Development Report:

Joint Education Program Between Technical High School and University for Technical High School Student Through Developing Robots

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[Received February 18, 2011; accepted July 11, 2011]

This report details, in terms of the management and course content, joint projects between technical high schools in Chiba Prefecture, Japan, and a university. The projects were courses that intended to improve, through a wide range of manufacturing activities involving the development of robots, the manufacturing abilities and basic skills as working people of technical high school students. In 2009 and 2010, various high schools and a university ran courses in cooperation, and through questionnaire surveys we discovered the significance of the use of robots as an educational subject of study and learned useful points regarding the course content.

Keywords: Education Program for Technical High School Student through Developing Robots, joint projects between high school and university, Science Partnership Project (SPP)

1. Introduction

Chiba Prefecture, covering the Keiyo Industrial Region on the shores of Tokyo Bay, has many key large, medium, and small manufacturing companies. While the jobs-to-applicants ratio for technical high school graduates is high, Chiba Prefecture has ten courses in eight technical high schools, which is the smallest number in the Greater Tokyo Area, according to school survey conducted by Chiba Prefecture in 2008. About 50% of students of Chiba Technical High School get jobs after graduating [1]. According to a report on technical high school manpower development for manufacturing [2], most companies expect independent, energetic students. The Ministry of Economy, Trade, and Industry advocates basic skills as working people [3], including the "ability to step forward (action)," "ability to think over (thinking)," and "ability to work as team members (teamwork)." These abilities are essential for technical high school students, as getting a job is one of their main options after graduating from school.

As an effort to develop students' basic skills as working people, each technical high school conducts a study of challenges. **Table 1** presents the results of studies conducted in 2009 by technical high schools in Chiba Prefecture. Among them, manufacturing-related fields account for as high as 57.4% of all efforts. However, since those classroom efforts are so limited in scale, they have some problems. For one thing, there are few opportunities to hand techniques down to underclassmen. Also, since it has been difficult for each technical high schools and their staff members to have opportunities to interact with each other frequently due to the location of each schools scattering throughout Chiba Prefecture. Therefore, the efforts to improve the teaching methods in this field must have been depended upon staff member's individual techniques and experience.

For these reasons, teachers of those high schools have wanted to provide an education program in collaboration with other high schools to improve the students' "manufacturing techniques" and to encourage them to acquire the necessary skills as working people. To realize such a program, the following issues have to be solved:

- Learning activities in all the technical high schools had to be developed, and differences in the level of manufacturing between the various technical high schools have to be considered.

- Since the courses in the program are relatively short due to limitations of time and space, the students have to be provided with individual, developmental efforts even after the course is finished.
  When selecting the content for the education program, importance is placed on the interests of the students and their sense of fulfillment after the course is finished. Such importance is also emphasized in an activity report [2] on work experience, which was provided to technical high school students in Chiba Prefecture from 2007 to 2010 in an effort to develop their motivation to work, energy for action, and sense of cooperation. There have been many examples of efforts to improve manufacturing techniques together with fostering interest and sense of fulfill-

Table 1. Study of challenge in 2009.

Study of Challenge		Number of Schools
Manufacturing-related fields 57.4 [%]	Design and manufacture of three-phase induction motors	5
	Design and manufacture of transformers	5
	Design and manufacture of electric vehicles	3
	Design and manufacture of arm robots	8
	Design and manufacture of electric bulletin boards	3
	Design and manufacture utilizing microcomputers	6
	Design and manufacture of three-phase linear motor cars	2
	Design and manufacture of elevators	4
	Design and manufacture of solar cars	3
Control practices 16.2 [%]	Control of electric motors by personal computers	4
	Control of power-supply voltages by temperature	4
	Control of room temperature	1
	Manufacture and control of automatic doors	2
Environment and various studies 26.4 [%]	Design and manufacture of wind power generators	3
	Study of photovoltaic power generation	5
	Study of fuel cells	2
	Others metering experiment	8

ment, such as many educational programs utilizing robots and mechatronics equipment, as reported in [4–6]. We assume that the following conditions satisfy the aforementioned criteria and select robots as the subject of study.

- The field of robots is interdisciplinary, including the mechanical, electric, and information fields. Selecting robots as the educational subject of study enables even the same subject to meet various areas of specialization of the students.
- Even if some students are not good at some of the fields, the use of template materials ensures them at least a minimum level of robot manufacturing, i.e., at least they can make the robots move. However, improving the movement requires advanced knowledge of each field, thereby allowing each student to enjoy a sense of accomplishment at his/her own level.
- Robot components are widely available, from the manual training level to the research institute level.

Using other successful examples in improving manufacturing techniques as a reference, this course encourages all the technical high schools in Chiba Prefecture in cooperation to improve manufacturing the technical abilities of technical high school students and to provide them with basic skills as working people. While many other efforts have been made by individual organizations, this course is the first attempt for all the technical high schools in Chiba Prefecture to work together and for technical high school students with a similar sense of purpose to take the course together.

Besides the technical high schools, a university is included in the collaboration because of its education and research in advanced, specialized content areas that are not taught in high schools. More specifically, the Chiba Institute of Technology was selected for its location, which makes it easy for technical high school students in Chiba Prefecture to attend, and for its dedicated faculty for robotics. The university is one of the universities that signed an agreement with high schools in order to promote technical education in Chiba Prefecture. This report includes a course of joint projects between high schools and a university through developing robots in 2009 and 2010.

2. Planning and Managing

For ten courses in the eight technical high schools in Chiba Prefecture to plan and manage a new project in cooperation involves organizational ability in addition to physical expenses, such as material costs, personnel costs including the salaries of lecturers, and other costs such as preparation of advanced course content not provided in the high schools and the verification of course results. To solve the problem of physical expenses, we utilized the Science Partnership Project [7] (SPP), supported by the Japan Science and Technology Agency. To solve the problem of personnel and other costs, we commissioned the Chiba Institute of Technology to plan and prepare the course content. In terms of organization, we utilized the organizational abilities of the Robot Competition Executive Committee of the Chiba Prefecture High School Technical Education Research Group and the Promotion Committee for Joint Projects between Technical High Schools and Universities in Chiba Prefecture.

SPP supports courses that meet the following conditions: schools, universities, and science museums conduct the courses in collaboration; the course content is intended to develop the interests and curiosities of students; and experiential, problem-solving learning activities are provided. In most cases, schools, universities, and science museums apply the SPP on a one-to-one cooperation basis, such as one school with one university or one school with one science museum. From 2006 to 2009, no technical high schools throughout the prefecture

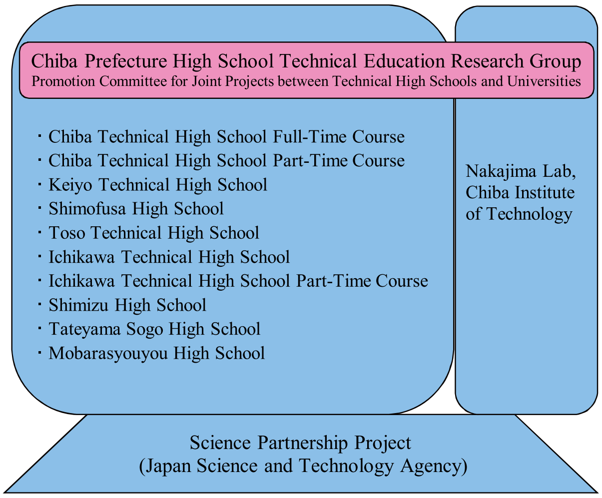

Fig. 1. Organization chart of robot education course of joint projects between high school and university.

conducted SPP courses in cooperation with universities. Since application under the name of the Robot Competition Executive Committee was not accepted, one main, representative school applied for the SPP under the condition that it conduct the course in cooperation with all the technical high schools in Chiba Prefecture. Through the Promotion Committee for Joint Projects between Technical High Schools and Universities, the technical high schools cooperated with the Nakajima Lab of the Department of Advanced Robotics, Chiba Institute of Technology. **Fig. 1** is a management organization chart of this course. Sufficiently utilizing an existing organization, the education program was successfully managed in cooperation with many organizations.

3. Course Content

This course, targeting mainly technical high school students who get jobs after finishing high school, has the following goals:

1. To improve the manufacturing abilities of technical high school students
2. To give them the basic skills as working people

To achieve the first goal, as seen in reference [4], the course was prepared so that the students could feel a sense of accomplishment during the manufacturing process. To achieve the second goal, group development processes such as discussion and joint development were prepared for the manufacturing process. As practiced in reference [8], this course intends to achieve those goals by using a robot as a subject of study. Robot development requires a wide range of course content, and the level of the course can be set appropriately. Robot development is an excellent subject of study for the following reasons:

- The field of robotics is interdisciplinary, including the mechanical, electronic, and information fields, thereby giving the students a chance to come in contact with a wide variety of technical fields.
- To fuse the three fields, the developers need to communicate during the development process.
- Since the parts to be developed by the students are simplified by being kitted or modularized, students at any level can handle the entire manufacturing process, including planning, developing, and operation testing.

Through discussions on the course contents, high school teachers and university teachers agreed that the program should be conscious of the following so that the course goals may be achieved:

- Introductory education: getting the students interested in robots to motivate them to attend the course.
- Robot element technology education: teaching the students the elements of robot technology, such as microcomputers, sensors, measuring techniques, and programming. Lectures and practice session will be given in combination to increase their effectiveness.
- Task setting: giving students tasks to work on between class sessions to facilitate their independent activities.
- Communication improvement activity: giving students opportunities to make presentations to all their peers to improve their communication skills through group discussions and Q&A sessions.

The course content was designed to include the above in each class of the course. In addition, it was decided that there would always be a teaching assistant (TA) standing by to help students at any level of practice. Specific course content is described below.

3.1. 2009 Course

Title: Manufacturing Course through Robot Development

Application contents: Manufacture of an SPP-dedicated microcomputer board and a biped walking robot

Teachers and TAs: Six in total (one university professor and five TAs)

Target students: Total of 30 persons, i.e., one teacher and two students from each of the ten courses in the eight technical high schools in Chiba Prefecture

Course length: Four days (16 hours in total)

Total budget: JPY 2M

Syllabus:

<First day, 23 July 2009> (Four hours)

(Introductory instruction) Students' interest in leading-edge robot technology is built up through lectures on the history of robots in Japan, the current state of the field of robots, robotics related to uneven ground location, ideas

Fig. 2. Research robot operation experience.

Fig. 3. Educational support by TA.

required for robotics, and the differences between internal sensor information and external sensor information. After demonstration of an rough terrain robot RT-Mover, the students experience its operation (**Fig. 2**), thereby increasing their motivation to learn.

(Robot element technology education) Components needed to manufacture a microcomputer board developed for this course are distributed so that the students may practice soldering IC sockets, various connecter pins, etc. A biped walking robot with combined servomotors is presented, and a lecture is given on the operating voltage of the battery and other topics.

(Task setting) The students are asked to manufacture the microcomputer board before the next class with distributed handouts for reference. They are also asked to assemble a biped walking robot and program its operations by the final class in preparation for a competition of biped walking robots in the final class.

<Second Day, 8 September 2009> (Four hours)

(Introductory instruction) A lecture is given on the basic concept of a robot that "senses situations and, based on information, sets its actions and operates." As specific examples, color information, the presence/absence of lines, switch input, and others are used to demonstrate actual examples of motor control and sound emissions based on the sensed input information.

(Instruction on the elements of robot technology) Using the microcomputer boards they manufactured for the task, students gain basic knowledge of things such as the connection of input/output devices, and they practice writing a program in the microcomputer board. Since some students take longer than others to complete the practice, the TAs provide careful support (**Fig. 3**).

(Task setting) As a task to be completed before the next class, the students manufacture a color sensor board and an acceleration sensor circuit board with distributed handouts for reference.

< Third day, 1 October 2009> (Four hours)

(Introductory instruction) A lecture on sensors is given on external sensors, which can gather information with-

Fig. 4. Microcomputer board, 2009.

out touching an object, and internal sensors, which easily extract necessary information.

(Robot element technology education) A lecture on the principles of sensors is given with a PSD sensor and a color sensor as examples of external sensors and a rotary encoder and acceleration sensor as examples of internal sensors. A lecture on basic programming of microcomputers is given and the students practice acquiring data from the sensors using the microcomputer board.

(Task setting) The following two tasks are given to be completed by the next class:

Producing a robot which utilizes the manufactured microcomputer board and preparing a presentation on related learning

Writing an operation program for a simple competition using a biped walking robot kit.

<Fourth day, 29 October 2009> (Four hours)

(Presentation improvement activity) The students make presentations on their achievements in the course. The presentation has two parts. In the first half, the students give presentations on the robot they manufactured using the microcomputer board for each school.

In the second half, a competition is held for the assembled biped walking robots. There is plenty of time for not only asking the teachers and TAs questions but also for questions and answers between the students. In the second half, the atmosphere around the table is particu-

Table 2. Questionnaire results from the students after finishing the 2009 course.

Q1. Interest in SPP course	Number of persons	Percentage [%]
Enjoyable	17	85
Rather enjoyable	2	10
Ordinary	1	5
Not Enjoyable	0	0
Q2. Level of understanding of the course contents		
Understood	4	20
Basically understood	12	60
Not well understood	4	20
Not understood	0	0
Q3. Change in interest towards manufacturing		
Increased after attending the course	9	45
Not changed because I already had an interest before the course	5	25
Became interested because of the course	6	30
Not interested	0	0
Q4. Motivation for independent learning		
Increased after attending the course	6	30
Not changed because I was already motivated before the course	6	30
Became motivated because of the course	7	35
Not motivated before or after attending the course	1	5
Q5. Acquisition of ability to gather and utilize information		
Acquired well	4	20
Acquired a little	10	50
Not acquired much	6	30
Not acquired at all	0	0
Q6. Acquisition of a method and ability to find tasks independently		
Acquired well	2	10
Acquired a little	15	75
Not acquired much	4	20
Not acquired at all	0	0
Q7. Acquisition of presentation skills		
Acquired well	1	5
Acquired a little	11	55
Not acquired much	8	40
Not acquired at all	0	0

Q8. Did attending the course make you want to be engaged in a manufacturing job in the future?	Number of persons	Percentage [%]
I want to more than I did before attending the course	7	35
I want to as much as I did before attending the course	6	30
I want to now even though I had not thought of it before attending the course	4	20
I did not want to before or after attending the course	3	15

Q9. Path after graduation from high school	Before the course	Percentage [%]	After the course	Percentage [%]
University	4	20	7	35
Vocational technical school	7	35	5	25
Work	7	35	7	35
Not decided	2	10	1	10

Q10. Did you find university students' opinions helpful in selecting your path?	Number of persons	Percentage [%]
Found them very helpful	8	40
Found them somewhat helpful	7	35
Found them not so helpful	4	20
Did not refer to them	1	5
Q11. Do you want to participate in a similar course?		
Very much so	14	70
A little	5	25
Not much	1	5
I do not want to participate	0	0

Comments by the students who attended the course.
It was my first experience with a biped walking robot, and I became more interested in them.
Presentation was really tough, but it was a good experience for me.
I talked with university students about my path. It was good to participate.
I had difficulty in embedded development but now it is possible thanks to SPP.
My programming technique improved. I will keep learning.
University students taught us very well.
I got very interested in microcomputer control.
I came to understand the definition and mechanism of robots.
I came to understand sensors.
I learned a lot from the tough tasks in each class.
I found it difficult to give a presentation to students from other schools.

larly free when the competition is being held. This facilitates the exchange of information and know-how among all concerned.

Development teaching materials: **Fig. 4** presents the small-sized microcomputer board for educational purposes newly developed for this course. The students operate various sensors and motors using the H8 microcomputer and learn the principles and uses of the microcomputer through this board. Various template programs are enclosed for them to try out and learn. The board's specifications allow the students to try various functions of the microcomputer so that they can continue to learn about it even after the course is finished.

Summary and evaluation for 2009: **Fig. 5** shows the presentations made in the final class. The left is the presentation in the first half and the right is the competition in the second half. Each school made its own unique idea reality and analyzed data in ingenious ways. The students, the TAs, and the teachers exchanged their views actively to develop the students' communication skills.

The teachers and the TAs evaluated the presentations and gave specific suggestions for improvement, thereby developing the students' curiosity and interest in manufacturing robots. At the end, high schools that had put forward the best efforts were awarded, thereby increasing their motivation. **Fig. 6** shows the students after finishing the course.

Table 2 presents the results of the questionnaire the students filled out after finishing the course.

Table 2 indicates that implementation of the course on robots improved the students' attitude toward independent learning while collaborating with others. They talked with university students, thereby making them think of entering university after graduating from high school. As indicated in **Table 2**, about 95% of the students wanted to take the course again. **Table 2** also indicates that some students failed to improve their presentation skills, including explanation their ideas to others in an easy-to-understand manner and their ability to identify and solve problems. The TAs answered in open-ended questionnaires that the following points were important in teaching high school students in an easy-to-understand manner.

Fig. 5. Presentation of achievements.

Fig. 6. Students after finishing the course.

- Giving explanations in an elaborative, theoretical manner
- Having active discussions
- Securing a sure understanding of the basics and then advancing step by step

3.2. 2010 Course

In the wake of the 2009 implementation, the students and teachers strongly requested that the course be run again in 2010. Therefore, the same basic content was kept intact, but the following points were taken into consideration in light of problems experienced in 2009.

- **Table 1** indicates that the improvement of the students' basic skills as working people, one of the goals of this course, was not successfully achieved. Each class was therefore given for a whole day, instead of the half day it was given in 2009. This ensured sufficient time for the students to discuss and consider the content in each session of the course.
- In project-based education, content that advances step by step has the maximum educational effect. Therefore, the classes this time made the students "think about robots" more than they did the first time. The students' comments in **Table 1** indicate a lack of appropriate difficulty that stimulates their motivation. Accordingly, the syllabus for 2010 includes introductory instruction that handles the "existence of theories behind robot operations" and the "necessity of sensor data processing based on a data sheet that leads to accurate control."
- An e-mail-based contact system was arranged so that the high school students could solve problems by asking the teachers and TAs questions even outside of class hours (**Fig. 7**).

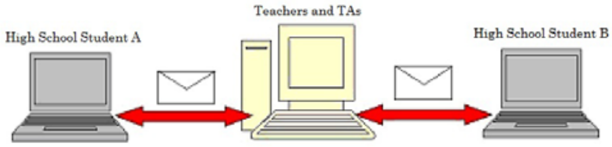

Fig. 7. Efforts to solve problems.

To maximize the feature of the robot development course that allows levels to be set in accordance with individual situations, a support system in accordance with the level of understanding of each student is necessary. The robot development course may include homework, so e-mail is useful because it does not have the limitations of place and time, and messages can be exchanged individually. Since the robot development course has a wide range of goal-setting to allow the students to feel a sense of accomplishment, the students often work on advance content even after the course is finished, depending on their interests. In such cases as well, a support system is important and e-mail is useful because it is free of the limitations described above.

Specific course content is described below.

Title: Manufacturing through Sensor Technologies

Application contents: Application of microcomputer control and production of an autonomous robot

Teachers and TAs: 12 in total (one university teacher, five TAs, and six TA assistants)

Target students: Total of 35 persons, i.e., about one teacher and about two students from each of the ten courses in the eight technical high schools in Chiba Prefecture

Course length: Three days (24 hours)

Total budget: JPY 2M

Syllabus:

<First day, 7 September 2010> (Eight hours)

(Introductory instruction) An introductory lecture on robots is given, including the current state of leading-edge robot research and development and some of the theories on which robot operations are based. A demonstration of the leading-edge robots being researched at universities helps the students picture the future of robots that are subjects of the course, thereby increasing their motivation. An autonomous mobile robot using the microcomputer board used in this course is demonstrated to present a model robot. In addition, an autonomous integration of the biped walking robot with sensors that was used in the 2009 course is demonstrated also to present a model biped walking robot. That is, by presenting "good examples," the students are encouraged to make independent efforts.

(Robot element technology education) A set of components of the microcomputer board to be developed are

Fig. 8. Task presentation session.

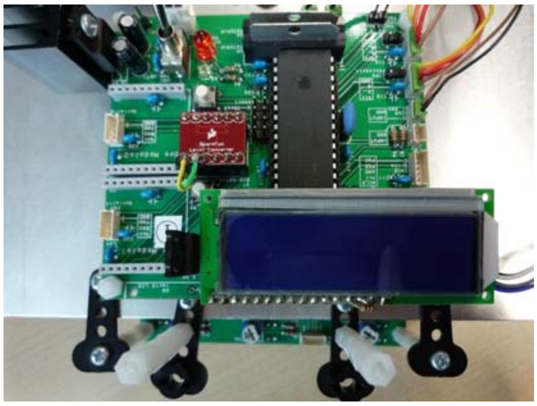

Fig. 9. 2010 microcomputer board.

distributed, and information necessary for manufacturing is presented. Trigger knowledge to successfully produce an autonomous biped walking robot is also presented so that the students may learn independently later.

(Communication improvement activity) Methods of utilization of the microcomputer board to be developed are discussed by each high school, and preferences regarding the course content and the content of the achievement presentations that take place in the final class are planned, including their schedules. Then, the high schools give a presentation on what they will work on and what they will present in the achievement presentations, and they also exchange information.

(Task setting) The students manufacture the microcomputer board before the next class, using distributed handouts for reference.

<Second day, 5 October 2010> (Eight hours)

(Robot element technology education) A lecture is given on components, such as various sensors to be connected to the microcomputer board: encoders, switches, LCD monitors, LEDs, and motor drivers. The students have a practice session on the development of control software for the microcomputer. In addition, they learn the rotation mechanism of motors and learn how microcomputers control the rotation of motors.

(Communication improvement activity) At the beginning of the course, the students give presentations on how the tasks they have worked on so far are going (**Fig. 8**) to share questions that arise during the manufacturing process of the microcomputer board. At the end of the day, the students review past efforts and newly learned content, discuss by high school the reviewed plan of achievement presentation given in the final class, and give presentations to other students.

(Task setting) The students manufacture a robot that utilizes the microcomputer board before the next achievement presentation.

<Third day, 4 November 2010> (Eight hours)

(Introduction education) A lecture is given using a measurement device, explaining that data obtained by a sensor can be accurately measured by processing based on a data sheet. With an example of a PSD sensor data sheet, the explanation is given that reading data sheets requires an understanding of logic.

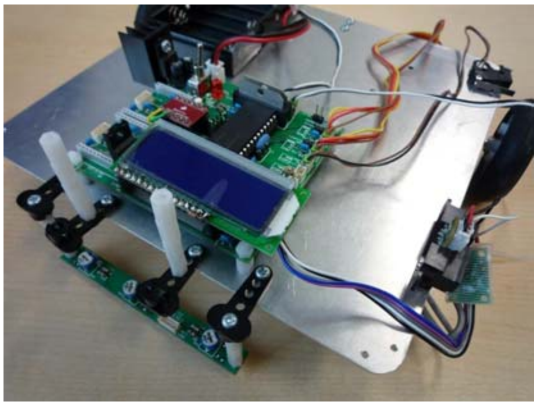

Fig. 10. Line tracing car robot.

(Robot element technology education) The students work on creating software for data processing and measuring the PSD sensor connected to the microcomputer board.

(Communication improvement activity) An achievement presentation is given on a robot using the manufactured microcomputer board. Some high schools give a presentation on an autonomous biped walking robot.

Development teaching materials: **Fig. 9** presents a small microcomputer board for educational purposes newly developed in 2010. Its main functions are to actuate the robot, such as its sensors and motors, using the dsPIC30F3014. This board includes sensor and motor interface circuits necessary for a line tracing car robot. For motivated students, functions can be extended, such as adding wireless communication. A template program of each function is enclosed for further advancement after the course. **Fig. 10** shows a line tracing car robot using the microcomputer board.

Summary and evaluation of 2010: The students are encouraged to “think” by setting tasks for which they independently set measurement conditions and conduct experiments. To provide an opportunity to improve communication skills, which was an issue in 2009, we set presentations on efforts made during each session, such

Table 3. Results of student questionnaire after the 2010 course.

Q1. Interest in SPP course	Number of persons	Percentage [%]
Enjoyable	13	56.5
Rather enjoyable	7	30.4
Ordinary	3	13
Not enjoyable	0	0
Q2. Level of understanding of the course contents		
Understood	3	13
Basically understood	12	52.2
Not well understood	8	34.8
Not Understood	0	0
Q3. Change in interest towards manufacturing		
Increased after attending the course	11	47.8
Not changed because I already had an interest before the course	9	39.1
Got interested because of the course	3	13
Not interested	0	0
Q4. Motivation for independent learning		
Increased after attending the course	11	47.8
Not changed because I was already motivated before the course	8	34.8
Got motivated because of the course	4	17.4
Not motivated before or after attending the course	0	0
Q5. Acquisition of the ability to gather and utilize Information		
Acquired well	5	21.7
Acquired a little	11	47.8
Not acquired much	7	30.4
Not acquired at all	0	0

Q6. Were you able to actively cooperate with others?	Number of persons	Percentage [%]
I was able to cooperate a lot	11	47.8
I was able to cooperate a little	10	43.5
I did not cooperate so much	2	8.7
I did not cooperate at all	0	0
Q7. Acquisition of presentation skills		
Acquired a lot	13	56.5
Acquired a little	9	39.1
Not acquired much	1	4.4
Not acquired at all	0	0
Q8. Do you want to participate in a similar course?		
I want to participate very much	10	43.5
I want to participate a little	12	52.2
I don't care one way or the other	1	4.4
I do not want to participate	0	0
Comments by the students who attended the course.		
I successfully applied the board to the line tracing car.		
I cooperated with others because I could not handle the course contents by myself.		
The course content was more advanced than that last year, but I cooperated with others.		
I will do my best to produce an autonomous robot.		
I had difficulty because the course included things other than manufacturing based simply on circuit diagrams.		
It was good to have university students teach me various things via e-mail.		
The three presentations gave me self-confidence.		
I was able to study by myself using a standard list and so on as a reference.		
I want to make a larger robot.		
I regret that I was not able to make the target robot. I want to complete it.		
I want to work on wireless via serial communication.		

Fig. 11. Achievement presentation.

as presentations summarizing what they learned based on the obtained measurement data, presentations on progress towards the final presentation, and the final presentation. After each presentation, time for questions and answers was provided, so that the students, the TAs, and the teachers could exchange their ideas. **Fig. 11** shows an achievement presentation. **Table 3** presents the results of a student questionnaire conducted after the course ended.

Table 3 indicates that about 95% of the students want to attend the course again, and it also indicates that interest in manufacturing and motivation to learn increased. About 95% of the students replied that their presentation skills improved and about 91% of the students replied that they were able to actively cooperate with others. As a result, their basic skills as working people improved.

On the other hand, about 30% of the students failed to improve their level of understanding of the course content or their ability to utilize information. Some comments indicate their attitudes towards working on content developed by them based on the course content. This can be regarded as the beginning of an attitude of "thinking" through advanced course content.

4. Summary and Evaluation of Robot Education Course After Two Years

After the course was implemented in the first year, the technical high school students showed and increase in interest in manufacturing and improved their attitude toward working on manufacturing independently, compared with before the course was implemented (**Table 2**, Q3 and Q4). However, they were lacking in the ability to give easy-to-understand, logical explanations of their thoughts to other students, the TAs, and the teachers. Therefore, the course in the second year included a reporting session for each class to give presentations on their experiences to the other students, thereby significantly improving their basic skills as working people (**Table 3**, Q4 to Q7). We only provided a minimum of knowledge on the new microcomputer board so that the students would make an effort to build the course by themselves. As a result, they developed an attitude favoring independent learning (**Table 3**, Q4, Q6, and comments). Meanwhile, it became essential

Table 4. Answers given on questionnaire by the high school teachers after the course was finished.

Comments by the high school teachers
The students made an effort to finish their work through processing aluminium boards.
Although they had little knowledge of electronics, they worked hard on it.
It was good to enter the general technology competition using the SPP board.
They examined data sheets and circuit diagrams after class.
Through the course, they learned difficulty and depth of making robots.
E-mail-based supports by university students was very good.
They were motivated to work on C language programming.
I want to use the board as a basic experiment board at the school.
They had good communication with the TAs.
There were differences between the students in the amount of knowledge, and the teachers were also the same situation.
Presentation was very good. Advice from the teachers and the TAs was also good.
Such courses tend to give unidirectional lectures, but it is good this course did not do so.

for the teachers to be actively involved in the students' progress and to give them advice in order to improve their ways of thinking and encourage activities.

Table 4 presents a summary of high school teachers' answers to an open-ended questionnaire on the second year of the robot education course.

Table 4 indicates that this course has the following features:

- The syllabus covers a wide range of content, such as machining including aluminium board machining, electronic circuits, and programming.
- The students at all levels in each field have come to apply themselves to learn the contents.
- Practice sessions give rise to interaction between the students and the TAs, thereby providing opportunities for discussion.
- The students have attempted to develop theoretical control based on data sheets.

Those effects are likely because of the selection of robots as a subject of the course. That is, the field of robots is a general technology including the mechanical, electric, and information fields. Depending on the scale of the robots developed, the field of robots gives the students opportunities to apply themselves according to their level and to set tasks that bring a sense of accomplishment. In addition, the process of actually operating the robots and troubleshooting causes the students to collaborate and interact with the TAs in the practice sessions. As they operate the robots, they increase their understanding and begin to become conscious of the theoretical background.

On the other hand, those students who are not good at independent work should not choose the subject on robots that provide a great degree of freedom for study.

We implemented the course on robot development for technical high school students for two years and analyzed a part of features of a course focusing on robots.

Table 5. Questionnaire results on utilization of microcomputer board after course (Target: Ten courses in the eight technical high schools).

How to utilize the microcomputer board
A study of challenge : Theme Study of microcomputer board The same theme by two schools
A study of challenge : Production of line tracing car
A study of challenge : Production of security device
Club activity : Utilized by an electric invention club as research material
Club activity : Utilized by a computer technology research club
Club activity : Utilized by a computer club as experiment material
Participated in general technology competition The same by three schools

4.1. Effects of Organized Course of Education Focusing on Robots

This course was organized in collaboration with all the technical high schools in Chiba Prefecture. The development from the efforts made in this course can be spread around all the technical high schools in Chiba Prefecture.

Table 5 summarizes the utilization of the microcomputer board by the high schools after the implementation of the course. The participating students were back in their own high schools, utilizing knowledge they acquired through this course to actively carry out activities in clubs they belonged to. They utilized the microcomputer board to research issues, and while they learned independently, they taught others, passing on the techniques learned to students who had not been able to participate in the course. Some of them are motivated to keep studying the microcomputer board via e-mail with the TAs even after they finished the course.

Their questions were often about content, most of which was related to programming and the components used in the microcomputer board, which was beyond the knowledge of the high school teachers. Some of the replies had images and programs attached, which indicates that the e-mail functions sufficiently. As shown above, the course improves manufacturing techniques of Chiba Prefecture's technical high schools as a whole.

In the robot competition section of the general technology competition held by the Chiba Prefecture Education Committee and Chiba Prefecture High School Technical Education Research Group, a new competition using the biped walking robots manufactured in this course was held. In the line tracing car section, a team using the microcomputer board manufactured in this course performed well (**Fig. 12**).

The above development is an effect of the setup of an inter-organizational course, such as this course.

5. Conclusion

This report has focused on the management and course content of a project-based course of education centered on developing robots and involving cooperation between technical high schools in Chiba Prefecture and a univer-

Fig. 12. General technology competition.

sity. Targeting technical high school students, the objective of the course was the improvement of the students' manufacturing abilities and basic skills as working people through manufacturing activities. The implementation of the course in collaboration with several high schools and a university 2009 and 2010 taught us the significance of the use of robots as a subject of study as well as specific points in terms of course content, which we learned through questionnaire surveys. We have also gotten an understanding of the actual effects of conducting the multi-organizational education program.

Lastly, high school teachers and staff members who brought the students were provided with an opportunity for advanced training. Learning the abilities of students and instructional methods of other schools as allowed them to objectively understand the current level and instruction of their own schools, thereby improving the instructional abilities of the teachers and staff members.

We have reported on the implementation of this course to the regional technology education center chief conference held by the Chiba Prefecture Education Committee, City of Chiba Education Research Group, and City of Ichihara Education Research Group, which target the industrial arts and home economics staffs of junior high schools, thereby producing a record of the activities of technical high schools in Chiba Prefecture.

Acknowledgements

This effort was funded for two years under the framework of the Science Partnership Project of the Japan Science and Technology Agency. We would like to express our gratitude to the parties concerned.

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