Pre-College Education of Engineering at Kanazawa Institute of Technology to Senior High School Students in Japan

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Abstract

In order to stimulate young students' interest in science and engineering, Kanazawa Institute of Technology (KIT) and Wakasa Senior High School (WSHS) started a collaboration project in 2000. KIT gives a two-day pre-college engineering course to students from WSHS. As students have little engineering knowledge, we intend to achieve the objective of the course by three pedagogical concepts: the Plan-Do-Check-Act Cycle, hands-on exercises, and cooperative learning.

This paper discusses the experience of the pre-college engineering course, which the students attended at KIT in March 2001, and results of student feedback.

Introduction

There is a growing tendency in Japan for students to lose interest in science and engineering. Therefore, the importance of stimulating young students' interest in science and engineering has been strongly emphasized.[1, 2] In order to stimulate young students' interest in science and engineering, a collaboration project started in 2000 between KIT and WSHS. KIT has been giving a two-day pre-college introductory engineering course to forty students from WSHS since March 2001.

The curricula for this two-day course has been carefully designed to include the Design Section of the Technology Content Standard as published in the Standards for Technological Literacy: Content for the Study of Technology.[3] The course provides an opportunity for students to develop an understanding of the attributes of design and engineering. In addition, students are also exposed to the roles of troubleshooting, research and development, invention, innovation, and experiment in problem solving.

On the first day of the pre-college engineering course at KIT, each student was asked to design and build one model bridge individually using light and flexible timber material, which is known as balsa wood. After completion, students applied loads onto the bridges until they collapsed. KIT faculty explained the basic strength of structures. At the end of the first day activity, students were assigned to teams and involved in group-discussion. Based upon the previous experience, which they acquired on the first day individually, each team strived to design and build a stronger model bridge so that it could withstand a much heavier load. Due to learning through hands-on exercises and group activities, the average load-carrying capacity of bridges designed by teams was 1.75 times larger than that for bridges designed by individual students.

Besides gaining technical knowledge, this project also helped students in initiating their decision on their majors before entering universities: e.g. engineering oriented majors or liberal arts. Students in Japan must choose their majors at the time of the entrance examination. They are not allowed to transfer afterwards. Those who want to transfer have to take an entrance examination again.

Course Content

The schedule of the 2-day pre-college engineering course is shown in Table 1. Students were asked to design and build model bridges from 900 mm x 2 mm x 2 mm pieces of balsa wood. Their goal was to complete strong model bridges using as little material as possible. Requirements for dimensions of the model bridge are shown in Table 2.

Table 1. Time Schedule of Pre-College Engineering Course

<table>
<tr><th>Day</th><th colspan="2">Activity</th><th>Time (in minutes)</th></tr>
<tr><td rowspan="7">1st Day</td><td colspan="2">Introduction of the course</td><td>40</td></tr>
<tr><td rowspan="3">Individual activity</td><td>Design of model bridge</td><td>50</td></tr>
<tr><td>Building model bridge</td><td>150</td></tr>
<tr><td>Failure test</td><td>30</td></tr>
<tr><td colspan="2">Lecture on bridge strength</td><td>60</td></tr>
<tr><td rowspan="6">Team activity</td><td>Orientation of team activity</td><td>20</td></tr>
<tr><td>Design of model bridge</td><td>Assignment to be completed at hotel</td></tr>
<tr><td rowspan="5">2nd Day</td><td>Building model bridge</td><td>200</td></tr>
<tr><td>Design contest</td><td>30</td></tr>
<tr><td>Load-carrying contest</td><td>60</td></tr>
<tr><td>Presentation contest</td><td>40</td></tr>
<tr><td colspan="2">Wrap up</td><td>20</td></tr>
</table>

Table 2. Dimensions of Model Bridge (in mm)

Maximum length	500
Span	360
Maximum breadth	150
Minimum height	90

Three contests were held in the course: design contest, load-carrying-capacity contest, and presentation contest. At the design contest, students and instructors cast votes to select the most attractive bridge. During the load-carrying-capacity contest, increasing loads were added to the bridge until it collapsed. A winning team was selected based on the value of the load-carrying capacity per weight of the bridge. During the presentation contest, each team produced slides to demonstrate their achievements. The performance of teams was evaluated based on quality of contents, quality of visuals, and enthusiasm of presentation. Ten teams competed for three prizes: best design award, maximum load-carrying-capacity award, and best presentation award.

The balsa bridge project was originated from the Steel Bridge-Building Competition, sponsored by the American Institute of Steel Construction.[4] The competition requires Civil Engineering students to design and construct a steel bridge. The bridge spans the abutments, which are fixed in places so that the distance between faces is 5,486 mm (18 feet). Construction of the bridge requires good workmanship, and is time-consuming as well as costly. Balsa wood and a quick curing adhesive containing cyanoacrylate were chosen as material of model bridges for the pre-college engineering course, because it is easy for high school students to work with and less costly budget-wise. The smallest section of balsa wood available at the market is 4 mm x 4 mm. Load-carrying-capacity tests were carried out after constructing model bridges using balsa wood with the section of 4 mm x 4 mm. And it was found that bridges failed at lower load because the joint failed before balsa wood broke. After several trials, we found that balsa wood with a section of 2 mm x 2 mm and a quick curing adhesive containing cyanoacrylate were a good combination of material for the pre-college engineering course.

On the first day of the course, each student was asked to design and build one model bridge individually. "Construction Manual of Model Bridges,"[5] developed by KIT, was distributed to students for reference. KIT faculty demonstrated how to build model bridges of good workmanship. Examples of model bridges, which students designed, are shown in Figure 1.

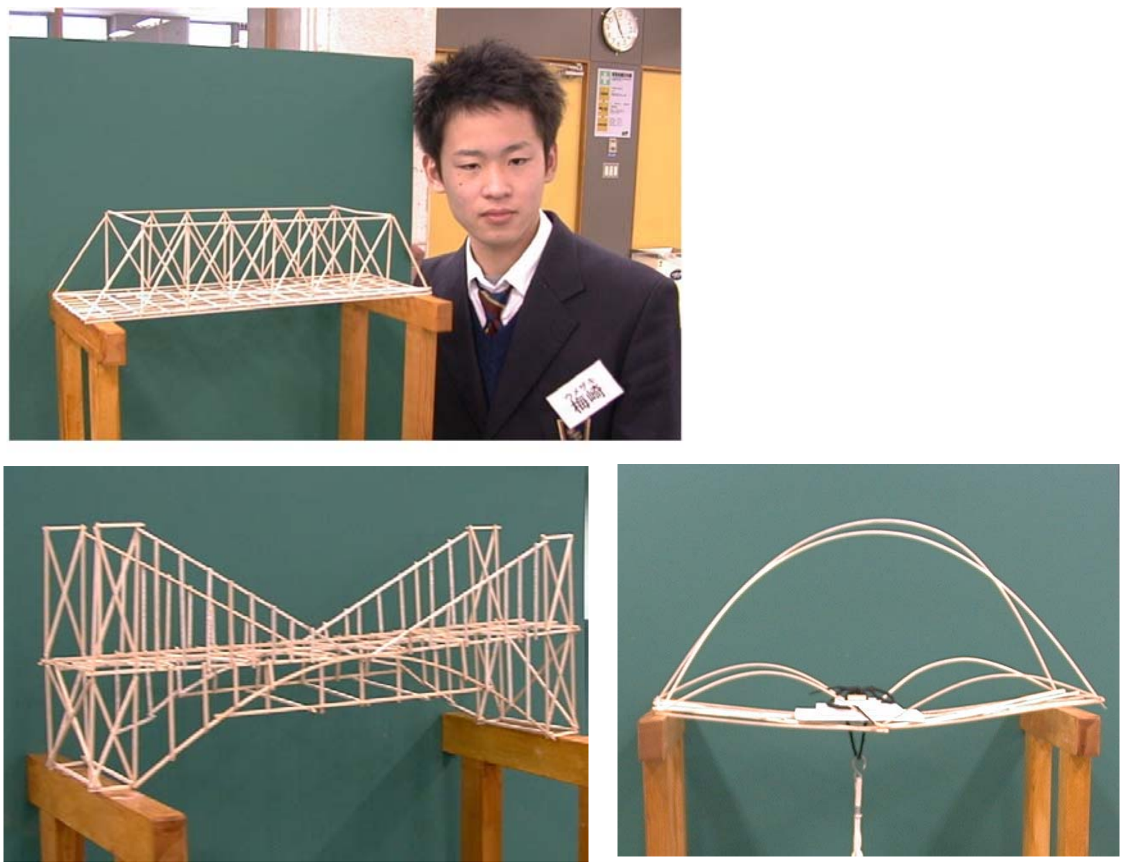

Figure 1. Examples of Model Bridges

After completion, students applied load onto the bridges until they collapsed as shown in Figure 2. Students measured the load-carrying capacity and observed the failure mode of bridges.

At the end of the first day activity, forty students were assigned to ten teams. KIT faculty explained various types of bridge structure and typical failure modes of bridge structures.[6] The faculty encouraged each team to design a stronger model bridge, which could withstand much heavier load by furnishing relevant reinforcement to the previous design and/or modifying the type of bridge structure. The presentation slides used in the course can be found in Appendix 1.

Figure 2. Load-Carrying-Capacity Test

On the second day, based upon the experience they acquired on the first day individually, and the instruction in bridge strength provided by KIT faculty, each team strived to design and build a stronger model bridge that could withstand much heavier load. After building the model bridges, three contests were held: the design contest, the load-carrying-capacity contest, and the presentation contest.

Educational Philosophy and Methodology

The pre-college engineering course at KIT is based on three pedagogical concepts: the Plan-Do-Check-Act Cycle, hands-on exercises, and cooperative learning. The Plan-Do-Check-Act Cycle, which is widely used in industries for quality control activities,[7] is composed of four stages (Plan, Do, Check, and Act) and carried out in the cycle as illustrated in Figure 3. Walter Shewhart originally developed the concept of the Plan-Do-Check-Act Cycle during the 1930's. It was taken up and promoted very effectively from the 1950's on by W. Edwards Deming and is consequently known as "the Deming Wheel".

The pre-college engineering education can be summarized in terms of the Plan-Do-Check-Act Cycle as follows:

(1) Individual activity on the first day:

(a) Plan: Students obtained necessary information, e.g. types of bridge structure, and designed strong model bridges using as little material as possible.

(b) Do: Students built model bridges.

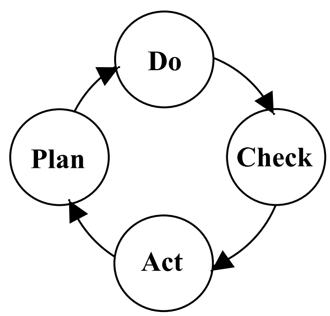

Figure 3. The PDCA Cycle (the Deming Wheel)

(c) Check: After completion of bridges, students applied load onto the bridges until collapse and observed the failure mode of the bridges.

(d) Act: Students improved their design so that the newly designed bridge could attain higher strength.

(2) Group activity on the second day: Forty students were assigned to ten teams.

(a) Plan: Each team designed a stronger bridge with minimum amount of material based upon their individual experience on the first day and lessons of bridge strengths given by KIT faculty.

(b) Do: Each team built a stronger bridge.

(c) Check: After completion, each team applied load onto the bridge until it collapsed and confirmed if the design was successful or not.

(d) Act: Each team produced a report and presented orally their achievement of study.

The Japanese high school educational system emphasizes knowledge acquisition and memorization with little consideration for open-ended problem solving, therefore hands-on exercises provided students a unique experience to design and build structural bridge models.

Assessment and Evaluation of Pre-College Engineering Course at KIT

Assessment and evaluation of the collaborative project between KIT and WSHS to stimulate young students' interest in science and engineering are divided into two classifications: assessment of course learning objectives and evaluation of project objectives. Assessing the effectiveness of the course in achieving the learning objectives is an important component of overall project evaluation. The course learning objectives are to understand the attributes of design and engineering. The project objectives are to design and construct stronger bridges with as small amount of material as possible.

Assessment of course learning objectives is measured by the progress that students made during the pre-college introductory engineering course. Project evaluation focuses on determining whether the project objectives described above are met.

The load-carrying capacities of model bridges designed by individual students and teams are shown in Table 3. Due to learning through the Plan-Do-Check-Act Cycle, hands-on exercises, and cooperative learning, the average load-carrying capacity of bridges designed by teams were 1.75 times larger than that for the bridges designed by individual students. And, the maximum load-carrying capacity of bridges designed by teams was 1.25 times greater than that for the one designed by individual students. The increase in the load-carrying capacity of bridges designed by teams is credited to this pre-college engineering course.

It can be concluded that high school students, who have little knowledge of engineering and technology, are able to work out solutions to engineering problems, such as design and building stronger bridges with minimum amount of material, based on the learning through the Plan-Do-Check-Act Cycle, hands-on exercises, and cooperative learning.

According to the observation by the instructors, students fulfilled their duties and contributed to team objectives as a member of a work group. This teamwork resulted in stronger bridges than those built by individual work (See Table 3).

A questionnaire shown in Appendix 2 was developed to assess the effectiveness of the introductory pre-college engineering course. After the pre-college engineering course, every student filled in the questionnaire. The feedback from students is also shown in Appendix 2.

Important information obtained through the questionnaire is summarized as follows:
(1) Students were very much interested in the design and building of model bridges.
(2) Students played major roles both in individual activities and team activities.

(3) Pre-college introductory engineering course was quite beneficial for students in initiating their decision on their majors before entering universities: e.g. engineering oriented majors or liberal arts.

Table 3. Summary of Maximum Load applied on Bridge /Weight of Model Bridge

	Average Strength (*)	Maximum Strength (**)
Designed by Individuals (A)	88	160
Designed by Teams (B)	154	200
A/B	1.75	1.25

Remarks:
* 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.

The favorable feedback from students, mentioned above, shows excitement and interest in the field. The results of the load-carrying-capacity tests, shown in Table 3, show that the students could understand the attributes of design and engineering.

Conclusions

The pre-college engineering course at KIT is based on three pedagogical concepts: the Plan-Do-Check-Act Cycle, hands-on exercises, and cooperative learning. The results of the introductory engineering course at KIT seem to be conspicuously successful in stimulating young students' interest in science and technology. The following important information was obtained through the pre-college engineering course to senior high school students.

1) Students were very much interested in the hands-on exercises of designing and building model bridges.

2) 95% of students found that the system of learning through experience was quite effective.

3) 80% of students could utilize their experience and knowledge, which were acquired by individual activities, to group activities.

4) Due to learning through hands-on exercises, group activities, and the instruction in bridge strength provided by KIT faculty, the maximum load-carrying capacity of bridges designed by teams was 1.75 times larger than the one designed by individual student.

5) 91% of students found that the pre-college introductory engineering course was quite beneficial to initiate their decision on their majors before entering universities.

KIT will continuously improve the content and teaching methodology of such pre-college engineering course, and offer to senior high school students to stimulate their interest in science and engineering.

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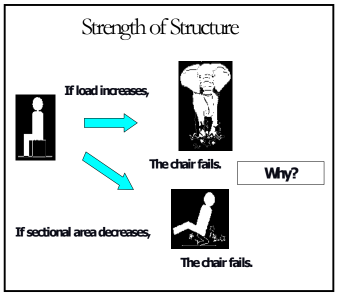
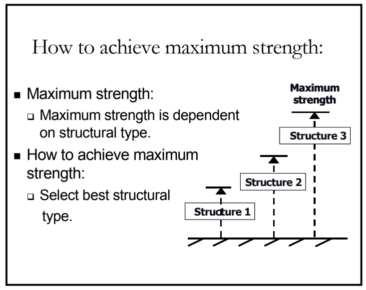
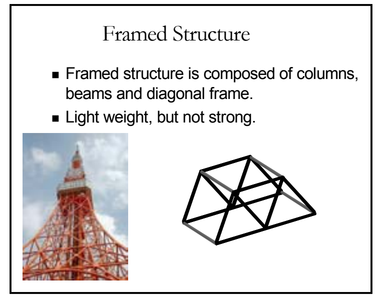
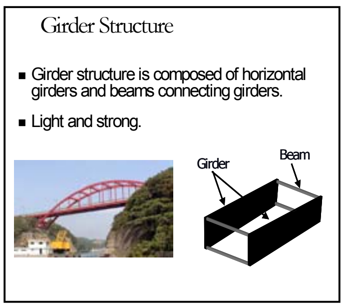
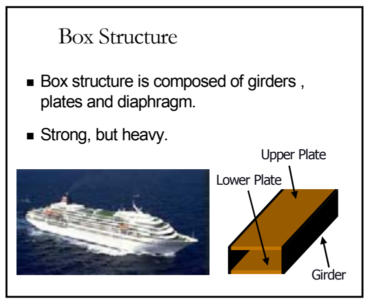
Appendix 1: Presentation Slides on Bridge Strength

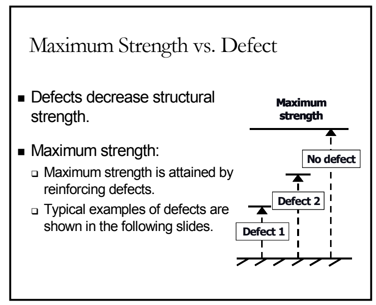


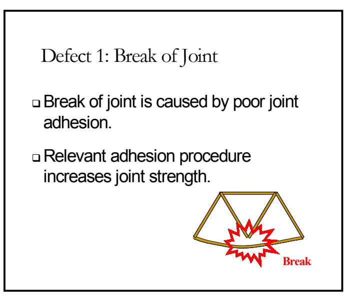


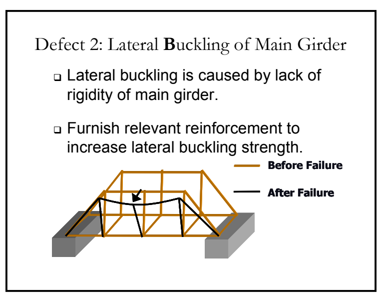


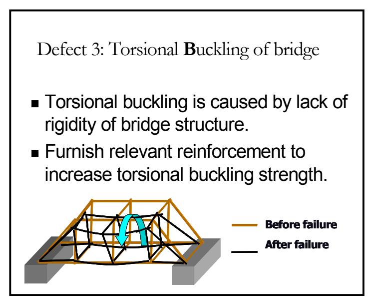


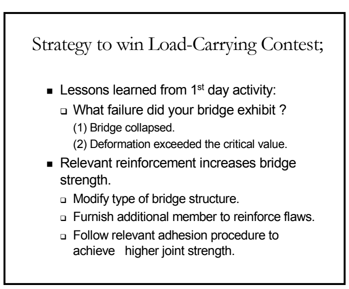












Appendix 2 Questionnaire and Student Feedback

This data you enter below will be used to make a plan for future improvement of the pre-college engineering course

Question 1: Were you interested in designing and building model bridges, which can withstand heavier load with less material?

Question 2: In which did you obtain better results: in individual activities or in group activities?

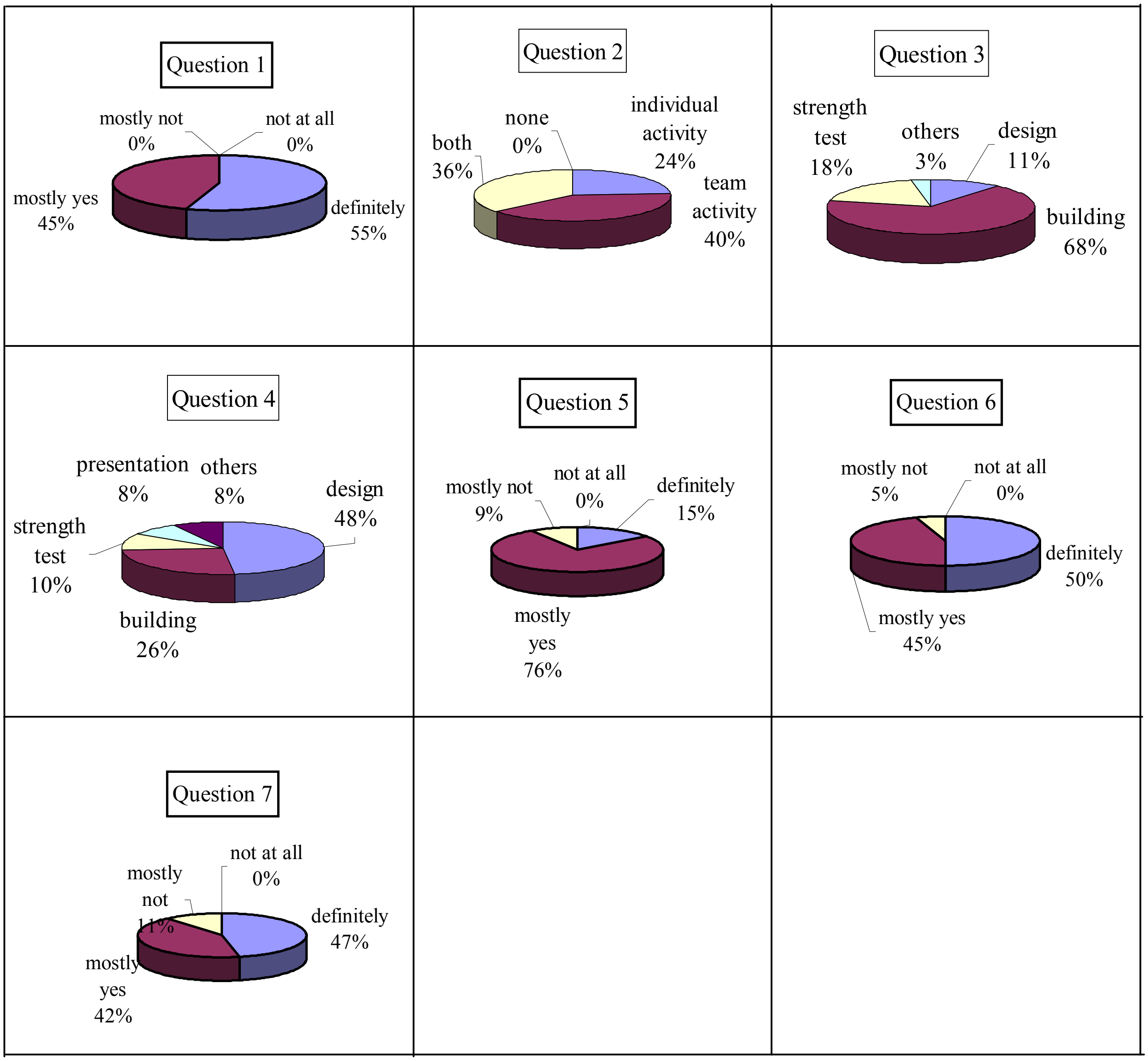
Question 3: What was most interesting about individual activities?

Question 4: What was most interesting about group-activities?

Question 5: Was the pre-college introductory engineering course beneficial to initiate your decision on your major before entering university: e.g. engineering oriented major or liberal arts?

Question 6: Was the system of learning through experience effective?

Question 7: Were you able to utilize your experience and knowledge, which were acquired by individual activities, to group activities?


Question 1
mostly not 0%
not at all 0%
mostly yes 45%
definitely 55%
Question 2
none 0%
individual activity 24%
both 36%
team activity 40%
Question 3
strength test 18%
others 3%
design 11%
building 68%
Question 4
presentation 8%
others 8%
design 48%
strength test 10%
building 26%
Question 5
mostly not 9%
not at all 0%
definitely 15%
mostly yes 76%
Question 6
mostly not 5%
not at all 0%
definitely 50%
mostly yes 45%
Question 7
not at all 0%
mostly not 11%
definitely 47%
mostly yes 42%