one course were staggering. At the end of ED II, a poster
session was held. Each team did a poster on their design project. The result was over 400 posters, more than most conferences. The poster section occupied all five floors of a large building and was well attended by students, faculty, and staff. It was very beneficial in informing the KIT community about the Engineering Design program.

The largest problem encountered in starting the program was finding faculty with the expertise, and interest, to teach 60 sections. To expose the students to a variety of ideas and different ways of thinking, the courses were taught not only by Japanese professors, but also by foreign professors with experience working for U. S. universities. The latter were assisted by teaching assistants who spoke both English and Japanese. Since these professors had varying backgrounds and interests, it was apparent that standards were needed to guide them.

Problems were also encountered with students' attitudes. They were not used to dealing with open-ended problems, and had difficulty in voicing their opinions and ideas. Also, they had difficulty taking a leadership role in a society where conformity and unity were the norm. This reluctance to take control led to many hours of discussion with little results, leaving little time for studying other courses.

3. Reforms

3.1 First Reform of Engineering Design Courses
In 1998 the first major evaluation of the EDE was carried out. Problems and needs were identified and an ED task force, “IDEA-KIT”, was formed. It consisted of Japanese and American professors. Their first task was to identify problems in the Engineering Design program. Some of the problems identified were:

1. Goals and grades scales were varied among instructors.
2. Differences in ED I and ED II were not clear to many instructors.
3. The transition from ED I to ED II was often awkward because of 1 above.

The task force suggested that standard course packages be developed for both students and instructors in order to standardize classroom instruction and grading criteria. The packages would consist of manuals easy to use by students and instructors. Also, it was proposed that ED I would be taught in the Fall quarter of the freshman year, and ED II would be taught in the Winter quarter of the sophomore year. AT KIT, the Spring quarter is the first quarter of the school year. Therefore, the Fall quarter is the second quarter of the school year and the Winter quarter is the last.

The course objectives of ED I and ED II are distinct and properly coupled in order to achieve a seamless transition. The three quarter gap between taking ED I and ED II could cause a knowledge
retention problem. To prevent this possible problem and to provide an easy transition, a “Project Summary Report” was designed for use in ED I<sup>(4)</sup>.

An Example of the Project Summary Report:

<table>
<thead>
<tr>
<th>Main theme</th>
<th>Promoting ecological life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project theme</td>
<td>Energy saving vending machine</td>
</tr>
<tr>
<td>Summary</td>
<td>Selected project theme related to the main theme. Surveyed exiting products in the market. Surveyed and analyzed customer needs. Decided design specification based upon the customer needs. Through brain storming, we generated viable design solutions with taking account of saving energy and usability.</td>
</tr>
<tr>
<td>Reasons for choosing the project theme:</td>
<td>Team members were interested in designing energy saving vending machine.</td>
</tr>
</tbody>
</table>

The Project Summary Report is a brief summary of the process each design team followed and the results they obtained on their projects in ED I. In addition to this summary, it contains an existing solution report, customer needs report, design specification report, and design concept report. This Report becomes the source document to be used by ED II students. Each ED II team can evaluate previous ED I projects by using the Design Project Evaluation Matrix with respect to a set of criterion and decide on a project it would like to pursue. See Figure 1A and 1B.

Each team carefully reads and evaluates the quality of the work produced by the previous ED I team as described in the Project Summary Report through the design specifications section. Each team then generates new quality design concepts based on customer needs and design specifications. The design process continues until each team determines the major characteristics of the final solution and defines the detailed characteristics of the solution, such as geometry, materials, dimensions, cost, and fabrication processes.

### 3.2 Second Reform of Engineering Design Courses

The second reform of the Engineering Design sequence started in 2000. The first change was the establishment of a website for ED I and ED II. This website contains teaching material and
templates for class assignments. Past student work such as final design reports and award winning posters, as well as frequently-asked-questions are also included. Students can also upload assignment files, get information off a course bulletin board, and ask questions of ED faculty.
In 2001, an Engineering Design Café was started for the instructors of ED I and ED II. The group meets every Saturday from 11:00 to 12:00. Yes, KIT has Saturday classes and the faculty work until noon each Saturday. Participants of the Engineering Design Café exchange ideas to improve ED I...
and ED II. Course packages for EDE are revised every year through the discussions at the Café. In 2002, 120 EDE faculty members participated in the Engineering Design Café.

A hybrid class management system was implemented in 2002 for ED I and ED II\(^5\). In this system both the usual face-to-face instruction method and e-Learning are employed. The face-to-face instruction system is used in the Engineering Design classrooms. Students can access the e-Learning system anytime through the 8500 network connections on the KIT campus or 3500 dormitory rooms, all through fiber optical cable, in order to start group activities. An e-Learning software platform, WebCT\(^6\), is used. The collaboration function of WebCT can be fully utilized by the design teams to develop group activities and to complete assignments such as determining design specifications, generating design concepts, evaluating and selecting final solutions, and defining the detailed characteristics of the solution. With the e-Learning system, student groups can meet and work anytime. Team members are no longer required to physically meet in a room to complete their assignments greatly reducing time required.

Engineering ethics was incorporated into ED I and ED II in 2003. Students now survey the ethical aspect of their design project to insure their designs are ethical. They also pay special attention to the ethnicity of their design in their final reports for it affects receptivity of their designs in specific cultures\(^7\).

### 4. Present Status of the Engineering Design Courses

At present, all Engineering Design classes are taught by Japanese professors. The KIT program has become a real Japanese design program. Foreign institutions are now sending representatives to KIT to study the program. Two visiting professors from Singapore Polytechnic (SP) stayed at KIT from November, 2002 through February, 2003 to study the ED courses. SP has now implemented ED courses and an international exchange program has started between KIT and SP. Students from KIT and SP are working on the same project theme, “roof top gardens”. Two ED II teams at KIT finished roof top garden projects in 2002. Eleven ED II teams at KIT and one team at SP are now working on the same projects this year. Their results will be compared early in 2004. Due to the differences in climate and culture in Japan and Singapore, both Japanese and Singaporean students are expected to generate unique and exciting design solutions.

#### 4.1 The Factory of Dreams and Ideas (Yumekobo)

KIT established Yumekobo, “Factory for Dreams and Ideas” in 1993. This innovative facility was designed to be used by the entire campus and is open to all KIT students from 8:45 a.m. until 9:00 a.m.
Yumekobo is fully equipped with the latest machines and tools, and is staffed with twenty highly skilled technicians to support KIT students. Therefore, students may build models and prototypes to demonstrate their designs created in ED I and ED II. They can see if their designs are feasible and useful, or find out what needs to be changed or added. Some examples of ED II designs which have been produced at Yumekobo are:

Example 1: Design an Ecological and Barrier-free Town
One ED I team tackled this design project. Their goal was to design a town where physically handicapped people could walk down a street unimpaired. The team choose Downtown Kanazawa as a model since it is typical of a crowded city in Japan. The population density in Kanazawa is about 1000 people per square kilometer. The Kyoto Protocol and Amendment calls for 10 trees per square kilometer in order to cope with global warming. The team could not find space for 10 trees in crowded Kanazawa. Therefore, they generated the idea of planting ivy on the walls of houses and buildings. They also conceived of using voice-guided facilities for the blind to help them navigate through the streets. A model was made to demonstrate their design. Figure 2 shows a town composed of walls covered with ivy and voice-guided handrails installed along the sidewalk.

Example 2: Design of Watches for the Blind
One of the ED II teams generated several viable ideas for watches for the blind which can display
precise time without any noise. After evaluating their designs, they selected an idea of a watch with a rotating dial with numbers in Braille. The team then produced a model at Yumekobo to confirm that their design was feasible. They noticed by observing the model that the Braille dial should be reinforced against force exerted by the user. They then redesigned the watch structure to withstand this force.

4.2 Pre-college Introductory Engineering Design Education

In order to stimulate young students' interest in science and engineering, KIT has started a two-day pre-college introductory engineering design course for high school students. The course provides an opportunity for students to develop an understanding of design and engineering, and is based on three pedagogical concepts: the plan-do-check-act cycle, hands-on exercises, and cooperative learning. Students are asked to design and build bridges from 900mm x 2mm x 2mm strips of balsa wood. The goal is to build a strong bridge using as little material as possible. See figure 3.

On the first day of the course, each student is asked to design and build one bridge. After completing the bridge, he/she applies loads on the bridge until it collapses. The design is then analyzed to find out where the bridge failed.

At the end of the first day, students are assigned to teams. Based on the experience gained the first day, each team tries to design and build a stronger bridge to withstand a heavier load. By learning through experience (the plan-do-check-act cycle), hands-on exercises, and group exercises (cooperative learning), the average load-carrying capacity of the bridges designed by teams was 1.75 times larger than the average for bridges designed by individual students. (See Table 1) The resulting student feedback indicates the program has reached a level suitable for quality pre-college engineering design education(9).

Figure 3 Load Carrying Capacity Test
Table 1: Summary of Maximum Loads applied to Bridges

<table>
<thead>
<tr>
<th></th>
<th>Average Strength (*)</th>
<th>Maximum Strength (**)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designed by Individuals (B)</td>
<td>88</td>
<td>160</td>
</tr>
<tr>
<td>Designed by Teams (A)</td>
<td>154</td>
<td>200</td>
</tr>
<tr>
<td>A/B</td>
<td>1.75</td>
<td>1.25</td>
</tr>
</tbody>
</table>

* Average Strength is the average of the ratio of maximum loads applied on bridges to weight of bridges.
** Maximum Strength is the maximum of the ratio of maximum loads applied on bridges to weight of bridges.

5. Conclusions

Engineering Design Education at KIT began in 1996 with the assistance of visiting professors from U.S. universities and has evolved as shown below. It has been satisfactorily serving the educational needs of Japanese students, and Japanese industry.

1. Complete course packages of ED I and ED II have been developed for both students and instructors in order to standardize instruction and grading in fifty-five different sections.
2. The course objectives of ED I and ED II are distinct and properly coupled in order to achieve a seamless transition. The three quarter gap between taking ED I and ED II could cause a knowledge retention problem. To prevent this possible problem and to provide an easy transition, a “Project Summary Report” was designed for use in ED I.
3. A website for ED I and ED II has been established, which contains teaching material, templates for class assignments, past student work such as final design reports and award winning posters, as well as frequently-asked-questions. Students can also upload assignment files, get information off a course bulletin board, and ask questions of ED faculty.
4. A hybrid class management system was implemented in 2002 for ED I and ED II. In this system both the usual face-to-face instruction method and e-Learning are employed. With the e-Learning system, team members are no longer required to physically meet in a room to complete their assignments, greatly reducing time required.
5. Engineering ethics was incorporated into ED I and ED II in 2003. Students now survey the ethical aspect of their design project to insure their designs are ethical.
6. An Engineering Design Café was started for the instructors of ED I and ED II. Participants of the Engineering Design Café exchange ideas to improve ED I and ED II. Course packages for EDE
are revised every year through the discussions at the Café.

(7) Foreign institutions are now sending representatives to KIT to study the Engineering Design program. Singapore Polytechnic (SP) has now implemented ED courses and an international exchange program has started between KIT and SP.

(8) KIT has started a two-day pre-college introductory engineering design course for high school students in order to stimulate young students’ interest in science and engineering. The course is based on three pedagogical concepts: the plan-do-check-act cycle, hands-on exercises, and cooperative learning. The resulting student feedback indicates the program has reached a level suitable for quality pre-college engineering design education.

We have reformed the structure of the EDE to suit Japanese context and are seeing if this model would work in other Asian contexts such as in Singapore. There might be another different set of adjustment needed to suit its target culture. Contrary to these infrastructure parts, the human habits and behaviors are more difficult to change. Students and instructors’ attitudes, such as reservation, passivity, or resistance to new concepts are much slower to be reformed. Initially, EDE was brought by American professors and was foreign to Japanese students as well as Japanese professors. The students were used to finding one answer to one problem throughout their pre-college education. Naturally, they were quite at a loss to find multiple solutions to open-ended questions which EDE encouraged. We needed to translate –not literally, but concept wise- these questions to fit into Japanese context. Teaching styles by American professors were also new to the students. They needed some time to become accustomed to this change. The American professors also needed cultural understanding to accept the students’ reservations and fear of standing up among their peers and to develop ways to get the students more involved in non-threatening ways. Now that the teaching methodologies and contents are fully transferred to Japanese professors, these difficulties are less evident. However, both American side and Japanese side have learned valuable cultural lessons. With all these experiences of transferring and translating new concepts to different culture, we hope to resolve problems which might arise when we attempt to further transfer EDE to other Asian countries.

**Bibliographical Information**


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Biographical Information

Dr. Masakatsu Matsuishi
Education: 1969, Doctor of Engineering, Naval architecture, Osaka University, 1964, Bachelor of Engineering, Naval architecture, Osaka University

Yuko Hoshino
Professional Experience: 1996-Present, Associate Professor of Foreign Languages, Kanazawa Institute of Technology, 1994-1996 and 1987-1989, Instructor, Harvard University

Dr. Wayne Sanders
Education: 1975, Ph.D., Mechanical Engineering, Southern Methodist University; 1970, M.E.S., Lamar University; 1960, B.S.M.E., Texas A&M University.