A COURSE WEBSITE AND E-LEARNING SYSTEM FOR THE ENHANCEMENT OF ENGINEERING DESIGN EDUCATION

Masakatsu Matsuishi, Kazuya Takemata, Toshiyuki Yamamoto

ABSTRACT

This paper presents an e-Learning enhanced instructional strategy to overcome instructional issues while conducting project-based learning in Engineering Design (henceforth, ED) courses targeting freshmen and sophomores in engineering institutions in Japan. It also reports the results of an experiment in support of the newly developed strategy.

In this study, a control group consisting of 7 teams and an experimental group consisting of 5 teams were compared. All teams tackled the main theme: "The Optimal Bus Transportation System in the 21st Century." To promote learning outside class, both control and experimental groups had access to a course website where the students could download course material, templates for reports, as well as reference material to aid their learning. The experimental group had additional access to an e-Learning system where the students could conduct team activities using collaboration tools in WebCT. In order to promote individual student's participation in the teamwork and contribution to the team's accomplishment, each student of the experimental group had to submit, on a weekly basis, what he or she thought to be their best contribution to the team's activities while they were developing their activities in groups. Each student is required to read the assignments completed by his/her team members prior to the team activity.

Furthermore, Kanazawa Institute of Technology's e-Learning enhanced strategy is discussed. The comparison of the learning outcome between the control group and the experimental group is reported with included data.

KEYWORDS

Web-based learning, course website, e-Learning, engineering design, group dynamics, project-based learning, learning outcomes, WebCT

INTRODUCTION

The Kanazawa Institute of Technology (henceforth, KIT) is a pioneering university that began its ED education in 1996. Our ED courses are characterized by project-based learning in groups. KIT started its educational reform in 1995 (Ishikawa, 1996). The basic principle behind the reform was to develop students who were able to learn autonomously. The paradigm shift was from "passive knowledge acquisition and problem solving" to "active problem discovery and wisdom seeking" (see Figure 1). The idea came from educational inadequacies up to that time when instructors had crammed knowledge into students.

KIT became the first university in Japan to offer courses in ED in 1996 (Matsuishi, Kubo, Matsumoto, 2002). The ED education consisted of two ED courses, namely, ED I and ED II. ED I was offered in the fall term of the freshman year, and ED II, in the winter term of the sophomore year. The ED courses were characterized by project-based learning in groups (Kaneko, Watanabe, 2002). Students chose engineering topics relating to their daily life, identified a project, characterized the design project, generated design concepts, evaluated design concepts, selected the most promising concept, and designed it in detail. Students were encouraged to develop distinct and creative design solutions.

In 2002, a website for EDI and EDII was made available for students and instructors to share the same learning environment outside class. The website contained teaching materials, templates for assignments, past student design projects, a bulletin board for information to students, and a question-and-answer box.

An e-Learning system was also introduced in Engineering Design courses in 2002. Both the face-to-face instruction system and the e-Learning system were employed in a hybrid way. An e-Learning content management system, WebCT, was adopted. The ED courses were being taught face-to-face in the classroom, while collaborative communication functions of the e-Learning system offered an environment for design teams to complete weekly assignments.

This study reports a case study in which the course website and the e-Learning system were used to enhance ED I. A control group consisting of 7 teams and an experimental group consisting of 5 teams were compared. Each team was composed of 5 to 6 students. All teams tackled the main theme: "The Optimal Bus Transportation System in the 21st Century." To promote learning outside class, both control and experimental groups had access to the course website where the students could download course material, templates for reports, as well as reference material to aid their learning. Furthermore, both groups had access to the self-assessment system in which the students were able to self-evaluate their level of achievements of knowledge and skills itemized in the course syllabus. The experimental group had additional access to an e-Learning system in which the students could conduct team activities using the collaboration tools in WebCT. In order to promote individual students' growth in learning, all students in the experimental group submitted on a weekly basis a log of what they thought to be their best contribution to the team's activities.

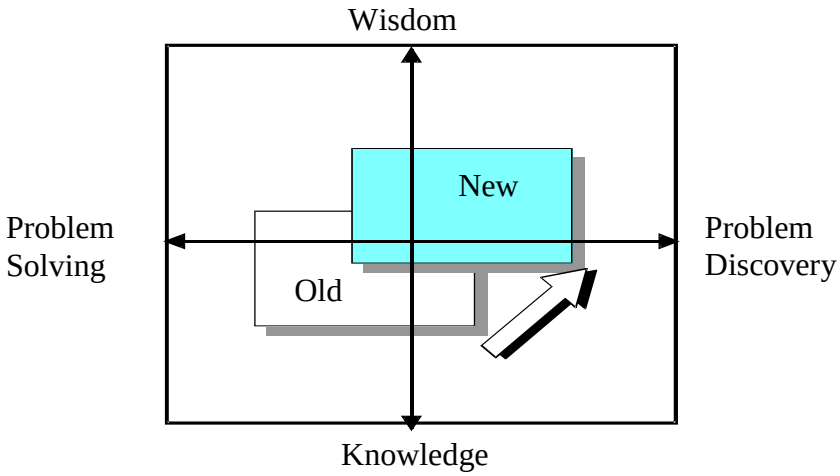


Figure 1. Paradigm shift during educational reform at KIT

ENGINEERING DESIGN EDUCATION AT KANAZAWA INSTITUTE OF TECHNOLOGY

Engineering design courses

One of the course requirements of ED courses was that ED I and ED II were distinct and yet properly coupled in order to achieve seamless transition. However, ED II was offered three terms after ED I. This three-term gap between ED I and ED II caused a knowledge retention problem. To prevent this problem and to provide easy transition, a "Project Summary Report" was introduced in ED I. The Project Summary Report was a brief summary of the process which each design team followed as well as their accomplishments in their projects in ED I. In other words, the Project Summary Report included an existing solution report, a customer needs report, a design specifications report, and a design concept report. This Project Summary Report became the source document to be used by students in ED II.

In what follows, a brief description of ED I and ED II is made. ED I started with the announcement of a main theme: the definition of a broad problem area with many specific problems and needs. Based on the main theme, each design team identified a project theme that seemed reasonably promising and went on applying the design process up through Stage 4 in an effort to fully understand the problem, defined it, and generated viable design concepts (see Figure 2). In ED II, as shown in Figure 2, each design team reviewed some of the information and design techniques presented in the Project Summary Report of ED I. By applying the design process up through Stage 5, the team developed the details of the design solution.

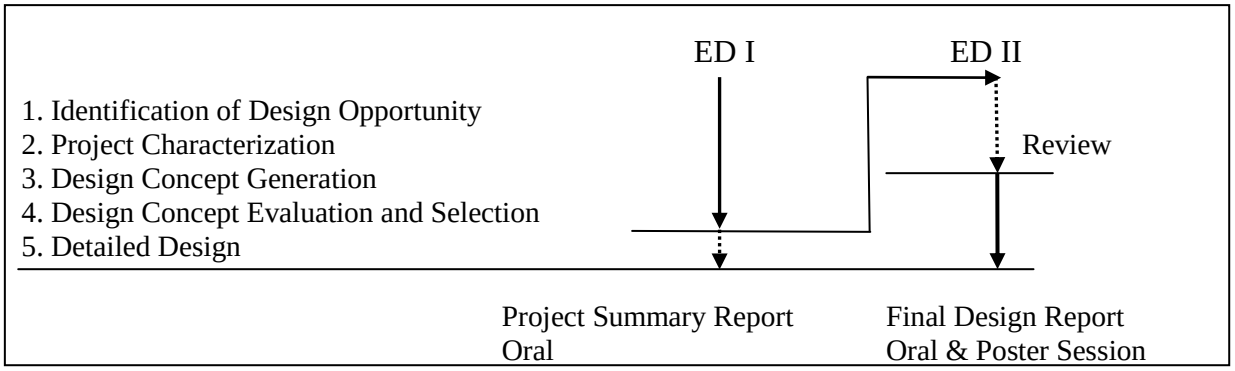


Figure 2. Flow of ED I and ED II

Each team in ED II carefully read and evaluated Project Summary Reports by teams in ED I. After selecting one, each team in ED II then generates new quality design concepts based on customer needs and design specifications. The design process continued until each team defined the major characteristics of the final solution and defines the detailed characteristics of the solution, such as geometry, materials, dimensions, cost, and fabrication processes.

ED courses were characterized by project-based learning in groups. 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. In the process, they were expected to learn teamwork skills such as communication skills and leadership. Students chose engineering topics relating to their daily life, identified project, characterized design project, generated design concepts, evaluated design concepts, selected the most promising concept, and designed in detail. Students were encouraged to develop distinct and creative design solutions.

The procedures covered in ED I and ED II were:

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

Complete course package was developed for the teaching of ED I and ED II (see Figure 3). The package consisted of manuals for both instructors and students, providing students with the basic information and requirements necessary to complete in class. Furthermore, these manuals were intended to provide structure to the in-class and out-of-class learning activities.

The Instructor's Manual included weekly Class Plans and instructional aids. Class Plans were quick summary of what the instructor must teach in a given week of class. Instructional aids were helpful

material for instructors. For example, an instructional aid document made suggestions for conducting peer-evaluation activities in class.

The Student's Manual included Weekly Activity Sheets, Assignment Sheet, Reference Materials, Lecture Slides and Templates. Activity Sheets and Assignment Sheets provided clear descriptions for what the students were to accomplish in class as well as outside of class each week. Reference Materials provided additional information for the design process or specific tools. Templates were used to give students formatting suggestions in forming their reports.

Originally developed textbooks by the teaching staff had been constantly modified each year to raise the quality level in ED courses.

Figure 3. Originally developed textbooks

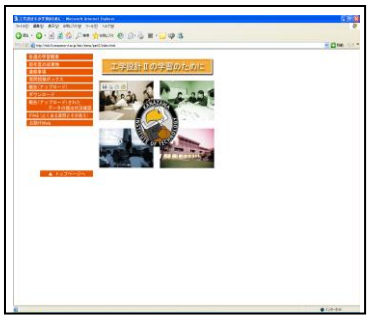


Figure 4. Front page of the course website

Course website
A website for ED I and ED II was established in 2000. This website contained teaching material and templates for class assignments. After the implementation of the website, students' work were all archived, including final design reports, award winning posters, and frequently-asked-questions, as well as the results of the self-assessment as to the level of achievements of knowledge and skills itemized in the course syllabus. The website also included students' uploaded assignments, threads of the course bulletin board. The main menu of the course website is shown in Figure 4.

E-Learning system
An e-Learning system, a hybrid course management system, was implemented in 2002 for ED I and ED II. In this system both the usual face-to-face instructional method and an e-Learning system were employed. Face-to-face instruction was employed in class contact hours. Students could access the e-Learning system anytime via over 6000 network connections on the KIT campus as well as from the 3500 dorm rooms for online group activities. WebCT was employed as a learning management system. The collaboration functions of WebCT were fully utilized by design teams to conduct group activities in order to complete assignments such as defining a project, generating design concepts, evaluating and selecting the final design concept or solution, and defining the detailed characteristics of the solution. With the e-Learning system, student teams could conduct team activities anytime of the day. Team

members were no longer required to physically meet to complete their assignments (Matsuishi, Takemata, Yamamoto, 2004).

Assessment of performance and progress

In ED I and ED II, students were expected to achieve the following learning goals:

- Students can engage in an engineering design problem with multiple solutions and generate viable solutions.
- Students can conduct a needs assessment to collect necessary information and then analyze the results.
- Students can create design specifications.
- Students can generate design solutions.
- Students can evaluate the solutions and select the most optimally possible solution.
- Students can design the selected solution in detail.
- Students can function effectively in team projects.
- Students can give a presentation effectively.

Details of the goals are specified as shown in Table 1. The Likert scale adopted is shown in Table 2. Once students logged in the course website, they were able to access the self-assessment system, in which they could self-evaluate their levels of achievements of knowledge and skills itemized in the course syllabus.

Students assessed their knowledge and skills corresponding to course goals three times while taking ED I: at the beginning of the course, i.e., on Week 1, in midterm period, i.e., on Week 5, and at the end of the course, i.e., on Week 9. By self-evaluating knowledge and skills that the students have acquired, it was expected that they reconfirmed the study goals and thus reorienting themselves toward the course goals. Knowledge and skills corresponding to the course objectives were listed in Table 1. Figure 5 displays the results of the average score of the entire class. The evaluation measure employed a five-point Likert scale: from the lowest, "1" to the highest, "5." "1" indicated "Not at all," "2" indicated "not very much," "3" indicated "a little," "4" indicated "very much," and "5" indicated "absolutely."

The average score on Week 1 was 2.62. The average score on Week 5 was 3.14. And the average score on Week 9 was 3.43. These figures showed that the score raised 1.3 times more compared with that of Week 1.

ED EDUCATION USING COURSE WEBSITE AND E-LERNING SYSTEM

Background

ED courses were characterized by project-based learning in groups. Most of the activities done in ED courses required collaborative efforts from the members of the design team. Students were required to participate in the teamwork and to contribute to the team's accomplishments. However, a few team members failed to participate in the teamwork or to contribute to the team's accomplishments.

The contribution of team members to the team's accomplishments was evaluated by a peer evaluation. Peer evaluation was a good tool used to evaluate the contribution of team members to the team effort. Each team member was asked to evaluate the other members of his/her team (also referred to as peers) based on his/her perception of their past contribution to the team's accomplishments. The summation of the evaluations for any given team member was a representation of his/her team's perception of his/her contribution. In ED courses, each student was given one hundred points to distribute among his/her team members excluding himself/herself. If all members contributed equally, they should have all received one hundred points. Examples of such peer evaluation were shown in Figures 6, Table 3 and Table 4. Figure 6(a) and Table 3 show a team where almost all members participated in the teamwork and contributed to the team's accomplishment almost equally. On the other hand, Figure 6(b) and Table 4 show a team in which a member A did not participate in the team activities or contributed to the

team's accomplishment at all. While another member C contributed to the team's accomplishment in order to compensate the meagre contribution by the member A.

Instructors had to use a combination of the carrot and the stick to let all team members participate in the teamwork and contribute to team's accomplishment. The individual student evaluation in terms of the peer evaluation was used to penalize non-participating team members and to give rewards to hard working team members.

Table 1. Objectives of Engineering Design courses

I. Communication
A- Oral Report

	Objective	Level	
		ED I	ED II
A1	Prepare quality presentation materials using PowerPoint	B	A
A2	Effectively integrate graphs, charts, tables, and pictures in a presentation	B	A
A3	Give a presentation with minimal reliance on written text, and make eye contact with the audience	B	A
A4	Answer questions from the audience effectively	B	A
A5	Ask appropriate questions as a member of the audience	B	A

B- Written Report

	Objective	Level	
		ED I	ED II
B1	Write clearly and logically	C	B
B2	Include quality graphs and graphics in a report	B	A

II. Prepare for Employment
C- Ability to Work in Teams

	Objective	Level	
		ED I	ED II
C1	Support and respect the work of team members, including managing his/her time effectively to produce the necessary deliverables in due time	B	A
C2	Make action plans to achieve objectives of the team	B	A
C3	Demonstrate leadership to address problems if any	C	B

D- Behave Professionally

	Objective	Level	
		ED I	ED II
D1	Behave professionally in discussing questions	B	A
D2	Improve design specifications and design solutions so that they conform to social requirement	C	B

E- Get, analyze and utilize information

	Objective	Level	
		ED I	ED II
E1	Understand importance of information gathering	B	A
E2	Gather necessary information	B	A
E3	Analyze, understand and utilize information	B	B

Table 1. Objectives of Engineering Design Courses (continued)

III. Understand the Design Process
F- Discovery of Project Theme

		Level	
	Objective	ED I	ED II
F1	Identify imperfect designs	A	A
F2	Translate design flaws and limitations into design opportunities	A	A
F3	Evaluate the suitability of a design opportunity relative to team resources and knowledge	B	A

G- Project Definition

		Level	
	Objective	ED I	ED II
G1	Find customer needs by interacting with potential customers	B	A
G2	Translate needs as identified by customers into design specifications	B	A

H- Concept Generation

		Level	
	Objective	ED I	ED II
H1	Generate a large number of design concepts in a short time	B	A
H2	Improve from design concepts to quality design solutions	B	A

I- Concept Evaluation and Selection

		Level	
	Objective	ED I	ED II
I1	Determine appropriate evaluation criteria	C	A
I2	Select the best design solution from a set and justify the selection	C	A

J- Detailed Design

		Level	
	Objective	ED I	ED II
J1	Generate system level design and	D	B
J2	Carry out strength analysis and experiment, and supply convincing data to demonstrate that major functions are achievable	D	B

Table 2. Level of performance and progress

Scale	Level of Performance and Progress
A	Students are expected to demonstrate proficiency
B	Students are expected to demonstrate some capability
C	Students are expected to at least try
D	The objective does not apply

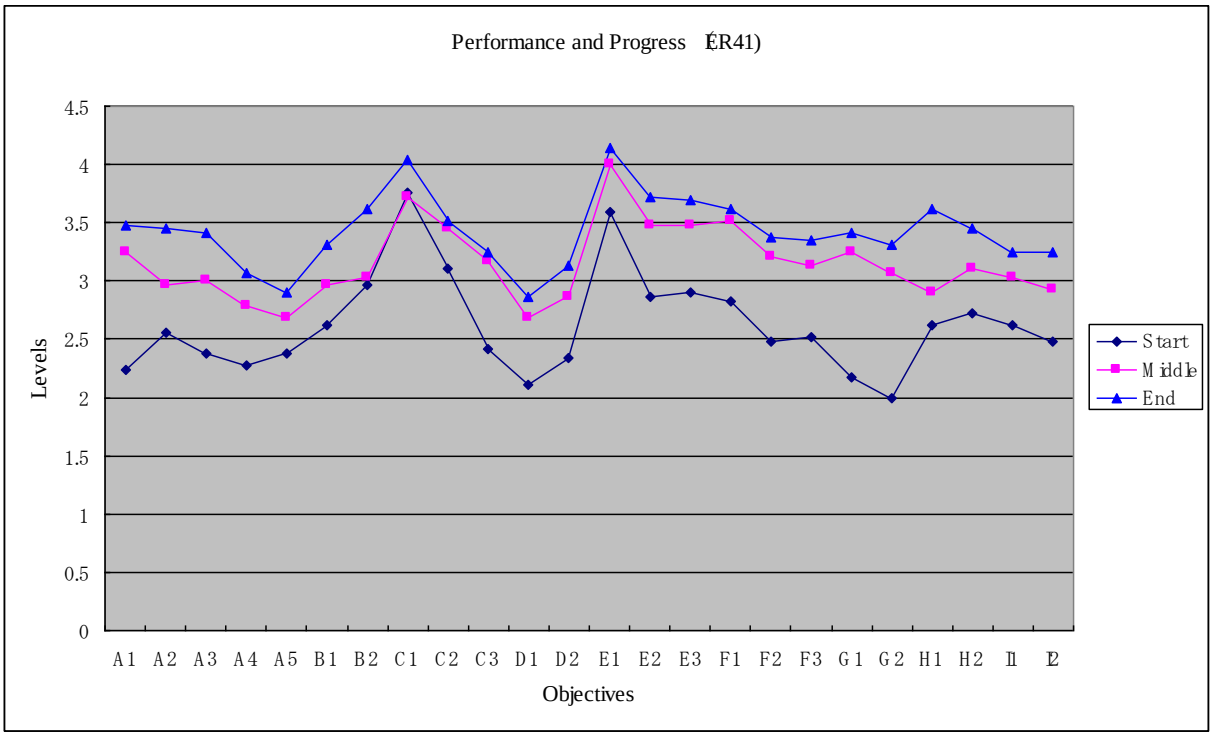
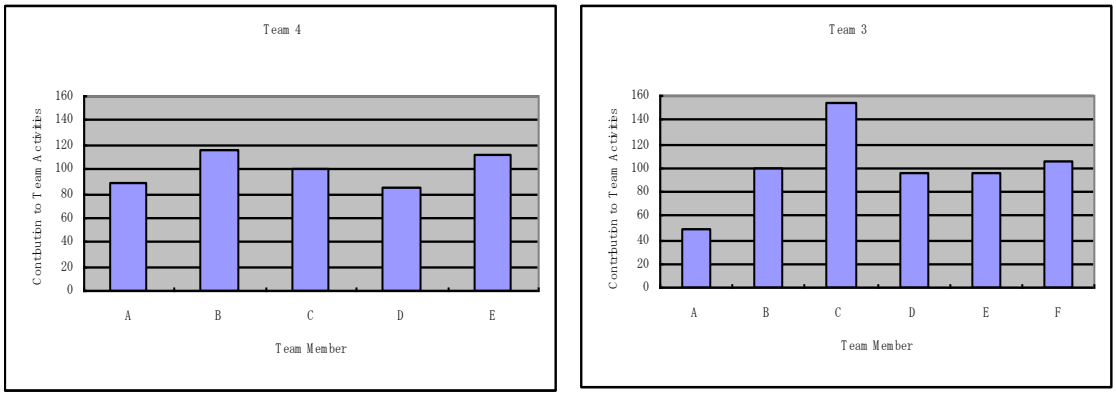


Figure 5. Averages of individual objectives



(a) An example of good teamwork (b) An example of bad teamwork

Figure 6. Contribution of team members to team activities

Table 3. Peer evaluation (An example of good teamwork)

		Peer					
		A	B	C	D	E	Total
Team member	A	-	24	20	20	25	89
	B	30	-	30	30	25	115
	C	25	26	-	20	30	101
	D	20	24	20	-	20	84
	E	25	26	30	30	-	111

Table 4. Peer evaluation (An example of bad teamwork)

		Peer						
		A	B	C	D	E	F	Total
Team member	A	-	10	18	10	0	10	48
	B	20	-	20	20	20	20	100
	C	20	35	-	40	30	30	155
	D	20	18	18	-	20	20	96
	E	20	19	22	15	-	20	96
	F	20	18	22	15	30	-	105

Table 5. Personal weekly assignment to be uploaded to the e-Learning system

Week	Personal Assignment
1	Give your thoughts on your first team activity of designing and making one chopsticks holder. ・ Post your reaction to the mini-engineering design project to the team's discussion board.
2	Propose three project themes selected by you. ・ Think of three project themes individually and post them to the team's discussion board.
3	Establish a goal for the project theme of your team. ・ Post design process to be solved for the theme.
4	Select the most important customer need. ・ Post what you think are the most important in clients' needs to the team's discussion board.
5	Define one set of design specifications which you think most important. ・ Out of design concepts proposed by the team, post to the team's discussion board the design concept which you think is the most important.
6	Select the most important design solution from those which you generated, and describe its advantages. Post them to the team's discussion board.
7	Select the most important design solution from those your team generated. Describe in detail your reasons why it is so important. Post them to the team's discussion board.
8	Describe a part which you will be in charge during the final oral presentation and its importance. Post them to the team's discussion board.
9	Describe your improved capabilities: (1) capabilities which improved remarkably, and (2) capabilities which improved slightly.

Proposal
It was important to promote an individual student's participation in the teamwork and contribution to the team's accomplishment. Therefore, in this study an e-Learning enhanced system was adopted where students were required to complete personal weekly assignment (see Table 5) and to read the assignments completed by their team members prior to their team activities.

An experimental group consisting of 5 teams and a control group consisting of 7 teams were compared. Each team was composed of 5 to 6 students. All teams tackled the same main theme: "The Optimal Bus Transportation System in the 21st Century." To promote learning outside class, both control and experimental groups had access to the course website where the students could download course material, templates for reports, as well as reference material to aid their learning. The experimental group had additional access to an e-Learning system where the students could conduct team activities using the collaboration tools in WebCT. In order to promote an individual student's participation in the teamwork and contribution to the team's accomplishment, each student in the experimental group had to submit what he or she thought to be their best contribution to the team's activities as they were developing their activities in groups. Each student was required to read the assignments posted to the discussion board of the e-Learning system by his/her team members prior to the team activity and to participate in the team activity.

Students' reaction
Students of the experimental group completed their personal assignments and posted to the discussion board of the e-Learning system every week. Examples of the personal assignment completed by one student of the experimental group are shown in Table 6.

Each team member of both the control group and the experimental group was asked to evaluate the other members of his/her team (also referred to as peers) based on his/her perception of their past contribution to the team's accomplishments. The standard deviations of the peer evaluation of both the control group and the experimental one are compared in Table 7. It was found that the standard deviation of peer evaluation of the experimental group is smaller than that of the control group. This means that the students of the experimental group participated in their team work and contributed to their teams' accomplishment more than those of the control group.

Table 6. Examples of assignment which were completed by one student of the experimental group

Week	Completed Assignment
1	We were tremendously busy at the end of this week because we delayed finishing our assignment. A lesson we learned this week was "Keep schedule!"
2	A bus driven by clean energy A bus which transports passengers swiftly and smoothly. A fully automated bus without an operator.
3	To design a bus stop where passengers will not feel tired while waiting for a bus
4	According to our survey of passengers' complaints, (1) the biggest one was that a bus arrival time is unpredictable and (2) the second biggest was that the number of seats was not enough. As the biggest complaint turned out not to coincide with our project theme, the most important customer need was designing a bus stop where a large number of seats are installed.
5	The most important issue is the time to wait for a bus at a bus stop because a bus does not arrive as scheduled.
6	My design solution is building a bus stop with wood material because wood is a good heat insulator.
7	Providing music at a bus stop so that passengers will be relaxed and stress will be reduced.
8	I will present a section on Engineering Ethics. Ethical issue is the key to our project.
9	Improved capabilities are skills for information gathering and analysis, and preparing good presentation slides. Less improved capabilities are asking relevant questions and answering questions precisely

Table 7. Standard deviation of the contribution of team members to the teamwork

Group	Standard Deviation	Access to e-Learning System	Personal Assignment
Experimental Group	27.6	Allowed	Assigned
Control Group	29.0	Not allowed	Not assigned

Remarks: Average is 100.

CONCLUDING REMARKS

In this study, an experiment was conducted using KIT's original e-Learning enhanced system.

An experimental group consisting of 5 teams and a control group consisting of 7 teams were compared. To promote learning outside class, both control and experimental groups had access to the course website where the students could download course material, templates for reports, as well as reference material to aid their learning. The experimental group had additional access to an e-Learning system where each student had to complete personal weekly assignment, to read the assignments completed by his/her team members prior to the team activity, and then to participate in the team activity.

Each team member of both the control group and the experimental group evaluated the other members of his/her team based on his/her perception of their past contribution to the team's accomplishments. The standard deviation of peer evaluation of the experimental group was smaller than that of the control group. This means that the students of the experimental group participated more actively in their team work and contributed to their teams' accomplishment compared with the students in the control group.

It was found that the e-Learning enhanced system composed of the course website and the e-Learning system was effective to draw students' participation in the teamwork as well as the contribution to the team activities.

REFERENCES

Ishikawa, K. (1996), Principles and Perspectives in Educational Reform at Kanazawa Institute of Technology, Changing Knowledge to Wisdom, KIT Progress, Vol.1, 5-10

Kaneko, S., Watanabe, T., (2002), Report on Overseas PBL Programs, Journal of Japanese society for Engineering Education, Vol. 50, No. 3, 29-33

Matsuishi, M., Kubo, T., Matsumoto, S., (2002) Engineering Design Education at Kanazawa Institute of Technology, ASEE/SEFI/TUB Colloquium

Matsuishi, M., Takemata, K., Yamamoto, T., (2004) Engineering Design Education in a Hybrid Way, Combining Face-to-Face Instruction with-Learning Collaboration, Proceedings of the 2004 ASEE Conference & Exposition

WebCT, http://www.webct.com/

Masakatsu Matsuishi, Dr. Eng.
Professor
Kanazawa Institute of Technology
7-1 Ohgigaoka, Nonoichi
Ishikawa 921-8501, Japan
Email: matsuishi@neptune.kanazawa-it.ac.jp

Kazuya Takematai, Dr. Eng
Associate Professor
Kanazawa Institute of Technology
7-1 Ohgigaoka, Nonoichi
Ishikawa 921-8501, Japan
Email: takemata@neptune.kanazawa-it.ac.jp

Toshiyuki Yamamoto, Ph. D.
Professor
Kanazawa Institute of Technology
7-1 Ohgigaoka, Nonoichi
Ishikawa 921-8501, Japan
Email: caitosh@neptune.kanazawa-it.ac.jp