Deep understanding of engineer’s social responsibility in themes of ethics education

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Structured abstract

BACKGROUND

Japan Accreditation Board of Engineering Education (JABEE) expresses that the aim of Engineering Ethics is to develop the understanding of Engineer’s social responsibility. However, according to the paper of Minagawa or Kobayashi, the following thing is understood. To realise this education purpose stated for JABEE, a method of self consciousness –driven Ethics Education unexpectable in usual education top-down type transmission of message is proposed.

PURPOSE

This study demonstrates is proposed the utility of group education in deepening importance of engineer’s social responsibility.

DESIGN/METHOD

We applied Yuria Engestrom’s activity theory for this purpose. This theory is that students notice the influence on society lead he creature with which one provided society.

RESULTS

The results are as follows

(1) Students recognized the effects of their products on local residents.
(2) Students identified differences between their opinions on safety and those of the local residents, and recognized the necessity of attention to society.

CONCLUSIONS

The paper has introduced engineering ethics classes based on a bottom-up approach, which are expected to replace top-down classes and offer a new direction in education.

KEYWORDS

Engineering Ethics Education, bottom-up learning system, Enlighten Theory of Group Education

Introduction

One of the goals for engineering ethics education is to encourage engineers to “comprehend” their social responsibility. Students cannot be taught to “consider understand” their responsibility; it is important for them to realize it by themselves. However, students are provided with knowledge and assignments unidirectionally in a top-down manner in engineering ethics classes implemented in universities and technical colleges, and they often have difficulty acquiring knowledge and “realizing” in their studies. In this context, the present paper introduces an education program, based on the theory of Learning by Expanding proposed by Yuria Engestrom, which encourages students to learn and understand independently by facilitating functional interactions between educational, labor, scientific, and other specific activities. The program allows students to identify problems and “realize” their social influences and responsibility in a bottom-up manner through interactions with society. The paper reports the results of the program implemented for fifth graders is the Department of Mechanical Engineering at Ariake National College of Technology, on a trial basis.

Status of engineering ethics education and problems with learning outcomes

Results of surveys of the syllabi of universities and technical colleges in Japan

Among its educational goals related to engineering ethics, JABEE stipulates that engineers should “comprehend the influences and effects of technology on society and nature and their social responsibility”.[1)] In 2011, the Investigative Research Committee on Engineering Ethics of the Japanese Society for Engineering Education conducted a survey of the syllabi of engineering ethics-related subjects used in 107 universities and technical colleges in Japan. The survey results suggest that: 1) A goal for engineering ethics education implemented in universities and technical colleges is to help students acquire skills required for problem-solving, analysis, consideration, and communication so that they can comprehend their social responsibility, roles, and influences;[2)] 2) Regarding methods for engineering ethics education, 60% of the classes were lectures, as shown in Table 1; 3) Almost 100% of the lessons were implemented in a top-down manner, including case method-based learning, presentations, and other self-study classes based on assignments provided by teachers. Figure 1 shows the results of a survey on the effects of engineering ethics education conducted by Minagawa et al. in 2009, involving 208 universities and technical colleges. Figure 2 suggests that engineering ethics education improved students’ abilities to communicate and perform activities, although it did not reveal whether or not there was an improvement in their ability to “comprehend” - a learning goal.

Table 1: Common methods for lessons in engineering ethics education[2)]

Main lesson methods	Number of cases
Lecture	979
Case study	234
Group discussion	148
Presentation	81
Group work	57
Others	50
Case method	44
Debate	40
Role-playing	1

Results of an attitude survey involving the students and graduates of Ariake National College of Technology

Figure 2 shows the results of a survey conducted in 2009 involving eight first-year students and ten graduates from the Department of Mechanical Engineering at Ariake National College of Technology who took engineering ethics classes. The questionnaire was basically on the necessity of engineering ethics education and important items in education. As shown in Figure 2, although the students recognized the necessity of engineering ethics education, their awareness was low except for a few items. On the other hand, the graduates with work experience placed less importance on its necessity, the graduate's concern is in a social problem rather than an educational issue. The question: “Do you think that engineering ethics activities are necessary in your work place?” was asked to the graduates of the Department of Mechanical Engineering at Ariake National College of Technology who had attended engineering ethics classes (Figure 3). As shown in the figure, their awareness levels became lower over time after graduation.

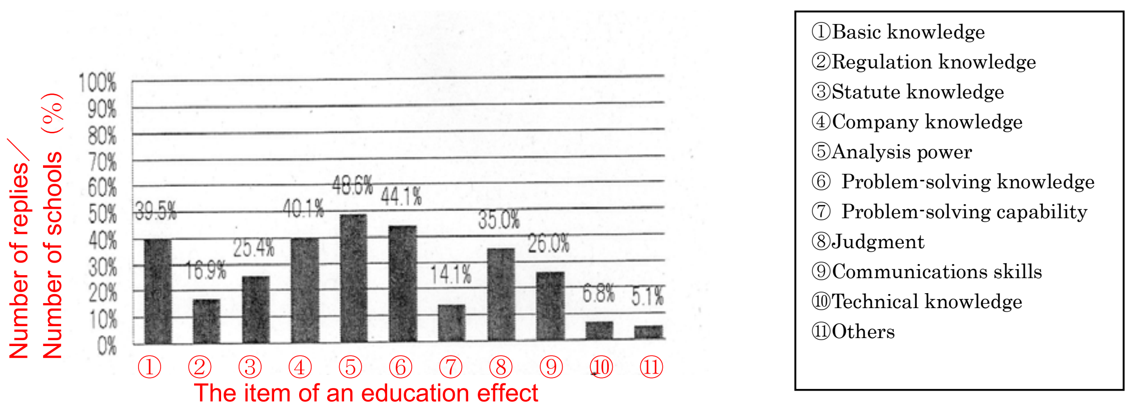


Figure 1: Effects of engineering ethics education[3)]

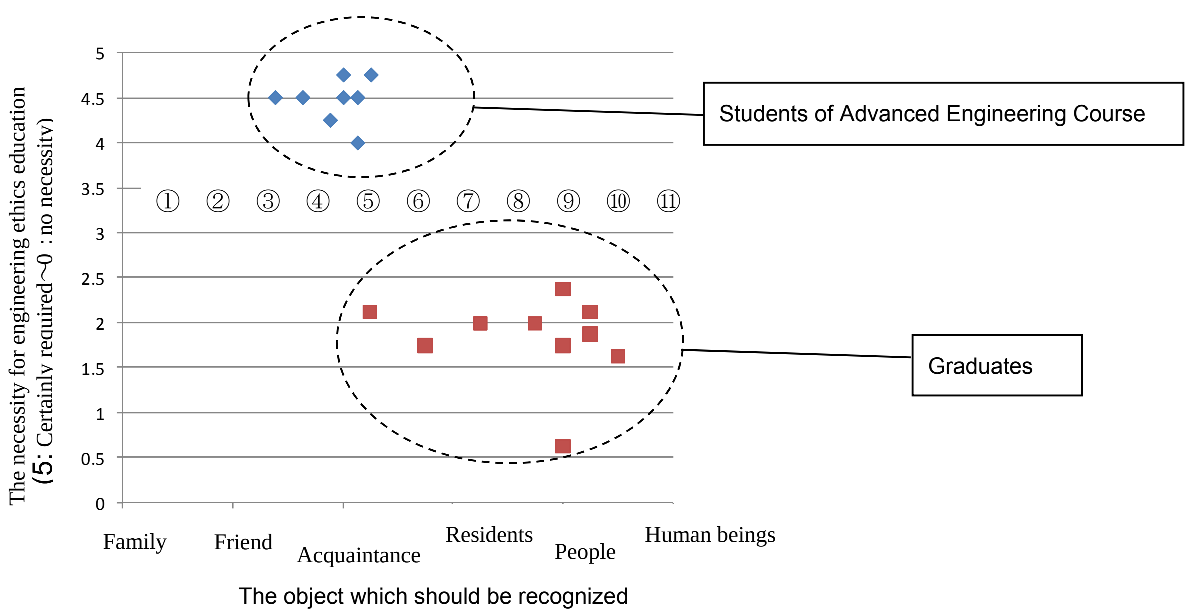


Figure 2: Necessity of engineering ethics education

(Survey involving the students and graduates of Ariake National College of Technology)

Problems with current engineering ethics education

According to the definition by the JABEE, people can comprehend something when they view it through its relation with themselves and apply it to thoughts and behaviors, and, as a result, have recognized and understood their responsibility, roles, and influences, as described in the above-mentioned survey of the syllabi. As Hishida et al. suggest,[4)] comprehension is not accomplished by observing society and nature. Students cannot be taught to comprehend; it can be accomplished only when they have worked on specific subjects. Figure 4 shows an education system based on existing syllabi. In self-study classes, assignments ("comprehension" of social responsibility, etc.) developed by teachers are provided for students in a top-down manner. Teachers are able to understand the educational effects on students when reports are submitted by them as feedback. Engineering ethics education based on this educational method has the following problems: (1) Because students are provided with knowledge during education, student's "comprehension" level is affected by teachers; (2) Analyses and discussions implemented by students who have not experienced actual, practical technologies and society cannot go beyond their own imagination; (3) When the case examples used in classes are virtual, students often fail to "recognize" important points by themselves and comprehend their responsibility, roles, and influences; and (4) Students can understand what they have learned only superficially and will not remember it after a certain period of time for the reasons described in (1) to (3). These problems are consistent with reports by Katakura[5)] and the Nikkei Industrial Newspaper[6)]: Students often experience difficulty applying what they have learned in unidirectional educational settings as their knowledge or "recognize" important points by themselves.

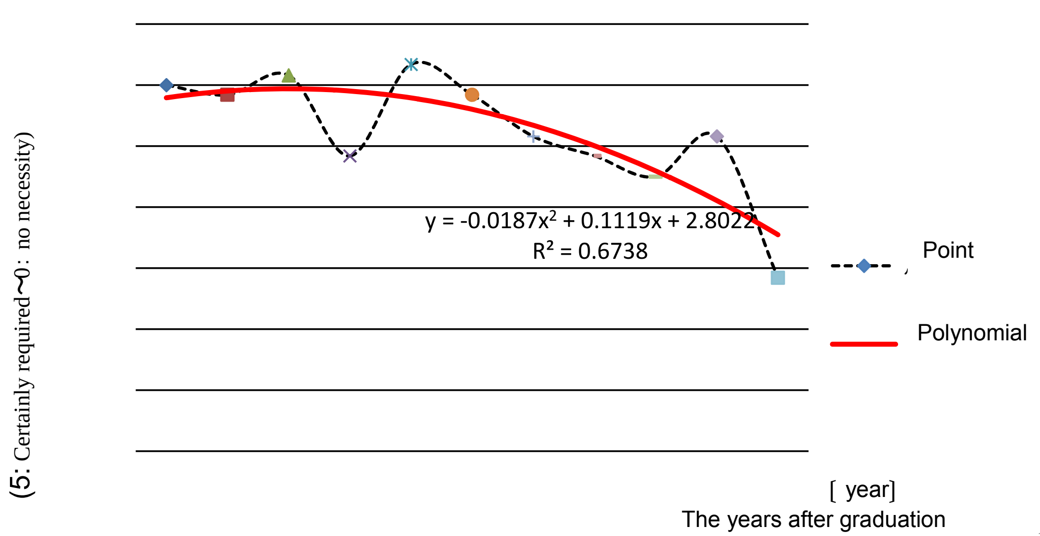


Figure 3: Changes in attitude toward engineering ethics education over time

Use of the theory of enlightenment for group education

Measure with problems in engineering ethics education

To solve problems with engineering ethics education described in the preceding paragraphs, it is necessary for students to realize the relationship between technology and society by exerting their influences on study subjects. Students "comprehend" the necessity of ethics through production activities: they present their products to society, undergo assessment, and "realize" their social influences and responsibility based on the assessment results.

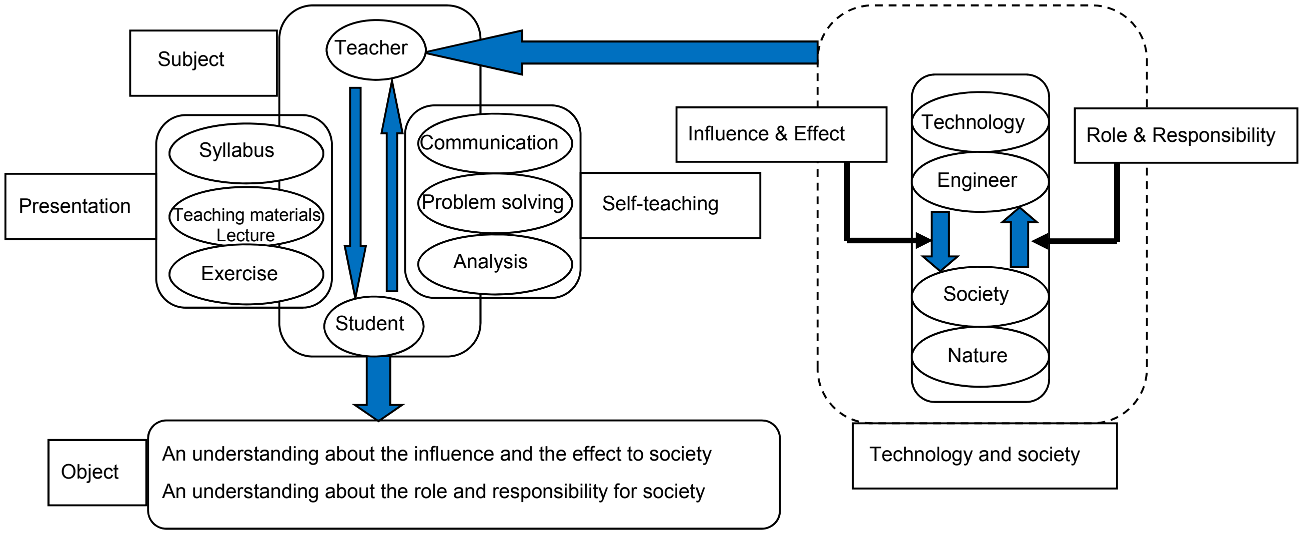


Figure 4: A system to help accomplish learning goals

These can be regarded as conventional lecture classes on engineering ethics combined with production activities and scientific knowledge. A production activity is considered to be the creation of values, and values are consumed, distributed, and exchanged. These points are also shared by the theory of enlightenment for group education. The theory compares learning to a production activity, which consists of the components shown in Figure 5: tools, subjects, objects, rules, communities, and division of labor. A student, as a subject, works on an object based on rules, using tools, through the division of labor. The results of production are consumed, distributed, and assessed in a community, the student is informed of the obtained results is feedback to students, and a new assignment is developed based on them. As this cycle repeats, a shift in the level of learning, or metacognition (from individual to group learning, or from passive learning to active learning) occurs.[7] If an "assignment" - an object - is "comprehension" as defined by the JABEE, the engineering ethics education can be regarded as an activity by students to accomplish "comprehension".

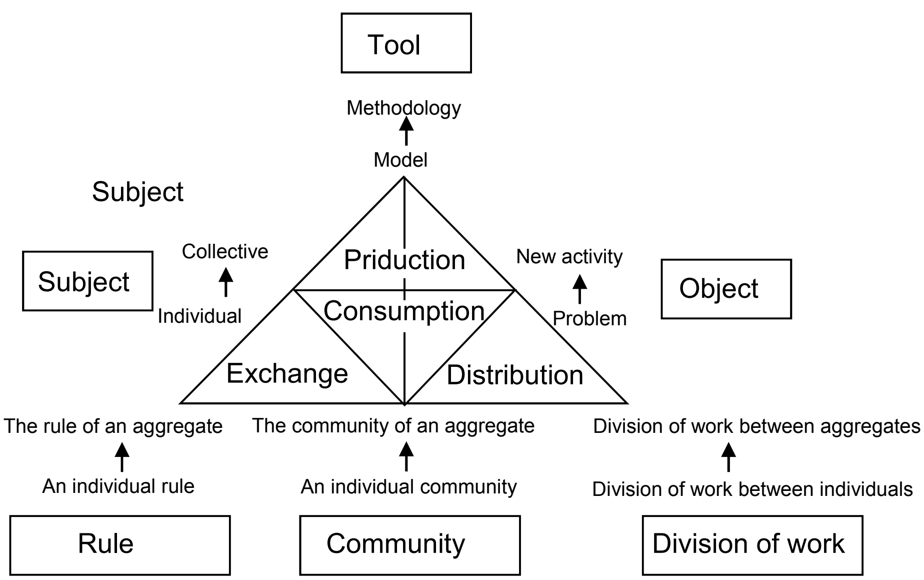


Figure 5: Structure of a learning activity based on the theory of enlightenment for group education[7]

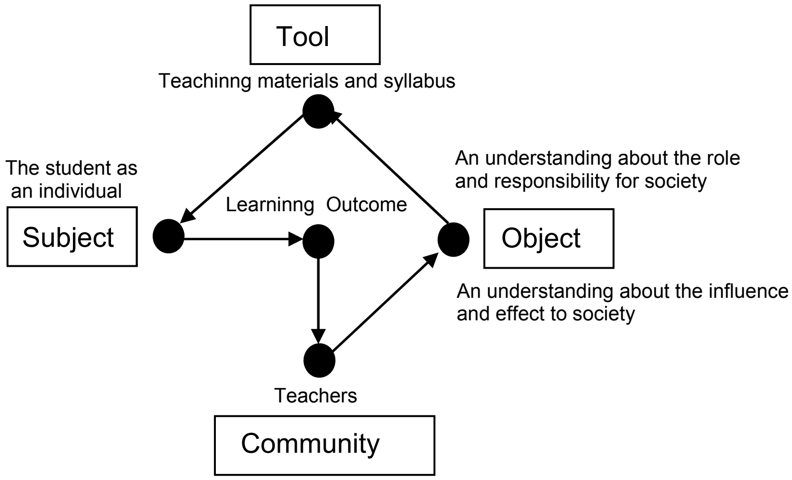


Figure 6: Structure of a conventional learning activity

Use of the theory of enlightenment for group education

When Figure 4 is applied to the theory of enlightenment for group education, conventional learning activities are expressed as in Figure 6. As shown in figure6, when students study using tools, such as educational materials and syllabi, prepared by teachers, what they have learned will only be presented by teachers unidirectionally. Students are not directly related to the object (an understanding of them role and influence to society). In this situation, students cannot understand the true meaning of an object. When students become involved in actual production activities, they will understand their position in the relationship between technology and society as shown in Figure 4, as well as the community positioned between the division of labor and rules shown in Figure 6. In a learning structure based on the theory of enlightenment for group education, as expressed in Figure 7, the methods for production are regarded as tools, and a production team or specific organization for production as a community.

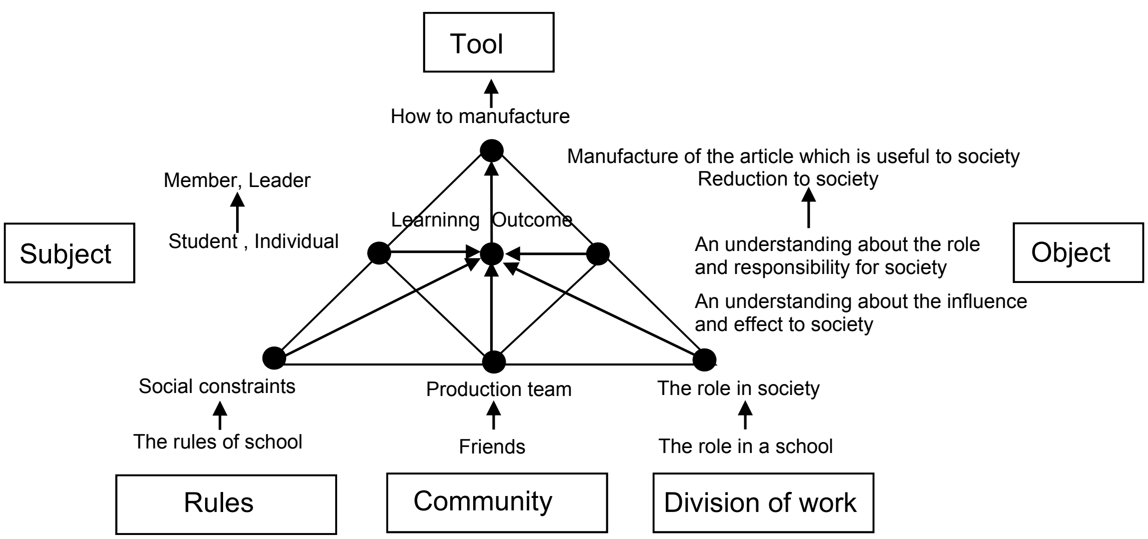


Figure 7: Extended-type, bottom-up education

The production team produces the products while complying with social restrictions or rules and recognizing the division of roles or specialization in society. A production teams distributes their products for people in society to use and assess them, and they comprehend the influences and effects of their products on society and nature and their roles and responsibilities. Through this experience, students comprehend their relationships with society and nature, and Students become find out the new target which returning an educational result to society and producing useful products. In summary, manufacture activities produce the learning effect which students regard safety as important rather than manufacture.

Engineering ethics education through the production of a water-purification system

Experienced-based engineering ethics classes through a production activity

A theory of learning activities which established by the theory of enlightenment for group education, was applied to an "engineering ethics" class for fifth-year students of the Department of Mechanical Engineering of Ariake National College of Technology; a set of two 50-minute sessions was implemented 15 times for 19 students. Specifically, "students manufactured disaster-prevention water-purification equipment, and asked community residents around the college to drink the water purified with the equipment". The following conditions and restrictions were established: Students had to secure drinking water for 30 local residents around the college and themselves, who had been left without water following a large earthquake, to survive for three days in the summer period while waiting for rescue. There was drinking water for 0.5 days left in the school. Prior to the implementation of this assignment, the functions of the activity were defined as shown in Figure 7. (1) Community: Team for the production of water-purification equipment; (2) Rules: Restrictions on the use of equipment due to the earthquake (Power and heat sources were unavailable, and students were only allowed to use materials available in the school); (3) Specialization: Division of roles among group members (procurement of filtration media, processing of components); (4) Tools: Machine tools used in the factory and mobile phones (to search for production methods).Following the design and manufacture of water-purification equipment, a meeting with the local residents was held to exchange opinions on the filtered water produced by the equipment to understand its effects on society (and the residents living around the school) and the producer's responsibility.

Status of the implementation of classes

The following paragraphs report the status of class implementation. To accomplish the goal of the above-mentioned simulation, students were required to secure a water supply for 30 people for 2.5 days by the end of the seventh class session (or within 11.7 hours). In the first to third sessions, explanations of rules and lectures were delivered, students were divided into four groups (each consisting of 19), and different roles were assigned to them. In the fourth to ninth sessions, water-purification equipment was manufactured. In the fourth session, each group examined the principle of the system, structure of the equipment, and materials required to create it. The discussion results suggested: 1) The required amount of water was 3 ℓ per day per person; 2) The volume of water produced using an RO (reverse osmosis) filter was approximately 60% of the water supply; 3) The required water supply capacity was 75 ℓ/day x 1.6 = 120 ℓ/day (= 10 ℓ/hour). Based on these results, three primary filters and one secondary filter were manufactured to remove foreign substances and bacteria, respectively. We planned that water supply secures 18 ℓ/hour by the primary filters and secures 10.8 ℓ/hour by secondary filter. In the fifth session, materials available in the school were collected, and the sixth to ninth sessions were spent for processing and assembly at the factory, as shown in Figure 8. Table 2 shows the specifications of the produced filters.

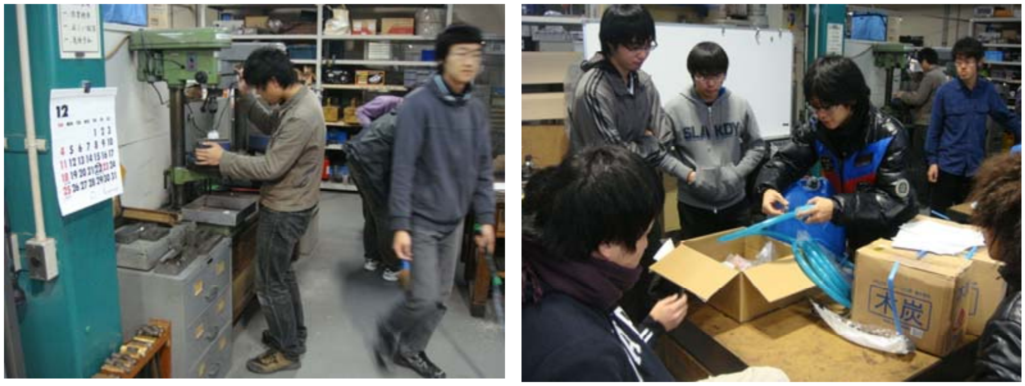


Figure 8: Scenes of the production of water-purification equipment at the factory

Table 2: Specifications of filters created by each group

Group	Filtration	Main filter media	Case material	Water supply	Filtration pressure
No.1	Dust	Sand, Gravel, Charcoal, Cotton	PET bottle	5ℓ/h	Gravity
No.2	Dust	Sand, Charcoal, Cotton	Plastic bucket	8.5ℓ/h	Gravity
No.3	Dust	Absorbent, Cotton, Sand, Charcoal,	Kerosense can	5.5ℓ/h	Gravity
No.4	Bacteria	RO film Filter	Aluminum container	11ℓ/h	Bicycle

Figure 9 shows the appearance of the completed water-purification equipment. The water in the container is: (1) put through the hose, (2) filtered by the primary filter, and (3) put into the bucket. (4) The water is pumped by hand, (5) put through the secondary filter, and (6) put into a water-purification tank, as illustrated in Figure 9. The required water pressure (5 kgf/cm^2) was applied to the RO (secondary) filter by manually rotating the handle of the pump. In the tenth session, the capacity of the filters was assessed. Using water samples, sensory (appearances and odors) and bacteriological (commissioned to the Department of Material Engineering) tests were conducted prior to and following the filtration. Table 3 shows the results. In the eleventh session, an open experiment on the water-purification equipment was conducted, inviting twelve people including community residents living in the neighborhood of the college, teachers, newspaper reporters, and students (Figure 10). In the open experiment, after providing an explanation of the principle of filtration and mechanism of the water-purification system, students demonstrated water purification using the equipment. At the end of the experiment, the researchers poured the water into paper cups and encouraged community residents to drink it. However, they refused to drink it.

This experiment was published in Ariake Shinpo, a local newspaper, on December 20, 2011.[8)] The responses of local residents invited to drink the water by students, the conductors of the experiment, were recorded in the video. Table 4 lists the differences in opinion between the students and residents.

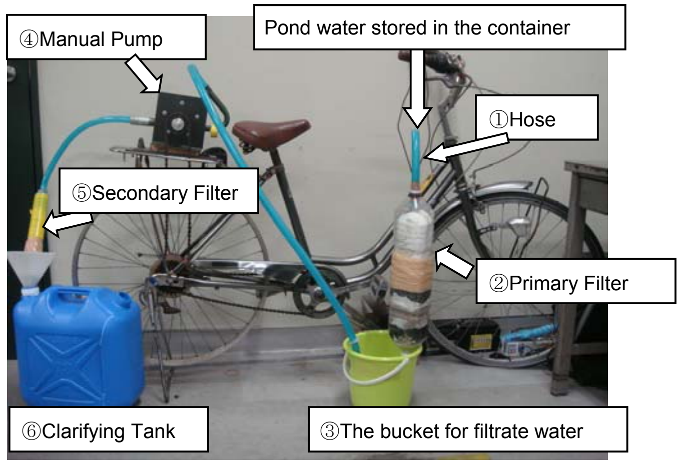


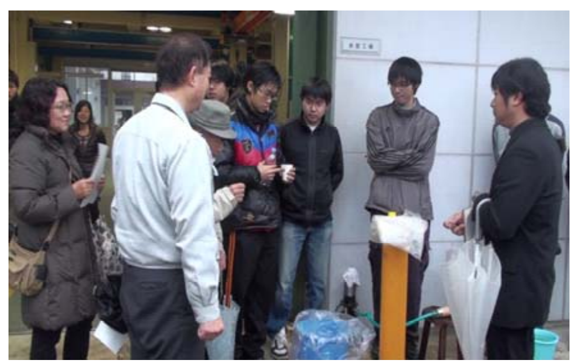
Figure 9: Completed water-purification equipment

Table 3: Capacity of water-purification equipment

Sample	Before Purification			After Purification		
	Appearance	Smell	Bacteria	Appearance	Smell	Bacteria
Coffee-flavored Milk	Brown	Characteristic	—	Transparent	Nothing	—
Tap water(three-day neglect)	Transparent	Existance	Detection	Transparent	Nothing	Detection*
Pond water	Muddiness	Nothing	Detection	Transparent	Nothing	Detection*

＊：Completely sterilized after the water was heated for a few minutes

(a) Students explaining to local residents



(b) Demonstration of the filtration for local residents

Figure 10: Scenes of the open experiment

In the twelfth session, a meeting for presentation was held for hearing both the opinions on the production of the water-purification equipment and on the open experiment. The same assignment as the fifth-year students were provided the fourth-year students graders as a case study, and they were made to design the virtual water-purification equipment. These 39 fouth-years students of the Department of Mechanical Engineering were not attend the lessson of Engineering Ethics. The survey was conducted both fourth- and fifth-year classes to ask them to decide on the most important point in the production of water-purification equipment in preparation for an earthquake. Figure 11 shows the results: 1) Awareness of the importance of technologies was high among both fourth- and fifth-graders; 2) Fifth-graders placed importance on not only technology but also considerations of society. This was because they interacted with community residents through the production of water-purification equipment, and directly learned social demands as shown in Table 4.

Table 4: Communication between students and local residents

Contents which the student wanted to tell	Contents which residents wanted to hear
The principle and structure of filtration	A head and pollution condition
Reliability of RO film	Safety of the last filtrate water
Contents studied about the structure of filtration	Knowledge grade
The valuation basis of filtered water is transparency	The basis which judges transparent water to be safe
Safety of filtered water	Residual risk of filtered water

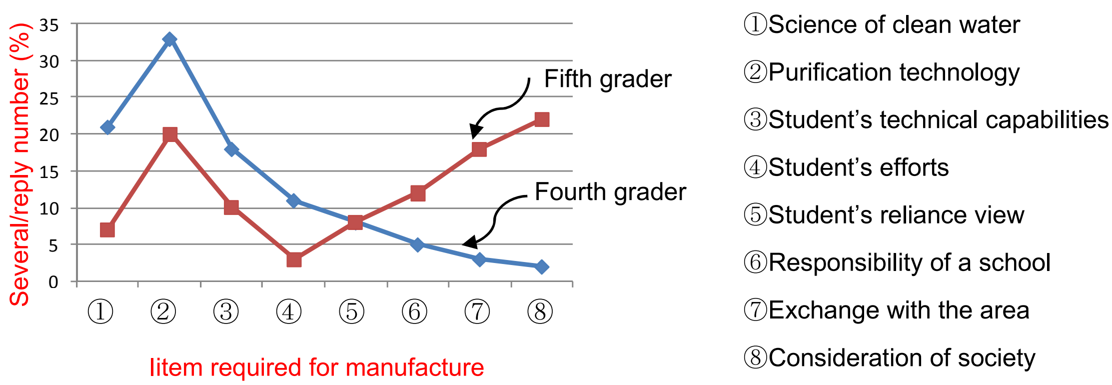


Figure 11: Differences in opinion between fourth- and fifth-graders of the Department of Mechanical Engineering of Ariake National College of Technology

Future challenges

Fifth-year students of the Department of Mechanical Engineering of Ariake National College of Technology indicated the following opinions other than the learning effects described in prior chapter : (1) Electricity and machines should not be used in engineering work performed in preparation for an earthquake; (2) Although I was motivated to develop venture products, their production required advanced knowledge not provided by the technical college; (3) There was insufficient time for production because it took a long time to coordinate members of the group; and (4) As we did not have sufficient knowledge of the criteria for the determination of its quality, the safety of the water produced by the student's developing water-purification equipment remained questionable. In future classes, it will be necessary to invite advisors on water-purification technology and promote the training of group leaders for maintaining of the learning program. For example, we utilise an adviser about (1),(2) and(4) ,and utilise a leader about (3). Then, we can aim at the improvement of a lesson.

Conclusions

The present study examined methods to accomplish the learning goals for engineering ethics education suggested by the Japan Accreditation Board for Engineering Education. The results of a survey involving universities and technical colleges identified inconsistency between education goals for conventional classes provided based on a top-down approach and their effects. Ariake National College of Technology challenged help of student's comprehension of their social responsibility - one of the education goals. According to the basic idea that students cannot be taught to "comprehend" something and have to accomplish "comprehension" by themselves, the school provided classes that applied the theory of enlightenment for group education. The results are as follows: (1) Students showed the effects of their products on local residents; (2) Students identified differences between their opinions on safety and those of the local residents, and recognized the necessity of attention to society. It was suggested that the classes introduced in the present study allow students to become aware that importance should be placed on not only technology but also considerations of society. The study has introduced engineering ethics classes based on a bottom-up approach, which are expected to replace top-down classes and offer a new direction in education.

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