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Street Performance Robot Contest as Practice in Creativity Education

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This paper introduces the curriculum for creativity education that has been conducted at the Department of Mechano-Aerospace Engineering, Tokyo Institute of Technology, for 20 years, for the purpose of systematization of education using robots. In particular, we describe the significance of the lecture and operational know-how of contests for street performance robots, which we have continuously held in the course called "machine creation." The results of a questionnaire survey of students indicate that this course is a valuable experience for students.

Keywords: creativity education, machine creation, street performance robot contest

Fig. 1. Street performance robot spinning a top (1994).

1. Introduction

Since Japan has achieved the world's highest standards in technology and there are no other particular pioneers for Japan to follow, it is an urgent task for Japanese educational institutions to systematically develop students' creativity. While many universities have recently become aware of the significance of "education on Monodzukuri (hands-on experience of design and manufacturing)" and "creativity development," the Department of Mechano-Aerospace Engineering at the Tokyo Institute of Technology has been addressing this issue since 1990 . 20 years ago . establishing a curriculum to develop creativity and conducting educational programs focused on practical training and manufacturing.

This study has two main purposes. One is to contribute to operation of future creativity-developing courses and systematization of robot education by introducing the curriculum to develop creativity, which the authors have proposed and conducted, the so-called "machine creation" course, including the street performance robot contest (Fig. 1). We will describe our operational know-how accumulated by continuing the machine creation course for 20 years to provide practical and specific information. The second purpose is to investigate and examine the educational effect of machine creation through a questionnaire survey.

The rest of this paper is organized as follows. Section 2 describes the basic way of thinking and idea behind education to design creativity. Section 3 introduces a specific curriculum to realize the idea. Section 4 explains in detail the actual operation of the course of machine creation. Section 5 introduces the street performance robot contest. Section 6 reports and examines the results of a questionnaire distributed to students of the academic year 2010. The final section presents the summary of this paper and future prospects.

2. Creativity Education and Street Performance Robot Contest

2.1. Issue Awareness

As seen in developments of electrical home appliances and automobiles during the high economic growth era in Japan when foreign products as role models and targeted functions were definite, improvements in technical capabilities and high-performance products could always generate profits. However, in this age of matured technologies for manufacturing, research and development, and diversification in values, a simple rule that“ achieving certain performance makes the product sell well ” no longer exists. Engineers are required to plan, create, and realize entirely new types of products and services.

Moreover, since technologies have become so sophisticated as to exceed the scope of one engineer ’s capability, specialization and segmentation of technologies are proceeding. Given such a situation, many engineers need to work together to develop a product or achieve success in a project. More communication skills and coordinating capabilities to execute a project are increasingly required of modern engineers.

However, recently, most students have been entering universities without any experience of handling machines or Monodzukuri even if they aspire to study mechanical engineering. According to a questionnaire distributed to the third-year students in the authors ’ class (the results are described later), only 40they had experience in Monodzukuri in the past, while 60courses. Some students did not even know which way to turn a driver to tighten a screw, despite majoring in mechanics.

Even though students learn solutions to problems through lectures, if their knowledge is not associated to the real physical world, it is difficult to solve problems in the actual world. Authors cannot help but be concerned about the future when such students graduate from universities and become engineers in society.

2.2. Education in the Department of Mechano-Aerospace Engineering at the Tokyo Institute of Technology

The Department ofMechano-AerospaceEngineering at the Tokyo Institute of Technology, which the authors belong to, introduced “ experience-based education ” through the most basic and primitive practical works to enable students to handle actual machines as much as possible for the purpose of fostering creative human resources to respond to social needs. Experience-based education is a type of education in which not only principles and phenomena are taught as academic theories, but also physical phenomena are actually observed or experienced by the students through physical contact such as touching with hands, if possible. We think that experience-based education is extremely important in engineering education that deals with problems in the actual world. The curriculum outline is given in Section 3. The curriculum includes explanation from corporate engineers as adjunct instructors on subjects such as decomposition and assembling of machines, composition of electric circuits and control programs, and designing and drawing of functionalmechanisms to meet the required specification in addition to practical works.

The comprehensive course is called “ machine creation, ”in which the “ street performance robot contest ” is held. In the contest, four to five students in a group create a robot for the ambiguous task of “ creating a robot to entertain people. ”Through this course, students can experience the comprehensive process of machine creation in a short time from designing, machining, manufacturing, and control to presentation at the contest.

This course holds an important educational aspect to carry out a project in a group. According to a questionnaire before the class, 60they did not have any experience of executing projects. By working with other group members toward a goal, students can acquire broad experience, such as schedule management, role sharing, communication, and cooperation.

Another point taken into consideration in course management is that the contest should be remembered by students as a successful experience. No matter how hard students make efforts to realize their unique ideas, if their robots are unfinished and do not work at all, the experiences may cause students to feel incompetent in Monodzukuri and may lead to inhibiting their creativity. Throughout the course, the progress of students ’ works is checked and appropriate adjustments are made so that all the groups can operate their robots at the contest.

2.3. Features of Street Performance Robot Contest

While most robot contests currently held are game-type ones, this course adopted the performance-type contest, which requires subjective judgment for the following reasons.

1)The task for students is ambiguous.
In game-type contests where rules are clearly set, students can focus on technical challenges to win the game. However, when it is easy to decide the winner, after holding the contests several times, solutions to win tend to concentrate on an orthodox and highly credible way, and thus opportunities to exercise creativity become narrow. Moreover, if all robots take similar forms, the winner may be determined only by the difference in manufacturing techniques, not by the difference in ideas. On the other hand, since there are diverse ways to entertain people, the performance-type contest allows a variety of ideas and thus provides many opportunities to exercise creativity. Students are also required to exercise their uniqueness from the planning stage to determine what type of robot they will create. Therefore, this course enhances not only the students ’ manufacturing ability but also their creativity, including planning ability to decide what they will create.

2)The contest is appealing to the audience.
With the task to create a robot to entertain people, all robots presented at the contest are different and they keep

the audience entertained. Students make presentations in front of a large audience and directly receive feedback such as laughter, cheer, or a cold response, which leaves a deep impression on them as a straightforward experience. In this contest, students cannot be highly evaluated if their robots are not appealing to the audience, no matter how excellent the technology is. It will be a valuable experience, especially for serious students who tend to pursue technical aspects, to understand the significance of conveying ideas to other people, and to learn an outsider 's viewpoint from the public. However, it is difficult to objectively judge entertainment value and attractiveness of the performance. In the evaluation of this course, not only evaluation from the contest audience but technical evaluation at intermediate reviews and reports are also considered.

3)Contests can be held continuously.
In performance-type contests, the same rules can be repeated every year, while in most game-type contests, the type of games is changed each time. This feature greatly reduces the burden on professors. Actually, the street performance robot contest has been held 20 times until this year with most rules remaining unchanged. Since the rules remain the same, items such as actuators, control equipment, and power sources can be reused for several years, reducing the cost to conduct the course.

3. Curriculum

Students with limited experience of Monodzukuri, as stated before, may not even know how to start their work if they are told to create a street performance robot. In this section, we introduce the outline of the curriculum used in the Department of Mechano-Aerospace Engineering to effectively give experience-based education in a limited timeframe for courses. The background for introduction and other detailed information are described in Reference [1]. Although the time line and duration of each course has been slightly adjusted along the years, the courses maintain their original goals and purposes. At present, each of the following courses run once a week for a 15-week semester.

3.1. Introduction to Machine Creation (2 Credits, 135 min perWeek)

This is a compulsory subject scheduled in the first semester of the second year when specialized education in mechanical engineering starts after students select their departments. For the purpose of handling as many machines as possible, four students in a group take apart various types of machines using distributed tools. The machines are donated by companies. The students not only disassemble the machines but also reassemble them after engineers from companies explain the inner structure, functions, materials, and processing methods of the machines. In practice classes with gasoline engines, students actually start the engines at the end of the class, and every year, we can hear the students 'cheer of relief and delight when they succeed in starting the engines.

3.2. Mechatronics (2 Credits, 135 min perWeek)

This is an selective subject held in the first semester of the third year to study the basis of analog-digital electronic circuits and to practice computer programming in C language and DC motor control using a motor driver circuit. In the academic year 2010, students manufactured inverting amplifier circuits with operational amplifiers, using a universal substrate, and circuits to drive relays and turn on/off the switch by digital I/O. Students can improve their soldering ability through circuit manufacturing, and the manufactured circuits are reused in the machine creation course later. With regard to a control computer, microcomputers were introduced in 2009, and students practice position control using motor driver circuits developed in our laboratory (to be described later). Moreover, by connecting microcomputers and personal computers by serial communication, an advanced control system is achieved. The course content is reviewed annually according to the current technical environment.

3.3. Design and Drawings (2 Credits, 3 hours per Week)

This is a compulsory course held in the first semester of the third year. In the first several weeks, drawing methods are briefly taught and a test is conducted. Thereafter, several specific tasks for designing are provided, for which each student freely designs machines. Engineers from companies create realistic tasks in the actual designing work. They also provide explanation using catalogues on such machinery elements as bearings and ball screws using materials. Students submit hand-drawn assembly drawings, and they need to explain the rationale for actuator selection and strength calculation in order to apply their knowledge obtained through lectures on practice works.

3.4. Relation to Other Courses

In addition to the abovementioned courses, the curriculumincludes other courses to study theories (Fig. 2). (Due to space limitations, only those courses directly related to robots are abstracted in this paper.) " Introduction to Robotics " is a course on robotics and vector analysis for robot control. " Machine Control " is a course to study the basis of feedback control and the state-feedback control systems. " Mechano-Aerospace Engineering Experiments I & II " are compulsory courses held in the second semester of the second year and the first semester of the third year. In these courses, students are divided into small groups and they conduct experiments on diverse themes such as heat, fluid, materials, vibration and robotics, which are changed once every two weeks. With regard to experiments on robotics, there are two targets: 1) trajectory control of hand position by a manipulator and

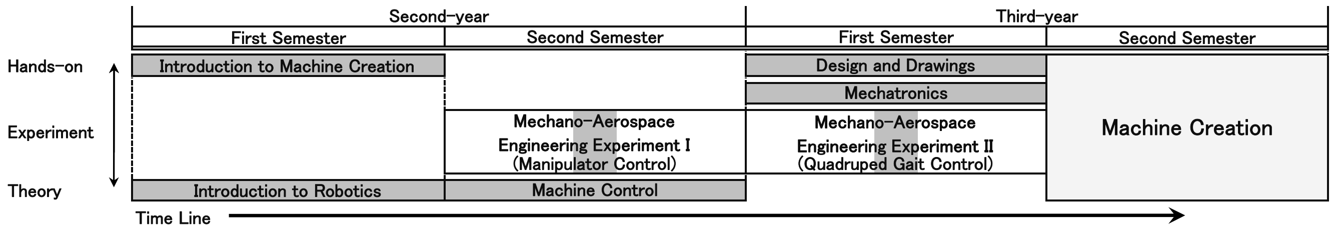

Fig. 2. Time line of courses as preparation for machine creation

2) gait control of quadruped robots [2]. Through these experiments, students are able to acquire experience in operating robots by means of computer programs.

As described above, the curriculum for the second and third years is designed to enable students to acquire necessary basic knowledge and techniques organically and seamlessly toward the goal of machine creation, which is the ultimate stage of the curriculum in the department before their assignments in laboratories.

4. Machine Creation

This is a compulsory course (3 credits, 4.5 hours per week) held in the second semester of the third year, following the curriculum described in the previous section. Students design and create robots with the goal of presenting them at the street performance robot contest held in the 14th week. Details are described below.

4.1. Tasks

The task for students is basically limited to “ creating a street performance robot with motions and sounds, ” and performance content completely depends on the students ’idea. However, from the perspective of education and operational convenience, the following rules are established: 1) motions should basically be generated by computer control, 2) both completely automatic performance and joint performance with people are acceptable, 3) synchronized performance with external devices to output sounds or movies are acceptable, 4) performance that may dirty the facilities or contest venue or endanger the audience is prohibited, 5) performance should not exceed three minutes, 6) each group has a budget of Y=20,000, and the excess amount should be borne by students, etc. In addition to these rules, approximate limits on the size and quantity of robots are defined. However, the limit is only for operational convenience, and most robots are accepted flexibly unless they cause serious problems.

4.2. CourseManagement

4.2.1. Grouping

Basically, four to five students constitute a group to work together. For the academic year 2010, 10 groups were organized. Since students were at first allocated in the order of their student ID numbers, many problems emerged due to differences in technical level between groups and opinion contradictions among group members. Since this course is compulsory, students are required to attend the class even if they are frustrated, and as a result, this may cause a negative effect even on other highly motivated students. If students are allowed to organize groups on their own, then only students who have a good understanding with each other will gather; while communication among the group members may seem to be smooth, students will be deprived of experiences such as developing new relationships and finding a common ground for different opinions. A serious problem encountered in past experiences was that the disparity between the groups widened since serious students and non-serious students tend to be divided into different groups.

Therefore, in recent years, a questionnaire has been distributed to students before grouping so that the professors can allocate the students according to their target for creation, desirable role in the groups, and experiences in Monodzukuri. The questionnaire includes the following: 1) what type of robot the students wish to create (a robot to make large-scale motions, a robot to play musical instruments, a robot to have a match with a human, etc.), 2) what role they want to play in the group (project manager, mechanic, electrician, programming, etc.), and 3) whether or not they have experiences in Monodzukuri (club activities, project class, etc.).

In the academic year 2010, grades for the mechanoaerospace engineering experiment were also considered in grouping in addition to the questionnaire results. The compulsory experiment required students to submit an average 20-page report for each theme, demanding considerable effort of students. Since the experiment includes subjects that students must voluntarily investigate such as examination of results and advanced questions, the grade is positively correlated with the students ’ motivation to study. We group students based on questionnaire results and average grades of group members, so as to narrow the gap in the levels of techniques and motivation among groups.

Although grouping may be considered a trivial matter, a bad personal relationship mostly provides students only with negative experiences. We consider grouping to be important because it has great implications on the students ’success experiences.

4.2.2. Safety Measures

Since students create robots using machine tools on their own, special attention should be paid to safety of this course. The first class provides general information such as clothes to wear while using machine tools and accident insurance. Then, students learn how to use drilling machines, band saws, milling machines, and lathes through practical works under guidance of the technical staff.

When students use machine tools, technical staff, professors, or Teaching Assistants (TA), who are trained graduate students, must supervise them to check if the tools are used correctly. In the academic year 2010, 40 students were always supervised by one professor, three members of the technical staff, and one TA. (There are 16 TAs in total. We ask two or more TAs to assist when the quantity of work is large.) Under this system, fortunately, no major accidents have occurred in the past 20 years.

4.2.3. Provision of Technical Information

Specifications and manuals of common parts to be used in manufacturing are posted on the website so that students can electronically obtain them when necessary [a]. The website also provides rough sketches of mechanism design and circuit diagrams, on which the professors give advice while responding to the students ' questions in the process of manufacturing to promote information sharing.

Other specific information on commonly used equipment, such as connecting methods with motor drivers and microcomputers, is effectively provided through lectures by adjunct instructors at a time scheduled according to the progress of work.

4.2.4. Progress Management

As this course consists of 15 classes in total and continues for about four months, most students find difficulty in time management. While the actual time for work is extremely limited, students cannot initially estimate their work capabilities and required time for the work. As a result, they proceed with the work very slowly, and toward the end of the course, they need to rush. When the robot is manufactured in haste, the quality is low and more importantly, there is an increase in risks of injuries and accidents at work.

To avoid such a situation, the course includes as many check points as possible, such as " idea presentation " in the 2nd week to present ideas on robots to be created, " mechanical review " in the 7th week to complete the basic mechanics of the robot, " technical review " in the 10th week to confirm motions through computer control, and " final review " in the 13th week to confirm the entire performance. After each review, students are required to submit a four-page (A4) report as a training to summarize the progress report briefly but with as much information as possible. Points and reports for these reviews are used for evaluation of the grades, but the underlying purpose is to set the target for the reviews considerably higher than the actual progress so that students can become aware that they are always in delay, and proceed with the work to be completed before the contest.

4.3. Evaluation

Students are evaluated based on the content of each group 's presentation and report at intermediate reviews and the street performance robot contest. Proportions of grades in the entire evaluation are as follows: the idea presentation accounts for 10%; mechanical review, 10%; technical review, 20%; final review, 40%; and street performance robot contest, 10%.

For presentations in each review, professors of the course and other teaching staff in the department evaluate the achievement level and degree of entertainment of the robot. The achievement level represents the ability to execute a project, while the degree of entertainment represents the degree of ingenuity of design and mechanics.

The important point in evaluation is that rankings at the contest are not necessarily reflected in the final evaluation in the course. Even if a robot does not successfully operate at the contest, students can obtain high evaluation if they challenge for difficult technical tasks, while students receive low evaluation if their robot is easily manufactured without considerable effort. In addition to the evaluation for groups, each student is evaluated on the basis of their attendance records and roles in the group.

4.4. StructuralMaterials and Mechanical Parts

Materials needed for creation of a robot are stocked in the space with a rack for parts in the Integrated Creation Studio, where the class takes place. When the course starts every year, such materials are restocked with adequate quantity: 1) structural materials, including aluminum sheets and bars, channels, rod bars, acrylic sheets, plywood, and rafters, 2) mechanical parts, including plastic bearings, ball bearings, gears, ladder chains, sprockets, and couplings, and 3) fastener components, including bolts, nuts, and wood screws. Some people may think that plywood and rafters are inappropriate as structural materials since they seem to be unsuitable for robot manufacturing and not a part of robotic appearance. However, wood is lightweight, reasonably priced, and strong, and above all, it can be easily fabricated. We think wood is extremely useful to realize ideas quickly in a limited time for manufacturing. In the past, some robots did not successfully operate because the set screw that fastened the actuator output shaft and the driving component loosened. Therefore, for the academic year 2010, we recommended the use of a clamping collar (Mismi, SCSW6-8), which works when a slit is fastened by a screw, to achieve firm fastening in parts for transmitting high torque. There were also problems with plastic gears whose teeth were broken when high torque was applied; thus, we prepared metallic gears so that students could select them when necessary. Through such minor changes in stocked parts, we continue our efforts to improve the quality of students ' manufacturing every year.

The important point in material management is that prices are indicated for all the parts. Since designing is an activity to optimize limited cost and time for development, it is natural to consider costs in designing. However, traditional designing courses have not focused on costs. In this course, students are required to make an accounting report in the last class on the price of materials they used to create the robot in order to provide the students with experience in economically efficient designing and manufacturing. Moreover, pricing of the stocked parts is very effective to prevent wasting of the parts. [1]

Each group is provided with a budget of Y=20,000 with which students can buy the stocked parts. They can also disassemble disused machines to find parts or purchase parts on their own at places such as Akihabara. Moreover, in the first class of the course, they disassemble robots manufactured in the previous year and are allowed to reuse those parts if necessary. Through such efforts, we can save the cost every year to a relatively low level; the amount of parts to be purchased when the course starts is about ¥200,000, and the entire budget of the course is about ¥350,000.

4.5. Actuator

As actuators, a DC motor with a gear head and an air cylinder are mainly used. We adopted the use of reasonably priced DC motors wherein the reduction ratio is selectable (Nidec Servo, DME33 series, etc.), so that students can select the reduction ratio according to the purpose. The maximum output power is as low as 5W, taking into account the capacity of the power supply unit distributed to each group. This is owing to the operational reason to save the cost. However, in addition, it is owing to the educational reason so that students have to design their robots in a rational way since it requires the students' ingenuity to create a well-considered mechanism, such as weight compensation mechanism using a spring or towing with a wire to drive the robot. Otherwise an actuator with low output power can not operate a robot whose size is relatively large, i.e., about 50 to 100 cm.

As for air cylinders, a number of double-acting cylinders with 16-mm diameter and 125-mm stroke (Koganei, PDA16x125) are prepared and lent to students along with solenoid operated valves, speed controllers, pneumatic joints, and air compressors according to each group's request. With an air supply pressure of about 0.4 MPa, a cylinder can produce a force of about 80 N. The cylinders are used in parts where large force is required, such as an actuator to operate long arms.

In addition to the abovementioned actuators, solenoids are used for simple linear motions.

1. Taking into account the budgets to be appropriated to each group, prices of parts and materials in the Studio are not necessarily market prices and are sometimes substantially discounted. Nevertheless, both the price in the Studio and the market price are indicated to promote the students' awareness on costs.

4.6. Control System

The control system has been changed depending on the technical environment. When this course started in 1990, we adopted a centralized control system, in which A/D and D/A boards were installed on a desktop PC, and the analog output was amplified by a power amplifier to drive an actuator. Then, the joint angle was measured by a potentiometer to feedback to the desktop PC. However, as motor drive circuits developed by students were unreliable and caused a lot of trouble, from 1996, we lent students the TITech Driver [3], which was developed in the authors' laboratory and is now available commercially. Since 2001, we lent the TITechWire [4], a small I/O module with A/D and D/A that can be controlled using a personal computer through a wireless LAN network to enable the control by commonly available notebook PCs. The TITech Driver and the TITech Wire are shown in Fig. 3.

With the recent upgrade and downsizing of processors, since 2009, we have used a control system with microcomputers and the TITech Drivers. In this system, motors are not operated directly with pulse width modulation, but the command is generated as an analog voltage after smoothing in an RC circuit, and then input to the TITech Driver. The purpose of this step is to establish a local servomechanism for position and speed in a motor driver circuit to achieve an open-loop control without complicated programs. In addition, since an analog output can be used as a command, students can conduct operational tests of the servomechanism with the motor driver circuit alone using potentiometers so that debugs and tests can be facilitated. The TITech Drivers are lent to students with connectors in different colors to prevent damage as a result of a wrong connection, and with the power-supply line, including poly switches for overcurrent protection, entirely insulated with silicon resin. Each group can ultimately use four TITech Drivers. For motor driving thatdoes not require servomechanism, H bridge motor driver IC (Toshiba, TA8428K) is recommended.

With the control system using microcomputers, students can develop the control programs at home. This has enabled students to make effective use of their winter vacation during which most of the mechanism is completed

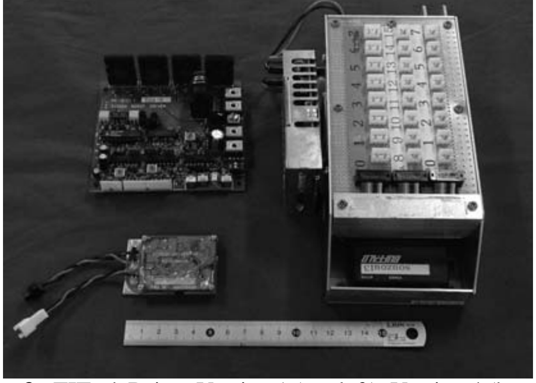

Fig. 3. TITech Driver Version 1 (top left), Version 4 (bottom left) and TITech Wire (right)

to develop software; so, the quality and the level of completion of programs have improved. In addition, collaboration with PC through serial communication has become popular, including use of voice-recognition software on PC and game controllers to obtain the acceleration data.

Similar to mechanical parts, electric parts such as resistors, capacitors, potentiometers, volume controllers, operational amplifiers, transistors, relays, limit switches, connectors, and universal substrates are stocked in adequate quantity on the shelves. Students can freely use them within the limit of their budget.

5. Street Performance Robot Contest

In the 14th week of the course, the street performance robot contest is conducted. Each group makes a presentation and a performance within three minutes, and professors and the audience vote for the most amusing robot to determine the ranking. Each spectator has two ping-pong balls, while each professor has 10 balls. The ranking is presented at the end of the contest by counting the number of votes. There is no restriction for the audience, and anyone can freely observe and vote, but all the secondyear students taking the machine creation course in the following year are required to observe the contest for the purposes of experiencing the atmosphere of the contest as well as for developing their own ideas for next year’s target to be presented in the contest.

Figures 4, 5, and 6 show scenes of the contest in the academic year 2010. Not only robots are decorated to improve the appearance, but presenters also wear costumes to make the presentation more interesting. The robot shown in Fig. 5 in the shape of a cartoon character peels and cuts an apple with its left hand, then pricks and brings it to a person’s mouth with its right hand. According to the students, “this robot is coveted by most students in our university.” Fig. 6 shows a robot playing the violin, and it won the contest. Students devised an easier way to play the violin than human way and succeeded in the performance, using a bow that continues rotating like a belt and changing chords by stopping strings from the side of the neck, and not from above.

There have been a wide variety of robots presented in the past 20 contests, whose functions are roughly classified into the following eight categories. [2] (Examples are provided in parentheses.)

1 Street performance (juggling, spinning a plate).

2 Playing an instrument (guitar, keyboard, violin).

3 Performing a specific function (batting).

4 Replacing people in a certain action (automatic teeth brushing, facial make-up).

5 Cooking and provision of a food or a drink (cooking Chinese noodles).

Fig. 4. Final presentation in front of the audience (Group 9: Animal Golf, 2010)

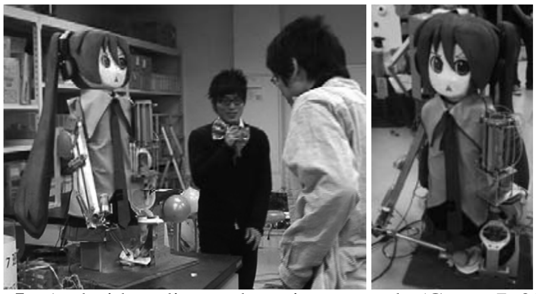

Fig. 5. Android peeling and serving an apple (Group 7, 2010)

Fig. 6. Violin playing robot (Group 5, 2010)

6 Having a game or an interaction with a person (shooting game).

7 Performing in a play with a story (fairy tale, marionette).

8 Collaboration with a video picture (the image actually pops out).

Conversely, even if students create robots according to their unique ideas, most of them are classified into the abovementioned categories, and as a result, there were similar robots in the past. Nevertheless, we think similarity is not a problem unless they are complete imitations. The reason is that since the most important purpose of this contest is the process in which students create an idea, make prototype models, conduct experiments, and find and solve problems on their own, the basis for evalu-

2. The number of robots in each category tends to be almost the same since each group adjusts to avoid overlapping of their presentation contents when ideas are presented in the first review.

ation of this course is essentially different from novelty in academic research.

In this contest, we place importance not on the creation of the world ’s first robots, but on the students ’ first experiences.

6. Results of Questionnaire Distributed to Students

In the last class, we conducted a questionnaire survey. Out of 40 students, 37 students participated in the survey. Questions were mainly on the following four themes: 1) students ’ past experiences in Monodzukuri and projects, 2) methods to operate the course, 3) creativity, and 4) impressions. In this section, we will report on 3) and 4).

6.1. Creativity

Figure 7 shows the questions and results about creativity. According to Q1, 40% answered that the final form of their robots was different from the initial idea. Students who selected “ somewhat different ” or “ very different ” were asked the reason and effect of changing the design, and most of them answered they revised the design downwardly due to restrictions of time and techniques. This shows that they found it difficult to realize their initial idea and had to create new designs. Some students answered it was not necessarily bad to change their designs because they could improve the degree of completion. The authors think that students can develop their creativity in the process to try to make a practical design under diverse restrictions such as time, ability, and costs, and this course provides students with a good opportunity for such experience.

According to Q2 and Q3, 50% answered they were able to exercise their creativity and 70% answered they could become creative, respectively. Since these questions are very ambiguous, if students were asked whether or not they were creative when this course began, they may not be able to concretely understand what “ creativity ”means. However, after the course, 50% of the students actually experienced how to use their creativity, while 70the meaning of “ being creative. ”

The abovementioned results prove that students can develop their creativity through this course.

6.2. Students’ Impressions

Figure 8 shows the students ’ impressions. In Q4, students provided multiple answers concerning what they learned through this course. The answers were in descending order: ‘ project management, ” “ creative design, ”and “ human relations. ” Other answers included the importance to proceed with the work as scheduled and to communicate with other students not only in words but also through sketches or drawing. These answers show that this course was a good training for students to work together with others.

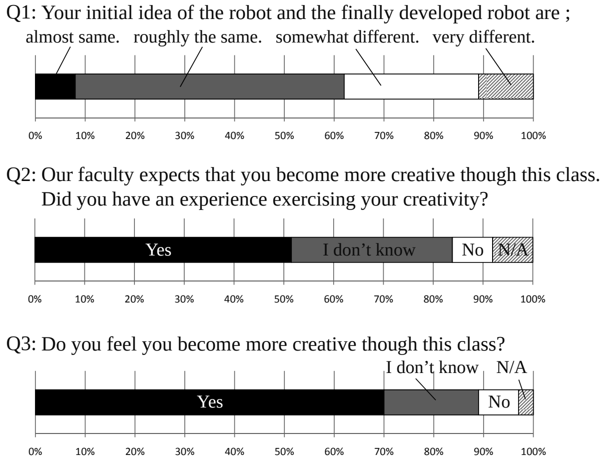

Fig. 7. Questionnaires about creativity

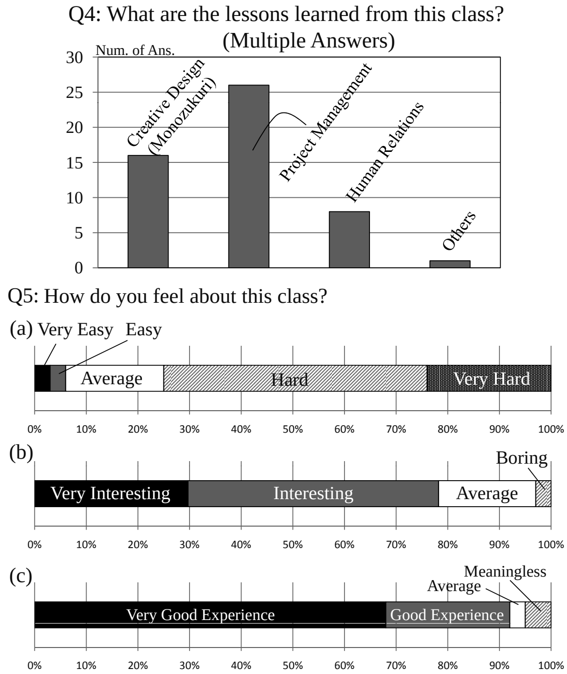

Fig. 8. Questionnaires about impressions of this class

In Q5, students were asked about their impressions of this course from the following three different viewpoints: (a) easy or hard, (b) interesting or not interesting, and (c) good experience or meaningless. As a result, more than 70% answered that this course was hard, while more than 70% answered that it was interesting. In other words, although students experienced many hardships in creating robots, they enjoyed it at the same time. It should be noted that 90% of all students answered that this course was a good experience with a high proportion of those who answered that they enjoyed it. This implies that the course provided students with a fruitful opportunity, including even uninteresting experiences.

Diversity in experiences was also seen in free descriptions at the end of the questionnaire. To the question on what impressed students the most, there were a wide variety of answers such as the favorable response of the audience to performance, a robot malfunction that led to laughter in the presentation, and the successful presentation of the mechanism as the student 's design, which were not necessarily related to the evaluation at the contest. Therefore, compared to the conventional game-type contests in which robots are evaluated only by wins and losses, this contest could provide students with more complex experiences.

Moreover, to the question on the relationship with other students in the course, 80% answered that they could become good friends. Improved communication between students caused a sense of unity in the department. This may be a great benefit for us since students will be more conscious about being an alumnus after graduating from the university.

Finally, students were asked whether or not they would recommend this course to juniors if this course was not compulsory, and more than 80% answered yes. This shows that the course was significant to most students.

7. Summary

This paper introduced the curriculum of creativity education conducted at the Department of Mechano-Aerospace Engineering at the Tokyo Institute of Technology, focusing on the course of " machine creation " aiming at creation of street performance robots to describe its purpose, details in course management, and reports on the contest. In addition, the results of a questionnaire distributed to students undertaken showed that 90responded that the course was a good experience. The future task is to conduct a questionnaire survey of the graduates of our department to examine the validity of this course. Since we have continued this course with the same rules for 20 years, the graduates and their age bracket include engineers in diverse levels from core engineers in companies to new recruits. We find it very interesting to examine the relation between the number of years in work experience and the opinions on this course. We will also review the results of the survey to improve this course further.

Finally, we want to mention the " Robot Grand Prix " hosted by the Robotics and Mechatronics Division of the Japan Society of Mechanical Engineers. Based on the idea that Monodzukuri is an intellectual sport [5], the Grand Prix is held in March every year to popularize Monodzukuri by providing opportunities for children to handle various objects and creatively combine them to develop machines to perform the given functions and also opportunities for the public at large to enjoy watching the games. Inspired by the street robot contest described in this paper, the Grand Prix includes a street performance contest in the program, which has been conducted 13 times as of 2011. Many students from technical colleges and universities, including our university, have participated in the contest and offered great entertainment for the public audience. Please come and join the Robot Grand Prix if you are interested.

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