Developing Female Engineers by Hands-on and Experiential Learning

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Abstract

The Kanazawa Institute of Technology has been concentrating on developing self-directed and innovative female engineers. Our strategy to achieve the educational goal is to combine curriculum and extracurricular activities. The main pillar of the curriculum is engineering design education and extracurricular activities are mainly conducted at the Factory for Dreams and Ideas, which is called Yumekobo in Japanese. Yumekobo provides facilities and gives technical support to students for their hands-on and experiential learning. Yumekobo supports fifteen students' projects. The Yumekobo project is defined as a student project in which students experience the full creative process from planning, market research, design, fabrication, operation, and troubleshooting to evaluation of their product's performance in a team. Combination of formal curriculum and project activities enable them to enhance their technical capability and personal/interpersonal skills. Thirty five female students join Yumekobo projects and work day and night. The author conducted a survey to evaluate if Yumekobo projects are useful for enhancing technical competencies and professional skills of female students. It was found that Yumekobo projects help them to enhance technical competencies and professional skills.

Keywords: *Hands-on and experiential learning, Developing technical competences and professional skills, Female engineer, Project activity*.

1. Introduction

It is widely known that fewer women enroll in engineering degree program and work in engineering fields than men. [1] Attracting and retaining women in engineering fields is important and urgent. Higher education institutions are expected to graduate women with all necessary preparation for their engineering careers. The Kanazawa Institute of Technology (henceforth, KIT) has been placing strong emphasis on providing excellent education to develop competent female engineers.

According to Engineering Council of UK [2], the competence and commitment standard for incorporated engineers are;

A. Use a combination of general and specialist engineering knowledge and understanding to apply existing and emerging technology.
B. Apply appropriate theoretical and practical methods to design, develop, manufacture, construct, commission, operate, maintain, decommission and re-cycle engineering processes, systems, services and products.
C. Provide technical and commercial management.
D. Demonstrate effective interpersonal skills.
E. Demonstrate a personal commitment to professional standards, recognising obligations to society, the profession and the environment.

The formation process through which engineering professionals become competent generally involves a combination of formal education and further training and experience.

The strategy KIT employs to develop competent female engineers includes a combination of curriculum and extracurricular activities. The reason why KIT includes extracurricular activities in the strategy is that in most universities number of days classes are in session is approximately 160 days a year. KIT decided to have its students spend the whole year in productive and creative ways in its campus. Therefore, KIT

established an innovative facility “the Factory for Dreams and Ideas” (henceforth, “Yumekobo”, which is the original Japanese name for the factory) in 1993 so that KIT students are able to pursue hands-on and experiential learning all through the year. [3] Engineering design education is the main pillar of the curriculum. [4]

The mission of Yumekobo is to enhance students’ motivation and creativity, and to develop technical competence and professional skills through extracurricular activities. Yumekobo provides facilities and gives technical support to students for their hands-on and experiential learning. Yumekobo opens 305 days a year; from 8:40 a.m. until 9:00 p.m. Yumekobo supports fifteen students’ projects, e.g. Solar Car Project, Human-powered Airplane Project, and Architecture Design Project. The Yumekobo project is defined as a student project in which students experience the full creative process from planning, market research, design, fabrication, operation, and troubleshooting to evaluation of their product’s performance in a team. Project activities take up tasks that cannot be achieved by individuals’ efforts alone. Yumekobo project gives students greater opportunities for hands-on and experiential learning. Combination of formal curriculum and Yumekobo project activities enable them to enhance their technical capability and personal/interpersonal skills.

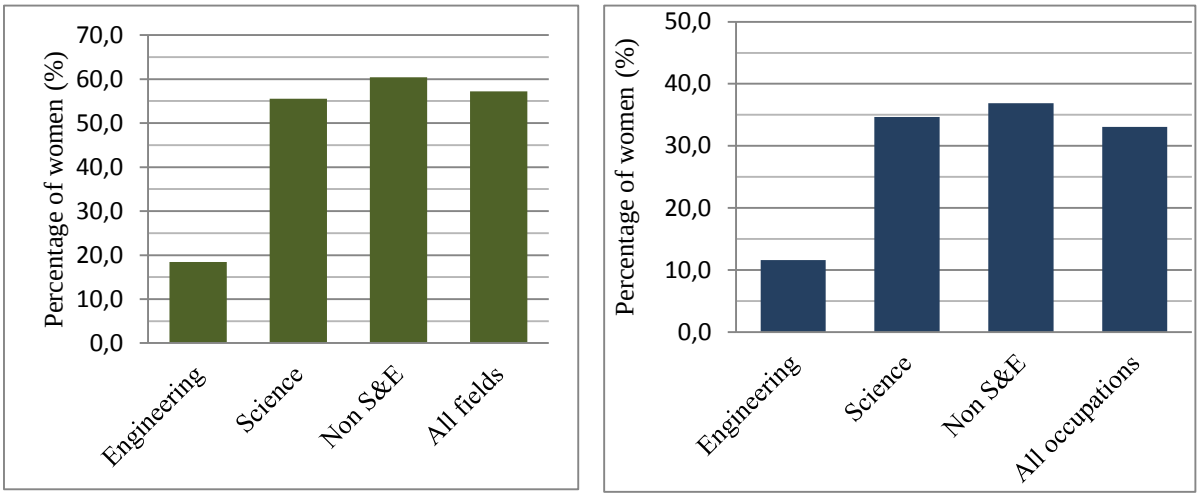
Thirty five female students join Yumekobo projects and work day and night. Although they do not get any credits for their project activities, they are eager to perform creative and productive activities of Yumekobo projects.

The author conducted a survey to evaluate if Yumekobo projects are useful for enhancing technical competencies and professional skills of female students. Technical competencies and professional skills include, for example, communication skills, schedule management, team spirit, and creative design & manufacturing capability. They evaluated their performance and progress of their technical competencies and professional skills. It was found that Yumekobo projects help them to enhance technical competencies and professional skills.

This paper discusses the details of hands-on and experiential learning of female students by Yumekobo projects and their achievements of educational objectives.

2. Women in Engineering Disciplines

According to statistical data of USA provided by The National Center for Science and Engineering Statistics (NCSES), the number of women in science and engineering is growing, yet men continue to outnumber women. [1] Figure 1(a) depicts the percentage of women awarded bachelor’s degrees in USA. While women comprise approximately 57 percent of the undergraduate population, fewer women earn bachelor’s degrees in engineering than men. Figure 1(b) depicts the percentage of occupations taken up by women in USA. While women comprise approximately 33 percent of all occupations, fewer women work in engineering fields than men, where they comprise 12 percent in engineering fields. In elementary, middle, and high school, girls and boys take math and science in roughly equal numbers and about as many girls as boys leave high school prepared to pursue science and engineering majors in college. Yet fewer women than men pursue these majors. [5]



(a) Women awarded bachelor's degree (b) Occupation taken up by women

Figure 1. Female percentage of bachelor's degrees and occupations in USA (2010).

Figure 2 depicts the percentage of women enrolling in universities in Japan. While women comprise approximately 45 percent of the undergraduate population, fewer women enroll in the school of engineering than men also in Japan.

Attracting and retaining women in engineering fields is vitally important, because percentages of women in engineering disciplines both in USA and Japan are lower than those of men.

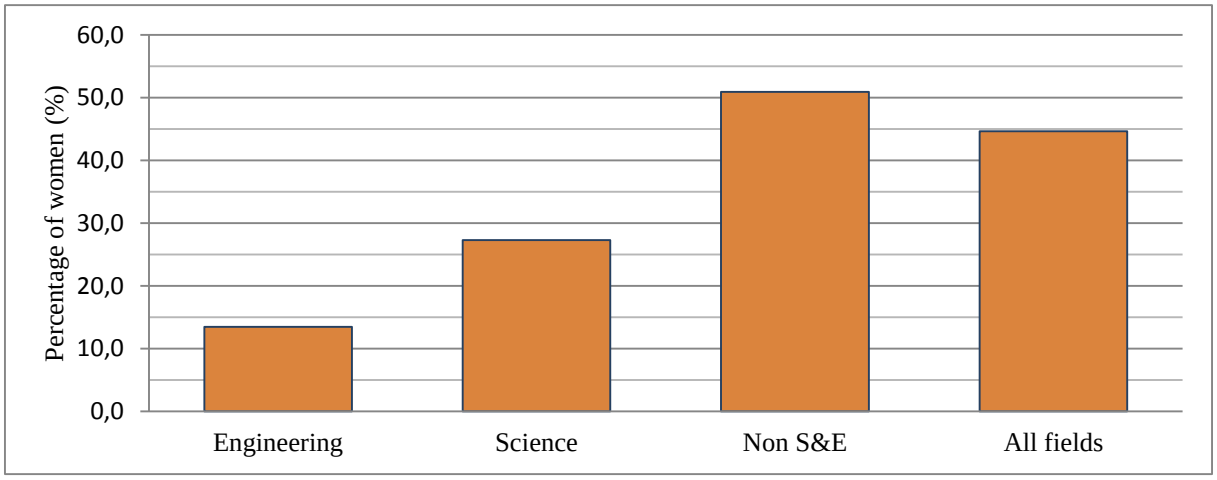


Figure 2. Percentage of women enrolled in universities in Japan (2013).

3. The Factory for Dreams and Ideas

3.1. Management of Yumekobo

Yumekobo is designed so that any students of KIT are able to convert their engineering ideas/dreams easily and safely into reality by designing and producing models/prototypes throughout the year. The mission of Yumekobo is to help students to enhance students' motivation and creativity, and to develop technical competence and professional skills by hands-on and experiential learning. Yumekobo is managed and equipped with a wide range of machines and tools in order to achieve its mission. Yumekobo opens from 8:40 AM until 9:00 PM, 305 days a year. Yumekobo is staffed with 14 full-time

technical staff, 5 part-time technicians, and 35 student staff to support students' hands-on and experiential activities.

Almost all students took neither practical training of machine tools nor safety training before entering KIT. Therefore, Yumekobo offers technical courses and give safety training so that they will be able to implement their ideas and create models/ prototypes easily and safely.

(1) Technical courses
Yumekobo offers twelve technical courses which are composed of three steps: Step 1 gives safety guidance, Step 2 offers courses on the operation of machine tools, electrical engineering & electronics courses, and woodworking courses, Step 3 offers advanced courses. All technical courses start after classes and end for the day. Each of the twelve courses is offered approximately thirty times a year. Those technical courses help students to develop technology and skills so that they can design and build prototypes easily and safely by themselves.

(2) Safety education and training
The possibilities of accident and/or injuries of inexperienced students working at Yumekobo are immeasurable without systematic and thorough safety management, because fifty plus percent of KIT students, approximately 3,500 students, work at Yumekobo each year. All of them are inexperienced. Therefore, Yumekobo holds paramount the safety of students. The strategy of safety management at Yumekobo is to combine safety education and environmental improvement as shown in Figure 3. The safety of education is composed of safety instruction, accident prediction training, training to eliminate potential hazards, periodic safety patrols, human error training, etc. The environmental improvements include removing potential hazards detected during safety patrols, hanging a warning plate showing potential hazards of each machine, and promoting dissemination of emergency procedures and first-aid treatment, etc.

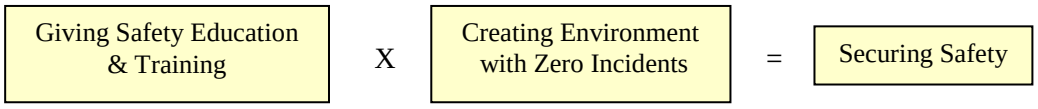


Figure 3. Measures to secure students' safety at Yumekobo.

3.2. Yumekobo Projects

Yumekobo has organized innovative and creative students' projects, "Yumekobo projects." The Yumekobo project is defined as a self-directed project of extracurricular activities in a team. Yumekobo presently houses fifteen Yumekobo projects. More than 500 students are working vigorously on the Yumekobo projects. Project examples include the Formula Car Project, Robot Project, Fuel-Efficient Car Project, Architecture Design Project, Embedded Software Project, and Human-Powered Airplane Project. Students experience the full creative process from planning, market research, design, fabrication, operation, and troubleshooting to analysis and evaluation of their product's performance in a team. All of these projects are self-directed with minimal guidance from professors. Students control their schedule and run the organization on their own. Project activities take up tasks that cannot be achieved by individuals' efforts alone. Yumekobo projects recruit members with diverse characteristics (e.g., majors, special abilities and knowledge, age).

Table 1. Primary technological fields of Yumekobo projects.

	Solar-powered car	Fuel-efficient car	Robot
Green technology	X	X	
Energy-saving technology	X	X	
Ergonomics	X	X	X
Robotics			X

Modelling technology	X	X	X
Simulation technology	X	X	X
Electronics	X	X	X

One of the ultimate goals of the Yumekobo project is to participate in regional, national, and international competitions and win championships. In order to achieve the goal, students design and manufacture their products by using sophisticated and state-of-the-art technologies, and optimize reliability and performance. Table 1 shows primary technological fields of the sophisticated and state-of-the-art technologies of Yumekobo projects. Combination of formal education and Yumekobo project activities enable students to enhance their technical capability and personal/interpersonal skills.

4. Female Students Working at Yumekobo Projects

Figure 4 depicts numbers of both female and male members of Yumekobo projects. Numbers of male and female students are 479 and 35, respectively. Although the female students are minority in Yumekobo projects, they are actively working at seven Yumekobo projects. Table 2 shows majors of the female students.

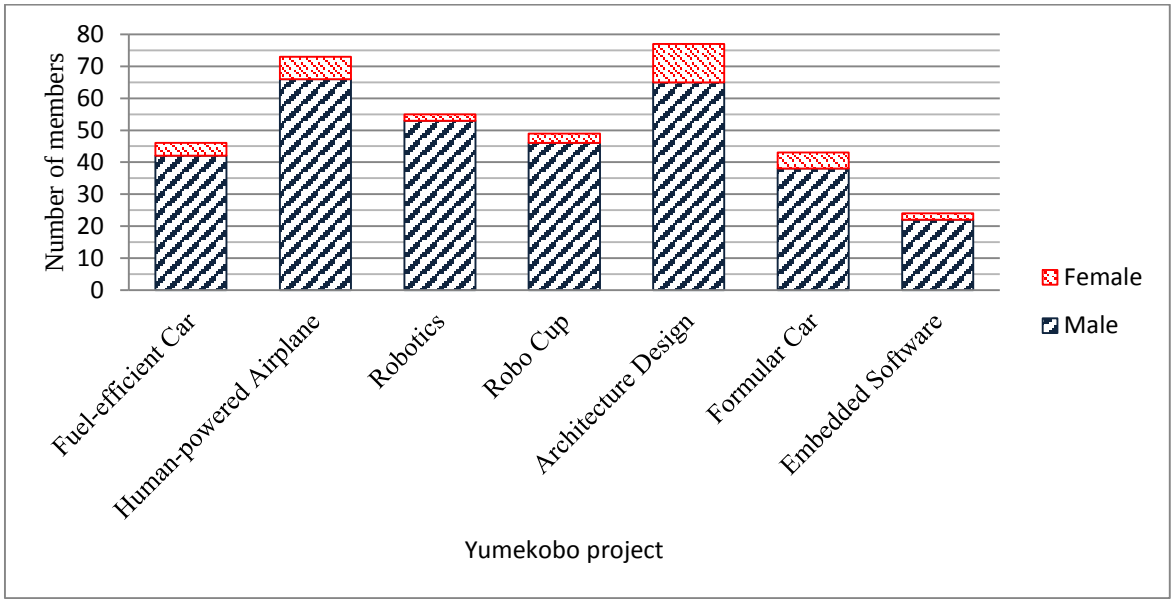


Figure 4. Number of female and male students of Yumekobo projects.

Table 2. Majors of female students of Yumekobo projects.

Mechanical Engineering	Robotics	Aeronautical Engineering	Electrical/ Electronics	Computer Science	Architecture	Others
6	5	7	2	2	11	2

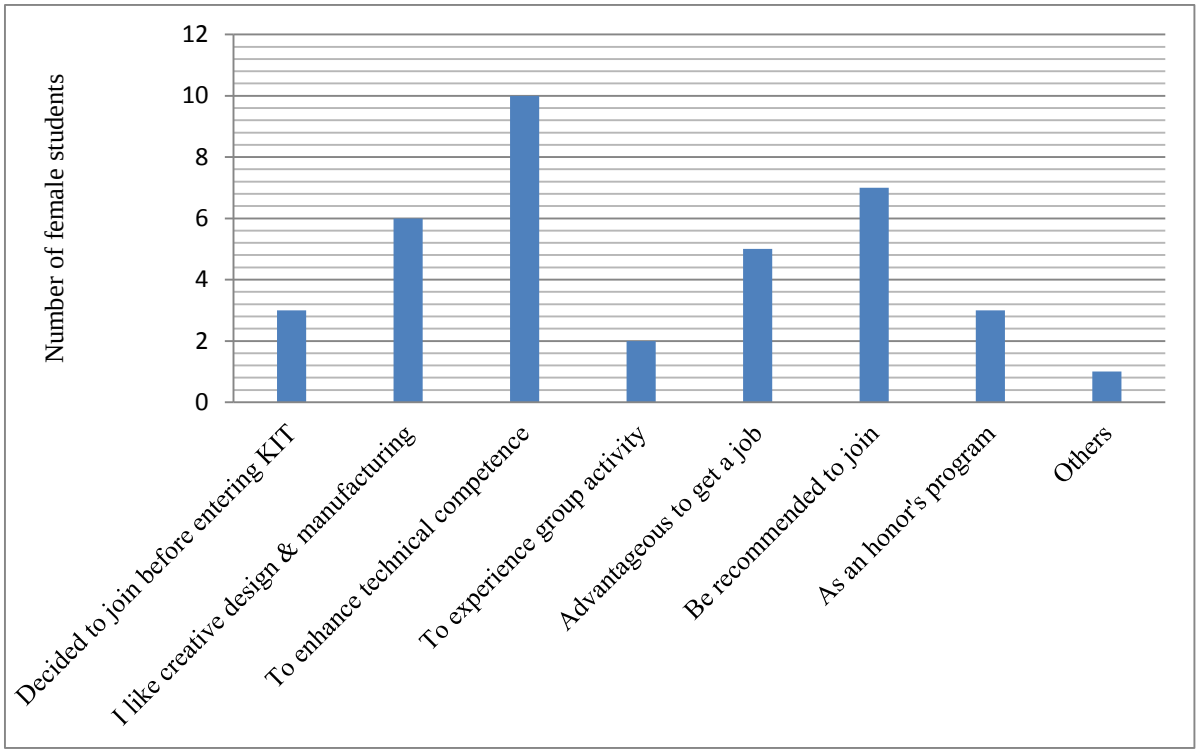


Figure 5. Motives for joining Yumekobo projects (multiple choices allowed).

The author distributed a questionnaire to Yumekobo project members to evaluate if Yumekobo projects help them to enhance their technical competencies and professional skills. Fifteen out of thirty five female students responded to the survey.

Figure 6. Did your technical competence improve after joining Yumekobo projects?

Figure 5 shows motives for joining Yumekobo projects. Some of the examples of the self-evaluations by the female students are shown in Figure 6 through Figure 9, where they evaluated their performance by the following five-point scale: 1 = not at all, 2 = mostly not, 3 = somewhat, 4 = mostly yes, and 5 = definitely. Figure 5 suggests that most of the female students have a variety of clear motives for joining Yumekobo projects. Figure 6 and Figure 7 suggest that Yumekobo projects helped them to improve their technical competencies and professional skills. This is because Yumekobo projects require sophisticated

and state-of-the-art technologies, project management skills, good team work, and schedule control. Figure 8 suggests that approximately three quarters of them are coping well with both schoolwork and project activities. Figure 9 suggests most of them are satisfied with Yumekobo projects. Their endeavour and effort are marvellous because the formal curriculum of KIT assigns a lot of homework and Yumekobo project requires hard and time-consuming design and manufacturing activities.

Figure 7. Are you collaborating well with your team members well?

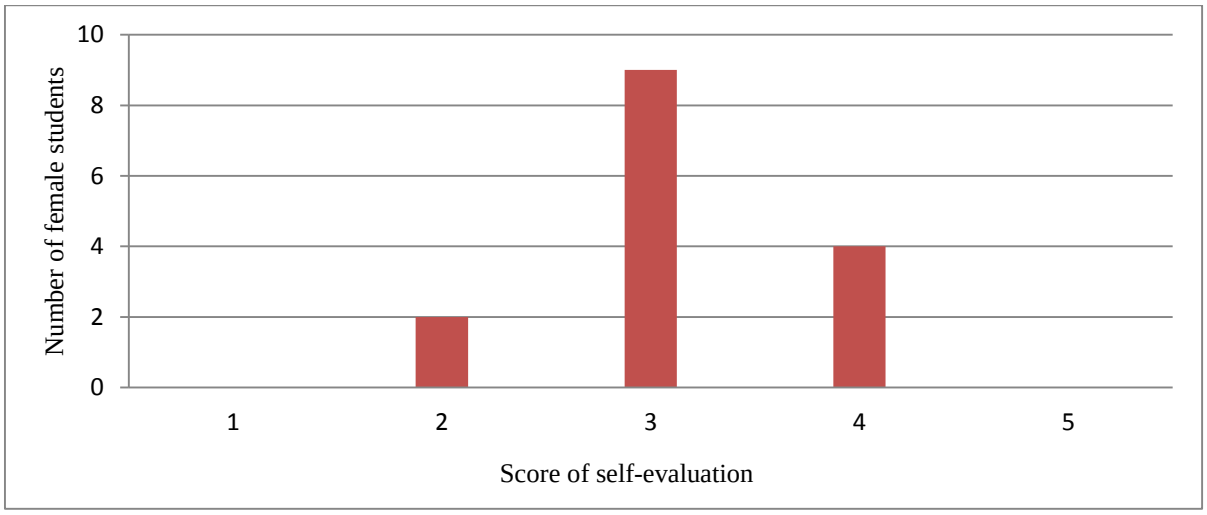


Figure 8. Are you coping well with both schoolwork and project activities?

Figure 9. Are you satisfied with Yumekobo projects?

5. Conclusion

The Kanazawa Institute of Technology has been concentrating on developing self-directed and innovative female engineers. Our strategy to achieve the educational goal is to combine curriculum and extracurricular activities. Extracurricular activities are mainly conducted at Yumekobo. Yumekobo supports fifteen students' projects. The Yumekobo project is defined as a student project in which students experience the full creative process from planning, market research, design, fabrication, operation, and troubleshooting to evaluation of their product's performance in a team.

Important information obtained through this study is as follows:
(1) Yumekobo projects helped female students to enhance their technical competencies and professional skills.
(2) Approximately three quarters of the female students are coping well with both schoolwork and project activities, although they are very busy with homework assigned by the formal education and extracurricular activities of Yumekobo projects.
(3) Most of the female students are satisfied with Yumekobo projects, although they cannot get any credits for the Yumekobo project activities.

Future issues and problems to be resolved are as follows:
(1) Try to find cause of barriers to participation of female students in Yumekobo projects
(2) Introduce programs which help female students to greatly enhance technical competencies and professional skills
(3) Compare differences in increase in technical competencies and professional skills between male and female students

6. Acknowledgements

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References

[1] National Science Foundation, "*Women, Minorities, and Persons with Disabilities in Science and Engineering"*, The National Center for Science and Engineering Statistics (NCSES), 2013, http://www.nsf.gov/statistics/wmpd/2013/start.cfm, Last accessed 23 January 2014.

[2] Engineering Council, "*UK Standard for Professional Engineering Competence, Engineering Technician, Incorporated Engineer and Chartered Engineer Standard"*, pp. 12-17, 2008, https://www.sussex.ac.uk/webteam/gateway/file.php?name=ecuk-charteredeng-spex&site=51, Last accessed 23 January 2014.

[3] Y. Hattori, "Education to Stimulate Students Motivation –Activity through The Factory for Dreams and Ideas-", *Proceedings of 2003 4th ASME_JSME Joint Fluids Engineering Conference*, ASME FEDSM'03, FEDSM200 3-, Hawaii, USA, 2003.

[4] M. Matsuishi, T. Kubo and S. Matsumoto, "Engineering Design Education at Kanazawa Institute of Technology in Japan: Second Report", *Proceedings of the 2002 ASEE/SEFI/TUB Colloquium*, Berlin, Germany, 2002.

[5] C. Hill, C. Corbett, S and Rose, "Why So Few? Women in Science, Technology, Engineering, and Mathematics," AAUW's 2010 research report, The American Association of University Women (AAUW), USA, February 2010.

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