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Engineering Education to Develop Self-Directed, Productive and Innovative Engineers at the Kanazawa Institute of Technology

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Abstract

The educational goal of the Kanazawa Institute of Technology (KIT) is to develop self-directed, productive, and innovative engineers. KIT developed a new curriculum and established an innovative facility named "Yumekobo", or "Factory for Dreams & Ideas", to achieve its educational goal. The major components of the curriculum are engineering design courses and engineering ethics courses. The key objective of the changes in KIT's engineering design curriculum is to shift student learning away from rote knowledge acquisition and problem solving to problem discovery and wisdom. The mission of Yumekobo is to enhance students' motivation and creativity through extracurricular activities. Any KIT students with technical dreams can realize them, in the engineering sense, at Yumekobo. Yumekobo provides students with many kinds of equipment to produce their concepts and is open 330 days a year. Yumekobo is staffed by 16 highly skilled full-time technicians who support students' activities and ensure that the use of the facility is easy and safe.
This paper describes the details of the engineering education methods used by KIT that are intended to develop self-directed, productive, and innovative engineers.

Keywords: engineering education; engineering design; engineering ethics; innovative facility

1. Introduction

The educational goal of the Kanazawa Institute of Technology (henceforth, KIT) is to develop self-directed, productive, and innovative engineers. The strategy KIT employs to achieve this educational goal includes a combination of engineering design education, engineering ethics education, and extracurricular activities which take place primarily at Yumekobo as shown in Fig.1.

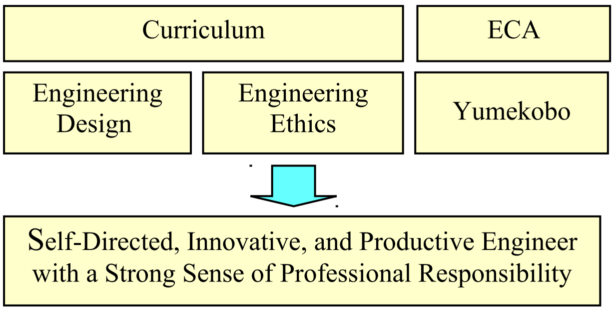


Fig. 1 Engineering education at KIT

KIT established an innovative facility "The Factory for Dreams and Ideas" (henceforth, "Yumekobo", which is the original Japanese name for the factory) in 1993[1]. Any KIT student with a technical dream can produce it at Yumekobo. In line with KIT's educational goal to train better engineering professionals with technical competencies and professional skills for growing global markets, Yumekobo allows students to undertake a Yumekobo project to develop their creativity and innovation freely; from conceptualization to final project completion. Yumekobo projects offer an extracurricular project-based learning process to improve student skills.

KIT is one of the first universities in Japan to offer and require the teaching of Engineering Design Education, which employs Project-Based Learning[2),3)] to teach students to tackle engineering design projects. KIT developed three engineering design courses; namely Engineering Design I (ED I), Engineering Design II (ED II), and Engineering Design III (ED III). KIT administers these courses to approximately 1,700 students every year. KIT began offering to and requiring ED I, ED II, and ED III of all freshman, sophomore and senior engineering students, respectively, in 1996[4)]. The objectives of the three courses are to provide students not only with superior technical capabilities, but also to enable them to identify and solve open-ended problems, generate a set of distinct and creative concepts, and implement the engineering design process, while working as a team. Furthermore, the course series encourages students to develop expertise and abilities for tackling problems independently and to acquire important skills such as communication and leadership.

In 2004, KIT implemented engineering ethics education in several engineering courses in order to achieve Ethics Across the Curriculum (henceforth, EAC)[5),6)]. The authors implemented engineering ethics in engineering design courses.

This paper describes the details of the engineering education to develop self-directed, productive, and innovative engineers with a strong sense of professional responsibility.

2. Engineering design education

2.1. Engineering design courses

KIT developed three compulsory engineering design courses; namely ED I, ED II, and ED III. ED I, ED II, and ED III are offered to all freshman, sophomore, and senior engineering students, respectively. ED I and ED II use Project-Based Learning. ED III is a capstone design or research project.

Skills taught in engineering design education are:

① To identify design opportunities
② To characterize a design project
③ To generate design concepts
④ To evaluate the design concepts and to select the most promising one
⑤ To design in detail
⑥ To present results

Other program outcomes expected from the engineering design education include:

① An ability to work effectively in teams
② An ability to communicate effectively in oral, writing, graphical, and visual forms
③ An ability to apply the skills and knowledge necessary for scientific and engineering practice
④ An ability to design a product to satisfy a client's needs

2.2. Mechanism to help students learn autonomously

In order to achieve the educational goals of KIT, the authors designed the following four mechanisms into KIT's engineering design courses.

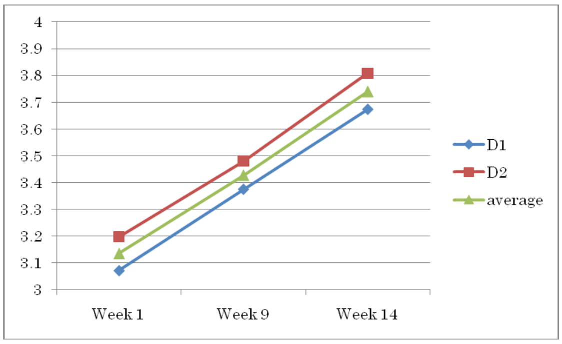
(A) Learning style

Students tackle problems independently, not by directions given by an instructor. The instructor is a facilitator who advises, identifies technical resources, and gives tutorials as needed. In addition to classroom learning, office hour meetings are arranged to help students improve the quality of their design work.

(B) Student self-evaluations

Course objectives are divided into 28 elements and shown to students. 18 objectives are related to professional engineering skills, e.g. an ability to communicate effectively in oral, writing, graphical, and visual forms. The remaining 10 objectives are related to understanding and following the engineering design process, e.g. an ability to carry out a conceptual design by generating multiple solutions that address client needs, evaluating the feasibility of the solutions, and choosing the best one. Students are asked to evaluate their performance and progress at the beginning, middle, and end of the course. Students are able to recognize their current level of achievement and try to attain higher levels. This process is referred to as the PDCA Cycle of Self-Learning.

Fig. 2 shows the average results of the self-evaluation of ED II conducted on Weeks 1, 9, and 14. It was found that students achieved steady progress in course objectives.



Remarks: 1 =Very Poor, 2= Poor, 3 = Average, 4 = Good, 5 = Very Good.

Fig. 2 Progress in course objectives

(C) Facilities for extracurricular activities

KIT established an innovative facility "Yumekobo" in 1993. Yumekobo is composed of two buildings. Fig. 3 depicts the number of instances that students used Yumekobo. The details of Yumekobo will be discussed in the following section.

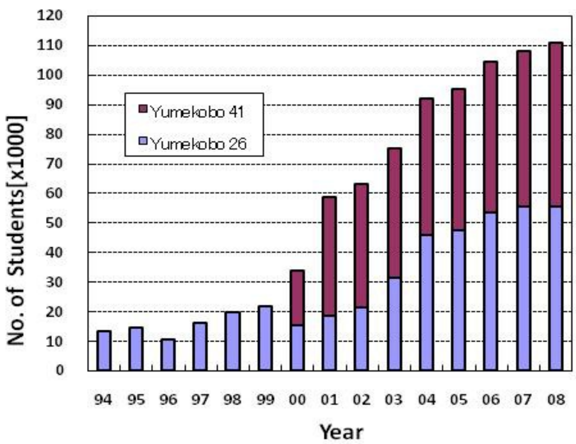


Fig. 3 Number of instances students used Yumekobo

The 24/7 self-study lounge was established in 2001. This lounge provides students with space for group activities related to engineering design courses after classes. Individual students accessed the self-study area more than 600,000 times last year. Fig. 4 depicts students working in the 24/7 self-study lounge.

Fig. 4 Students working in the self-study lounge

KIT has pursued an initiative called E-Campus. Approximately 7,000 network connections are installed across the KIT campus. Fiber optical cables are connected to 3,500 student apartments. Students can access E-learning systems through this computer network.

(D) Peer evaluation from team members

Peer evaluation is used to evaluate individual contributions to team efforts. The peer evaluations are conducted twice during the term; in the middle and at the end of the course. The peer evaluations conducted in the middle of the course are used to advise students whose contributions are judged insufficient.

At the end of the term, the instructors evaluate both the team results and the individual effort invested by each team member. The information from peer evaluations can provide instructors with insights regarding the work distribution inside a team.

3. Engineering ethics education

3.1. Ethics across the curriculum

KIT implemented engineering ethics instruction in nine engineering courses in order to achieve EAC as shown in table 1[5), 6)]. EAC is a pervasive approach to ethics, infusing a discussion of ethics in existing courses at all levels. Micro-insertion Techniques[5)], which introduce ethics and related topics into technical courses in small units so as not to push out technical material, were employed in integrating ethics education into these classes.

Table 1 Engineering ethics courses at KIT

Year	Courses
Freshman	Introduction to Engineering I, II and III Science, Technology and Society Engineering Design I
Sophomore	Engineering Design II
Junior	Science and Engineering Ethics Humanity and Nature III
Senior	Engineering Design III

Ethical outcomes sought by EAC are;

① Ethical Sensitivity
② Knowledge of relevant standards of conduct
③ Ethical judgment
④ Ethical will-power

3.2. Ethics in engineering design courses

In engineering design courses, students are required to generate design solutions which;

1 Do not harm the global environment,
2 Do not endanger human life or health,
3 Contribute to the welfare and happiness of the human race,
4 Do not infringe intellectual property rights.

Ethics education in engineering design courses is composed of the following:

1 An instructor gives a short lecture on engineering ethics.
2 An instructor provides advice on engineering ethics to design teams during office hour meetings.
3 Students are required to judge their project and make ethical decisions.
4 Students assess their progress in understanding of and behavior in engineering ethics.

(A) Engineering ethics lecture

An instructor gives a short lecture on some fundamental strategies for approaching professional responsibilities and engineering ethics.

(B) Advice during office hour meetings

Students follow the engineering design process to develop design solutions which will contribute to the welfare and happiness of the human race. Instructors give advice tailored to each group to enhance the ethical sensitivity, ethical judgment, and ethical will-power of the students to help them deal with the specific ethical challenges of their project.

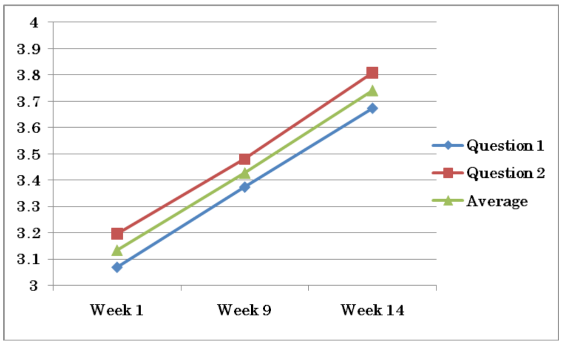
(C) Course objectives and self-evaluation

As discussed in the preceding section “Engineering design education”, the course objectives are divided into 28 elements. Students are advised to evaluate their performance and progress three times during the term. Two out of the twenty eight course objectives are related to engineering ethics. Students answer the following two questions for their self-evaluation on Weeks 1, 9, and 14.

Question 1: Can you confirm that your design specifications and design solutions do not harm the global environment and do contribute to the welfare and happiness of the human race?

Question 2: Can you improve the design solutions so that they satisfy the above-mentioned requirements?

The self-evaluation results for these two objectives were analyzed and the results are shown in Fig. 5, Table 2, and Table 3. Fig. 5 depicts the change in the self-evaluation results across the length of the course. Table 2 and Table 3 exhibit the averages and standard deviations of the self-evaluations.



Remarks: 1 =Very Poor, 2= Poor, 3 = Average, 4 = Good, 5 = Very Good.

Fig. 5 Engineering ethics self-evaluation results

It was found that students made steady progress in engineering ethics understanding and behavior.

Table 2 Self-evaluation of Question 1

	Week 1	Week 9	Week 14
Average	3.07	3.37	3.67
Standard Deviation	0.74	0.69	0.74

Table 3 Self-evaluation of Question 2

	Week 1	Week 9	Week 14
Average	3.20	3.48	3.81
Standard Deviation	0.77	0.75	0.76

4. Extracurricular activities at Yumekobo

Yumekobo is designed to be available to all students from 8:40AM until 9:00PM, 330 days a year. Yumekobo is equipped with a wide range of machines and tools, and is staffed with skilled full-time technicians to support students' extracurricular activities.

Yumekobo offers twelve technical courses in the areas of safety guidance, metalworking, electronics, and woodworking as shown below. The courses start after academic classes end for the day, to fit into students' schedules. Each course is offered approximately thirty times a year.

Step 1 [Safety guidance]
1. Safety guidance

Step 2 [Operation of machine tools]
1. Woodworking
2. Electrical & electronic circuit
3. Plate forming
4. Welding
5. Drilling machine
6. Milling machine
7. Lathe

Step 3 [Advanced course]
1. Printed circuit board (PCB)
2. Design of electronic circuit
3. Surface grinding machine
4. CNC milling machine

Students are encouraged to build models and prototypes at Yumekobo to see if the designs they have generated in engineering design courses are feasible and useful, or to find out what needs to be improved.

The creative process is the exercise of the higher skills listed in Bloom's taxonomy: analysis, synthesis and evaluation[7]. Throughout the engineering design courses, students analyze, synthesize, and evaluate information gathered from both in-class instruction and activities, and outside-class activities, e.g. hands-on practice at Yumekobo.

Fig. 6 illustrates an example of student activities at Yumekobo. A design team selected a project theme "Designing a safe and pleasant monkey bar". Their design concept was composed of a rotating drum with bars and a cover.

Design concept

Model

Device to rotate slowly

Design concept and a model

(a) A student showing a poster and a model

Fig. 6 An example of using Yumekobo in ED II

As shown in Fig. 6(b), they produced a model at Yumekobo to see if the design was feasible and useful, or to find out what needed to be improved. After carrying out an experiment using the model, they found that the rotating drum was too dangerous because it rotated too fast. They therefore developed a device to slow the drum's rotation to ensure safety. Fig. 6 (a) depicts one team member showing their poster and the model in order to display the work done and the information gained.

5. Conclusion

The educational goal of KIT is to develop self-directed, productive, and innovative engineers. The major components of the curriculum are engineering design courses and engineering ethics courses. The mission of the innovative facility, Yumekobo, is to enhance students' motivation and creativity through extracurricular activities.

The authors employed four mechanisms in KIT's engineering design courses; learning style, self-evaluation of the course objectives, facilities for extracurricular activities, and peer evaluation from team members.

KIT implemented engineering ethics education in nine engineering courses in order to achieve Ethics Across the Curriculum. Micro-insertion Techniques were employed for this ethics education content.

KIT established an innovative facility "Yumekobo" to support students' extracurricular activities. Yumekobo is designed to be available to the entire campus population 330 days a year. Students are encouraged to build models and prototypes at Yumekobo to see if their designs, generated in engineering design courses, are feasible and useful, or to find out what needs to be improved.

The strategies used by KIT to develop self-directed, productive, and innovative engineers seem to be successful judging by KIT's employment rate of 99.8 % and the fact that it has been ranked by the Asahi Newspaper as the number one college in the category of undergraduate education for Japan for the past five consecutive years.

References

1. Y. Hattori, Education to Stimulate Students Motivation –Activity through the Factory for Dreams and Ideas–, Proceedings of ASME, FEDSM 03, 4th ASME-JSME Joint Fluids Engineering Conference(CD-Rom), Honolulu, USA, 2003, ,pp.1-4.
2. F. K. Fink, Integration of engineering practice into curriculum – 25 years of experience with problem based learning, Proceedings of the 29th ASEE/IEEE Frontiers in Education Conference, San Juan, Puerto Rico, 1999, pp. 11a2-7–11a2-12.
3. C. L. Dym, P. Little, Engineering Design; A Project-Based Introduction, John Wiley & Sons, Inc., 2000
4. M. Matsuishi, T. Kubo, S. Matsumoto, Engineering Design Education at Kanazawa Institute of Technology in Japan -First Report: Four Years Experience in Teaching 2000 Students-, ASEE/SEFI/TUB Colloquium, Berlin, Germany, 2002.
5. H. Nishimura, Approach of Kanazawa Institute of Technology for the achievement of Ethics Across the Curriculum Journal of JSEE, Japanese Society for Engineering Education, 54 (5), (2006) pp. 44-47 (in Japanese).
6. M. Davis, Teaching Ethics Across the Engineering Curriculum, the Online Ethics Center for Engineering and Science, Case Western Reserve University, 2004.
7. Bloom, B. S, Taxonomy of educational objectives; The classification of educational goals, Handbook I, Cognitive domain, New York, McKay, 1956.