Science and mathematics education using robot simulations

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Abstract - We have developed four courses using special teaching materials, taking advantage of simulation experiments, and using game-like procedures with modern technologies to help students in primary and junior high schools understand science and mathematics and to augment their interest in these disciplines. These are based on commonly observed phenomena: (1) experiments help students feel and understand laws and principles of science and mathematics, and (2) amazing game-like operations often provide students with interest in these disciplines. We found that consecutive classes of these four courses in a short period promote their performance. For development, we have produced robots that simulate scientific experiments and perform game-like operations. Additionally, we have conducted experimental classes in primary and junior high schools to place our materials at the disposal of schools and to improve the materials by doing so. This research has been conducted under the auspices of Science Partnership Projects (SPP, a public research project) of the Japan Science and Technology Agency, an independent administrative institution.

Keywords: young students' aversion to science, robot, education, game

1. INTRODUCTION

We can recognize and appreciate recent developments in electronic devices, appliances, and vehicles that have been achieved through rapid development of microprocessors making full use of technologies of communication and control. Those technologies have transformed capabilities of mechanisms and electromechanical parts and have allowed them to mature over the years into higher systems. Consequently, boosted by growing human technology, great innovation has occurred in human–machine interfaces. In particular, remarkable innovations have been made in semiconductor and electronic parts. Hierarchical hardware and software mechanisms in conjunction with product development and computer aided design (CAD) systems have worked together effectively. Systems in product development are structured hierarchically and virtualized. Complicated products incorporating various technologies can be realized rapidly. That virtualization technology is indispensable in modern product and system development. Although that technology is a key in those endeavors, we only slightly recognize its exciting nature [1].

Students of the younger generation are moving away from exploration of science, perhaps because of virtualization technology. Although students of primary and junior high schools enjoy and resort to the convenience that products made using virtualization technology provide them, they might not be interested in overly complicated products themselves. Showing them the inside of a complicated product might be effective to help them become interested in science and related technologies, but we have not taken that road in this research. Instead, we have invented a course providing them simulation experiments using robots. The experiments, although not very spectacular, can be repeated at any time and can therefore offer students game-like fun. Consequently, we have sought to help them feel and know the laws and principles of science and mathematics. Our four courses are equipped with features of both simulation and game-like fun realized using robots.

2. PEDAGOGICAL CONSIDERATIONS

The trend of young people moving away from science has neither been defined clearly nor investigated sufficiently as a problem of elementary education systems in Japan. Although the importance of experiments in courses teaching science has been emphasized as a countermeasure against that trend, it has never been overlooked [2]. Not all problems in education are attributable to those of elementary education. We might think of three measures to settle any problem. The first is to remove the cause of the problem if found, the second is to alleviate problems irrespective of the knowledge of their causes. The third is to do nothing. We have taken the second option to activate science education.

The methodology of edutainment, with instruction accompanied by entertaining elements, was introduced long ago to enlighten and educate the public; in 1970, it was incorporated into radio programs. Such efforts are based on the idea that games enrich education [3][4]. We can imagine education-giving robots of three types. The first is a robot contest, in which students compete with their own developed robots. In this type of activity, students learn many techniques and skills in developing robots that might work. They acquire, along the way, better capabilities of working together. Then, the second is a course using robots where students learn the dynamics of robot behavior by watching them and learning further general knowledge and theory [5]. Finally in the third type, students learn with robots or robots teach them. Their robots become their friends and partners [6].

3. DEVELOPMENT OF TEACHING ROBOTS

We have developed four robots for courses in primary and junior high schools and tested them in experimental classes as activities of Science Partnership Projects (SPP) [7] of Japan Science and Technology Agency, an Independent Administrative Institution. Four robots are an Imagine car of the future robot (FUTURE VEHICLE), a SUMO ROBOT, a Parabola-throwing bio-pitcher (BIO PITCHER), and a MATH ROBOT. Features of these robots are presented in Table 1.

Table 1: Education programs using Robots

	FUTURE VEHICHLE	SUMO ROBOT	BIO PITCHER	MATH ROBOTE
Educational merit in science and mathematics	very small	small	medium	large
Teaching skills using game-like procedures	large	medium	small	very small

Table1 shows the ratio of the element.
large > medium > small > very small

In the table, the row of “educational merit in science and mathematics” expresses the educational performance of each robot in illustrating or teaching laws and principles of science and mathematics. The next row of “teaching skills by game-like procedures” expresses how each robot teaches skills involved in these disciplines in a game-like environment. These four robots contained the element of “educational merit in science and mathematics” and” teaching skills by game-like procedures” though it did not intend. “Bioloid Beginner Kit” [8] and “ROBOBUILDER” [9] were used for our experiments.

3.1 FUTURE VEHICLE

This is a robot simulation automobile that is very familiar to students. Safety devices embedded in automobiles are crucial for the eventual implementation of safe cars. The central technology in them is automatic control using microprocessors. We have developed a robot that can stop immediately before colliding with a wall or a human. Such devices for real automobiles are under development [10] and will soon be mounted in them. Our robot is hoped to help students understand the future automobile we are anticipating. Figs. 1 and 2 depict the concept of our robot.

The robot is equipped with an obstacle-avoidance mechanism. Its sensor unit has an infrared transceiver module. Working together with these supportive devices, the PC maneuvers the robot through Zig-Bee communication. Students might simulate a driving situation, operating a PC by watching a picture transmitted from the camera mounted on the robot head. This driving simulation provides them with various effective edutainment, teaching safe driving techniques through two robots racing for example. This robot is intended to introduce sensor and control technology.

The first goal of the course using the “FUTURE VEHICLE” is to help students learn the outline of infrared communication that is widely used in our electric appliances, such as the remote controller for a TV set. Students therefore understand that they are relying on invisible light rays. The second is to learn a method to develop automobiles that might forestall collision by themselves. Students are asked to tune their robot vehicles equipped with obstacle avoidance mechanisms and a sensor unit that has not been adjusted properly yet. Third, students experience car racing and learn how to avoid accidents. Figure 3 shows the class scenery in the primary school.

Figure 1: Configurations of future vehicles.

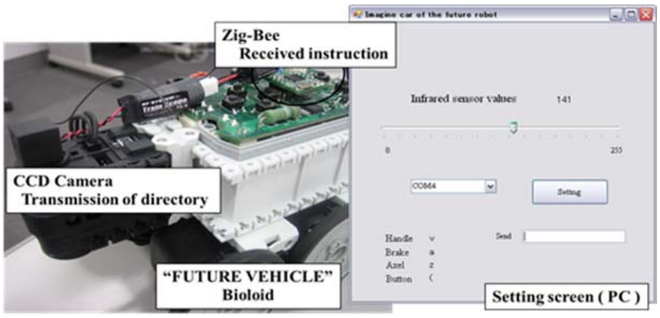

Figure 2: Configurations of future vehicles.

Figure 3: Air of the lecture [11]

3.2 SUMO ROBOT

Students often encounter robots, enjoying animated movies, for example. Such robots typically move exactly as human beings and their performance often outpaces that of human beings. However, practical robots perform only a few functions. Using this robot, we expect students to understand whether robots can move exactly as human beings. Students are asked to discuss that after manipulating the robot we prepared for them.

For this robot, we used “ROBOBUILDER”, which walks with two legs and which can be maneuvered by students quite easily. “ROBOBUILDER” can memorize any movement of the body (motion), if one gives any motion to it using one’s hand. This procedure is designated as “making a motion.” Figure 4 shows the PC display when this is being performed.

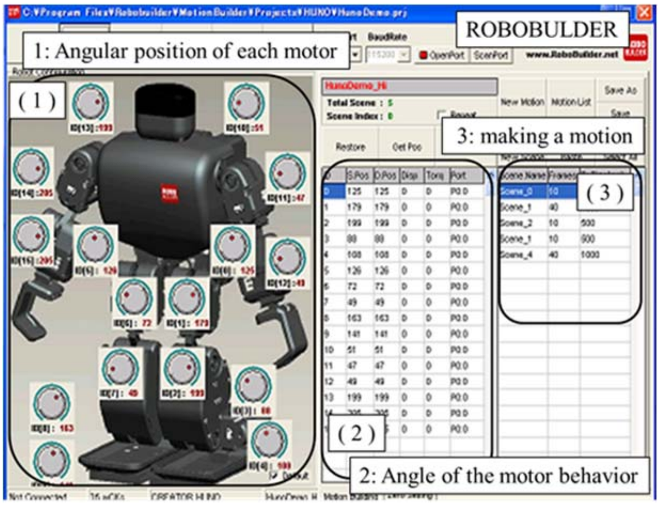

Figure 4: Sumo robot’s programming motions on display.

The first goal of this Sumo robot is to make students recognize the difference of movements between those of robots and human beings. Students learn about the low visibility and poor maneuverability of robots and their difficulties in balancing. They then try to teach the robot some jujitsu moves (sumo wrestling). Meanwhile, they recognize the mobility and flexibility of human muscles. The second is to develop a robot itself making use of the “ROBOBUILDER”. They program motions while considering the movement of the center of gravity and balance of the body. Finally they fight each other, maneuvering their robots using their own planned motions. Students might notice the difference in field of vision between the human eye and that of a robot because they fight only through wireless cameras mounted on robots. Figure 5 shows the lecture making scenery. Figure 6 shows the class scenery in the primary school.

Figure 5: Development scenery

3.3 BIO PITCHER

By maneuvering this robot, students explore the skill of throwing by questioning how far they can throw. They learn about the high degrees of freedom of joint characteristics of humans and the difference of body movements between robots and human beings at the scene of throwing. We expect

Figure 6: Air of the lecture [12]

them to understand the function of force and the nature of parabolas through this experiment of throwing. Furthermore, we hope they realize that force is a vector, having two properties of magnitude and direction, and that the natural phenomena are controlled by the principles of science and mathematics. Figure 7 portrays a parabolic course of a ball thrown by the “BIO PITCHER”.

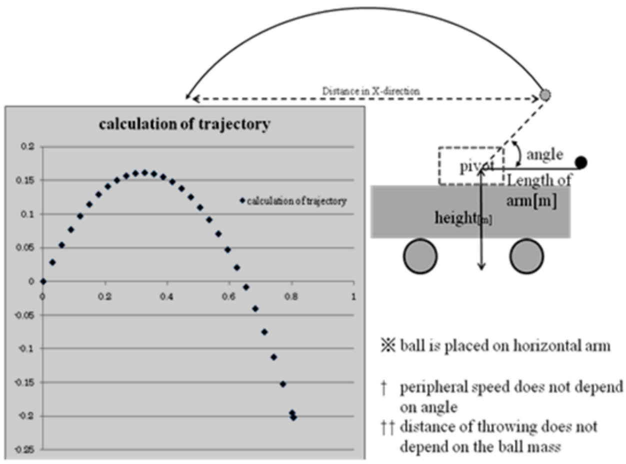

Figure 7: Parabolic path that a Bio-pitcher makes.

Our bio-pitcher is equipped with a controller and actuator and can exert force on an object. Students recognize that force can deform things and change the condition of movement. Furthermore, as described above, they are to understand that force has two properties of magnitude and direction. The configuration of our BIO PITCHER is portrayed in Fig. 8.

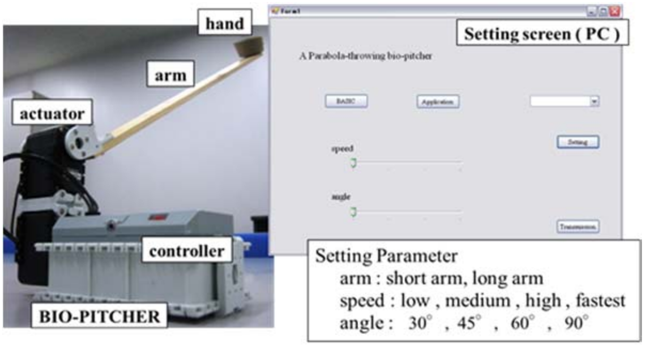

Figure 8: Configurations and setting parameter of Bio-pitcher

Students adjust parameters of throwing on their display and find, experimentally, the best setting to get the longest distance of throwing. Subsequently, they are asked to submit instinctive and logical estimations about throwing summarizing their group discussion. The adjustable parameters of throwing are the arm length, the actuator angle, and the launch speed: 32 combinations of these parameters can be set. Figure 9 shows the class scenery in the junior high school.

Figure 9: Air of the lecture

Students collect the throwing distance data for all these settings and discuss the differences between data and the two estimations presented above. It is necessary about the following two items if it is possible and learns. Simulation and reality differ, experiment is important.

3.4 MATH ROBOT

Displacement, velocity, and time are some of the central concepts in physics and the relations among them described by mathematics. Using this robot, students learn the relations from the travel motion of the robot car. They feel and recognize the relations at two occasions. The first occurs when they are watching a running robot; the second is when they are preparing graphs demonstrating the robot car's travel motion. They might feel them as they like. It might be the proportional relation or the linearity of graph. If they expect the existence of a functional relation, then the experiments can be said to have been very productive.

The graph doesn't do the thing generally drawn in the line chart. Because a few error margins go out. However, the elementary school student uses the line chart because it doesn't learn it. Finding the relation becomes a purpose in the graph. Drawing style in graph is learning by the compulsory education accurately. Figure 10 Gap by graph.

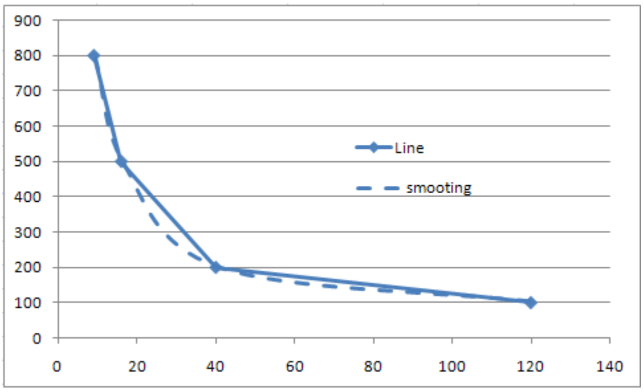

Figure 10: Gap by graph

Students are guessing, in daily life, the relation between displacement, velocity, and time by knowing the time interval required for walking a finite distance. Using the Math robot, they measure the displacement and time by themselves and present the data on graphs. They feel the relation among these physical quantities and then might reduce it to a simple mathematical expression. A set of these experiences is of the primary importance. In many classrooms, teachers are apt to adhere to teaching of the mathematical expression and will try to ask students to memorize it. This is, we believe, one of the causes of the trend among young students away from science. Our Math robot might make a linear run with uniform velocity and students might set a relation among displacement, time, and velocity on their PCs. Figure 11 shows our Math robot and the program controlling it. We merely ask students to show their data on a graph. At that time, we should not tell them about the type of graph and co-ordinate system. We should merely ask for some graphical representations. Perhaps they should be told that the common graph type used in these situations is only a rough representation. The instructor should not specify the type of graphical representation. If that were done, it would become another cause of young people's aversion to science. Figure 12 shows the lecture making scenery.

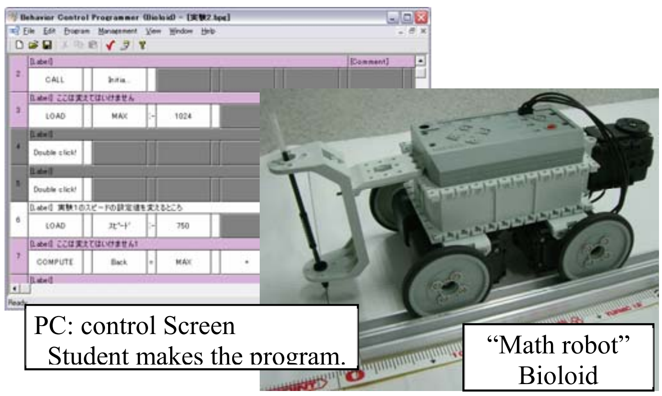

Figure 11: Math robot and program controlling it.

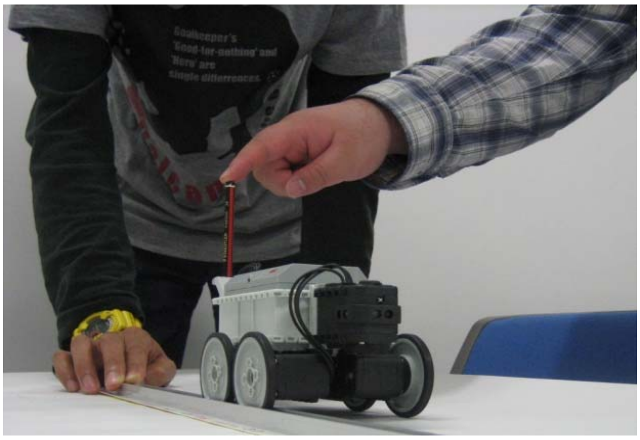

Figure 12: Development scenery

4. EXPERIMENTS AND EVALUATION

We gave experimental classes for 35 students of primary school and 16 students of junior high school and made a questionnaire survey of the change of interest toward science and mathematics after experiencing our experimental classes. The results of the survey are shown in Fig. 13. Before the classes, the percentage of students in primary school who liked (L) science and mathematics was 45%. That of students in junior high school was 38%. The weighted mean of these is 43.1%: all are less than 50%, as expected. After the classes, the percentage of students in primary school who changed from “dislike” (D) to “like” was 40%, whereas that of students in junior high school was 43.8%. The weighted mean of these is 41.2%.

In summation, students voted the L element (D⇒L⇒LL) after the classes, they occupied 85.7% in primary school. That percentage in junior high school was 81.2%. The weighted mean of these two marks was 84.3%.

We must refine the art of asking questions next. Although we shall expect no great improvement by this first trial, we have not detected anything bad. Therefore, similar ones are worth further trial.

Some students in junior high school confessed that they attended our classes simply because their friends did so. Therefore, their attendance did not necessarily reflect a special curiosity about science and mathematics, and these data suggest the effectiveness of group learning. In a free description section of the questionnaire, students in primary school wrote that they found the role of science and mathematics in daily life and that they were interested in the mechanical and electronic parts used in robots. This report suggests polarization of the effectiveness of the robots: as an experiment or as a game. Some students said that they could accommodate the tough discipline of science and mathematics if they were helped by a robot. This might be a similar notion to that shown by students imitating their friends, and might reflect the recent loneliness of students in Japan. If so, it might be developing not only to an aversion to science and mathematics but also to an aversion to human beings, which we might also be concerned about. To our great surprise, many students of junior high school expressed skepticism and criticism of the idea of robots in the questionnaire before the class because of their imaginary nature. We are greatly interested in the underlying cause of that skepticism, whether it is the rough nature of robot systems or the surrealism of stories of robots losing touch with real life. However, students seemed happy touching and using the robots. Robots might constitute an effective countermeasure against the trend of young people moving away from science and mathematics and might simultaneously provide them with fun.

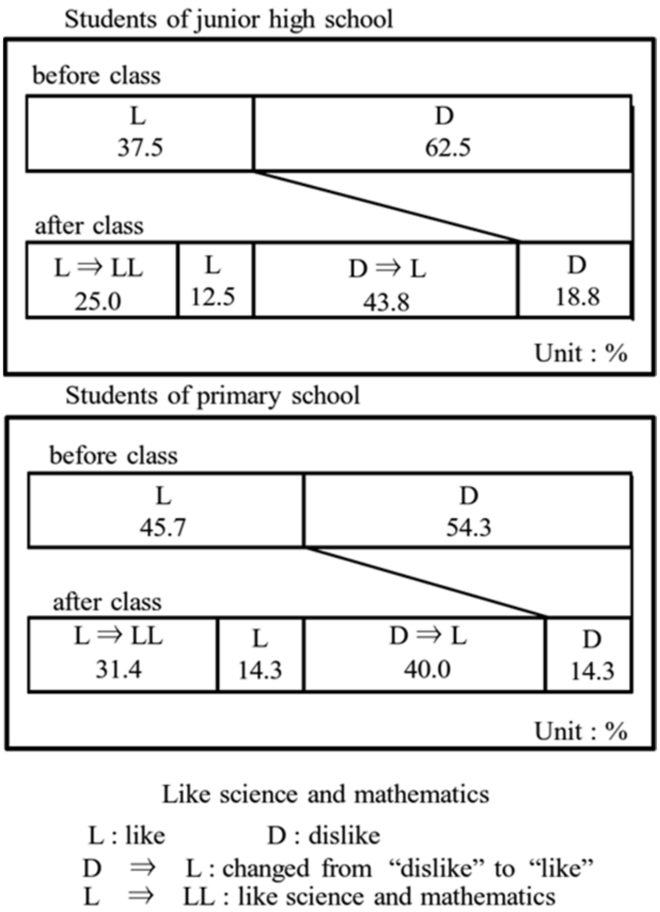

Figure 13: Students’ interests changed after attending the course.

The first key point is to abandon one-sided lectures and explanations and to ask students to repeat a simple measuring experiment. The second is to make them understand the meaning of that experiment, playing games packed with modern technologies. Do not teach theory and natural laws first. Summarize them simply after the experiment and playing game. Do not place importance on theories and natural laws. Never ask students to memorize them. That surely enhances the aversion of young people to science and mathematics.

It is important as a countermeasure against aversion to science and mathematics to lead students to infer something from simple repeated actions. That stance is valuable by itself as well and encourages students to pursue their definite goal. To guide students into that direction is the very role of education. We have felt some success in this context. After experiments, students exercised great enthusiasm in calculation, discussion, and presentation. Students of primary school have been very active and excited, and have shown strong concentration. Students of junior high school have shown excellent persistence in their logical progression to raising points at a question and answer session given after the presentation.

5. SUMMARY

We have developed four teaching materials to induce students in elementary education to be more interested in science and mathematics. Each covered the elements of experiments and games in different weight. Then we had experimental classes making use of those teaching materials in primary and junior high schools. We made questionnaire studies of the change of interest toward science and mathematics before and after our experimental classes, finding a positive trend. Providing four courses consecutively in a class yielded unexpected success. Students operated different robots, made group discussions and attended presentations. They were filled with tense excitement and made a unified effort with group members. They struggled and fought with science and mathematics, and then became winners.

In this article, two problems were left. First, it questioned immediately after and immediately before. It was very a great result. Next stage, we want to investigate and to examine whether the interest and the concern continue. Second, we have developed four teaching materials to induce students in elementary education to be more interested in science and mathematics. But they were only continuously executed. Next stage, how do the concern and the concern change while teaching each element (“Technical element” and “Educational element ") from a strong lecture to a weak lecture? This will become one of the research topics.

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