Journal of Asian Vocational Education and Training
Vol. 7, pp. 84-91, 2014

ISSN 2005-0550

Development of Exercise Equipment for Special Needs Learners: A Project-Based Learning at a Japanese University

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ABSTRACT

Tottori University has been using project-based learning (PBL) to educate undergraduate engineering majors since 2003. This article reported a case study of a PBL-based collaboration between a small group of engineering majors and a special needs school. In 2010, third-year engineering majors were asked to make an exercise equipment for a special needs school. They interviewed teachers at the school and observed classes to grasp the special needs students' reality and needs. Based on their investigations, they designed and built exercise equipment for the students. They used trial and error to devise many improvements on their designs and materials. PBL has provided them with a learning experience comprising planning, design, production and product assessment. As a result of this educational program, the engineering students displayed a significant change in their consciousness and behaviors. The study showed that PBL plays an important role in engineering education.

Keywords: Project-Based Learning (PBL), engineering education, special students exercise equipment, Japan

INTRODUCTION

Tottori University has been using Project-Based Learning (PBL) to educate undergraduate engineering majors since 2003 (Tottori University, 2011). Project-based learning is an instructional approach built upon active learning that engages students' interest and motivation. This approach allows students to gain special experience outside of the lecture hall. Tottori university has the four core academic fields: Sciences, Medicine, Engineering and Agriculture. These fields formed the foundation of this university. Therefore, Tottori University has spearheaded its philosophy, "the fusion of knowledge and practice" and aims to produce human resources who have deep specialized knowledge as well as an ability to uncover and solve problems; thus put the knowledge to practical use.

The university has a population of about 5,000 students and more than 40% of these students are from the faculty of engineering. Engineers and researchers who advanced technical knowledge are essential in the era of k-economy. As an education and research organization, the faculty of engineering offers a wide range of fields, from manufacturing and environmental sciences to software engineering. Engineering education should produce graduates not only with technical competency but also with creative and innovative thinking skills. However, conventional curriculum and social hierarchy stifle the creativity of university students in Japan (McCreedy, 2004). Thus, university has to produce graduates equipped with creative and problem-solving skills.

For this purpose, Tottori University established the Innovation Center for Engineering Education (ICEE). ICEE aims to develop creative human resources in the main engineering fields. In order to achieve this goal, the center supports production for research and education. It also introduces a new manufacturing education program in collaboration with local companies in Tottori. ICEE has embedded project-based learning actively.

Project-Based Learning

Project-Based Learning (PBL) is a student-centered approach in learning. This method is to learn a subject through the experience of project solving. Based on the project, the students learn thinking strategies. Project and Problem-based learnings are quite similar in concept. Problem-based learning was developed at McMaster University in Canada in the 1960s. Now it has spread around the world. Hmelo-Silver and Cindy (2004) pointed out that the goals of this educational approach is to nurture the students' ability, including to develop "flexible knowledge", "effective problem-solving skills", "self-directed learning", "effective collaboration skills" and so on. Barrows (1996) defined problem-based learning as follows: "Focusing on student-centered", "Learning is done in small groups", "Facilitators guide the students rather than teach". A problem forms the basis for the organized focus of the groups and stimulates learning. Problem is a vehicle for the development of problem solving-skills and a knowledge is obtained through self-directed learning. To carry out the problem-based learning, a teacher should focus on these following aspects: (1) problem, (2) driving questions, (3) constructive investigations, (4) autonomy, and (5) realism.

Mustapha and Abdul Rahim (2011) identified the problem faced by electrical and electronic engineering students studying difficult topics. In this study, he pointed out that students' attitude became more positive through the experience of PBL. Also, this study was based on the action research model by Kemmis and Mc Taggart (1998). Okano and Sessa (2012) analyzed the difficulties and ways to improve the introduction of the PBL approach to developing countries. Their research found difficulties such as non-homogeneous student backgrounds and weakness in adapting learning diversity. They pointed out that the importance of group dynamics and curriculum modification to solve these problems.

In the case of Japan, recently, a growing number of higher education institutions has adopted Project-Based Learning, especially in the undergraduate level. For example, Shimoda *et al*. (2014) reported software development using PBL was carried out in Chiba Institute of Technology. For the undergraduates whose experience were limited, they pointed out that the PBL has facilitated and supported the students' learning. Okumoto and Iwase (2012) investigated self-motivation in group work. Their findings indicated that voluntary behavior is derived from group interaction, and suggested a group-design factor to develop participants' voluntary behavior. Takashi *et al*. (2013) proposed a framework to use the Plan-Do-Check-Action (PDCA) cycle effectively aiming to improve the creativity of the students. They assert that it is critical to embed PBL in the engineering curriculum.

RESEARCH PROBLEM

At Tottori University, Project-Based Learning (PBL) has beem implemented since 2003 with the cooperation from companies and schools. Some of the products produced in the PBL have the potential to be commercialized. However, the students often faced challenges in identifying the real problems. Some supervisors of the PBL also have limited knowledge to supervise the students. Thus, some supervisors are in the process of trial and error in actual practice of PBL. In this study PBL was conducted to explore the learning effects of the students who involved in PBL.

Practical Education of PBL at Tottori University

This article reports a case study of a PBL-based collaboration between engineering majors and a special needs school.

Flow Chart of this Study

Figure 1 shows the flow chart of PBL in engineering education. The students found the problem by observing the challenges faced by special needs students in a school. Then the students designed problem-solving plan and produced the equipment. A well-designed program leads students to search for the central concepts and principles of a discipline. In order for students to complete the project, they need to sharpen certain skills. These skills include communication, presentation, organization, time management, research, self-assessment, reflection, group work and leadership skills. Table 1 shows a list of PBLs in 2010. The Department of Engineering has conducted PBL for undergraduate students since 2003 with about 30 collaborative companies or schools.

PBL Curriculum in Engineering Education at Tottori University

- ***Academic Discipline*:**
  "Practice Project" in the Department of Engineering, Tottori University. This is an elective course, with 4.5 hours of class per week, meeting a total of 35 times, throughout the year.

- ***Period of Implementation*:**
  April 2010 to March 2011.

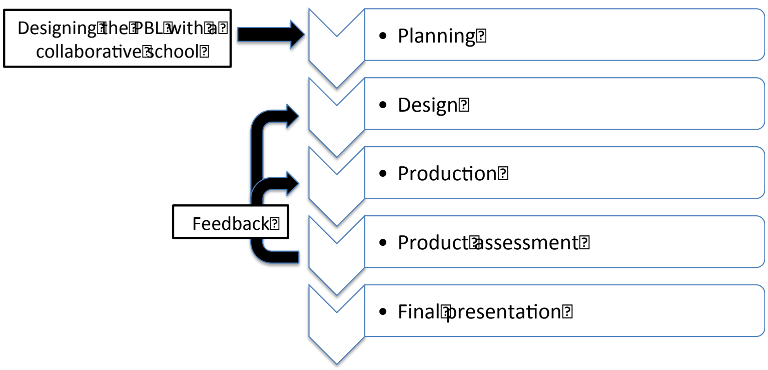

Figure 1: Flow chart of the PBL in Engineering Education

Table 1: List of PBLs in 2010

Research Problem	Number of Students	Participated Companies / Schools
Development of Concrete Product	4	KYC Machine Industry Co., Ltd.
Product Development Using the Antiviral Agent	16	Mochigase Co., Ltd.
Product Development for Livingware Using the LVL and LED	4	Wood-Factory Co., Ltd. / Shimizu Design Institute
Experimental Verification of Alternating Electromagnetic Field Generator	7	SKA Ltd. / G-Spec Co., Ltd.
Product Development of Machinery	1	Diamond Electric Co., Ltd.
Study of Production Process Improvement of Screen Printer	2	CubeSMT Lab Co., Ltd.
Product Development of Exercise Equipment for Students with Special Needs	3	Affiliated School for Children with Special Needs

- ***Students*:**
  Three third-year Mechanical Engineering students - two men and one woman.

- ***Method of Implementation*:**
  One teacher teaches the course for this project. Furthermore, a special coordinator who is a retired engineer and two senior supervisors of engineering at the university provide technical assistance and training. Students submit project reports every week, comprising: (1) this week's goals, (2) task details, (3) percentage achieved, and (4) next week's goals.

PURPOSE OF THE PROJECT

The purpose of this project was to develop and exercise equipment for special needs students. It is important for orthopedically impaired students to perform physical activities in school. At present, few stores sell the necessary equipment, but they do have a limited selection and/or high prices. Therefore, the director of the special needs school commissioned these undergraduate students to create the exercise equipment for special needs learners.

EXERCISE EQUIPMENT

Using PBL, the students developed exercise equipment that can improve balance. It consists of a main body and an operation board (see Figure 2). The user inclines his/her body to match the movement of an animal character on the LED display panel on the operation board of the main body. When the user matches the animal's movements, the hands of the clock in the lower main body turn (see Figure 3). One of the clock hands turns along with the user, and the other turns at a speed controlled by the microcomputer. If the user's clock hand overtakes the microcomputer's, a melody sounds and the game is over (see Figure 4). Thus, the users play a game. Of course, the user can regulate the speed of the microcomputer by the adjustment knob. The degree of the user's body inclined on the operation board is detected by a pressure sensor, and it is displayed by the character on the main board (see Figure 2). This equipment is currently being used in the special needs school.

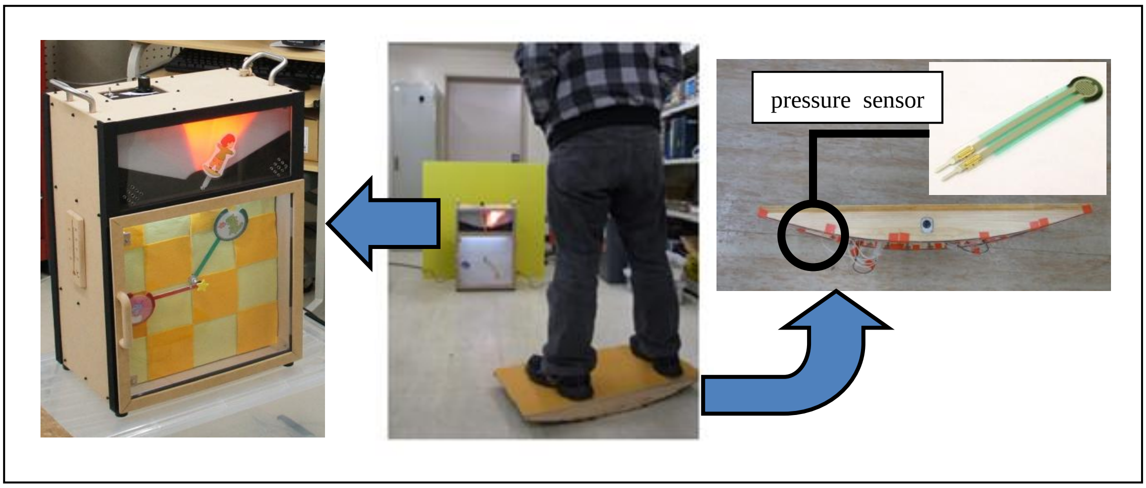

Figure 2: Main body and operating board

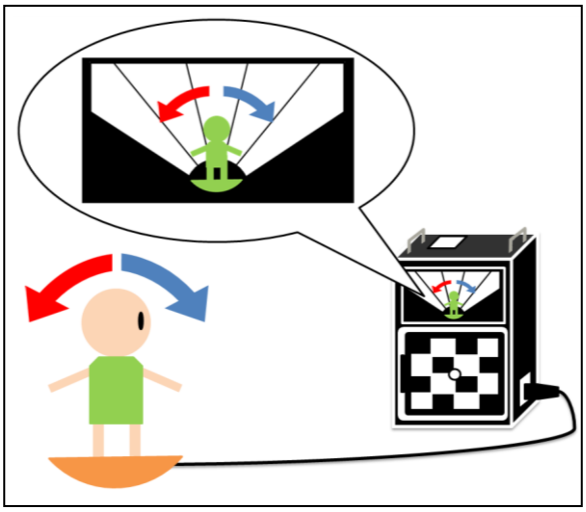

Figure 3: Explanation of the equipment

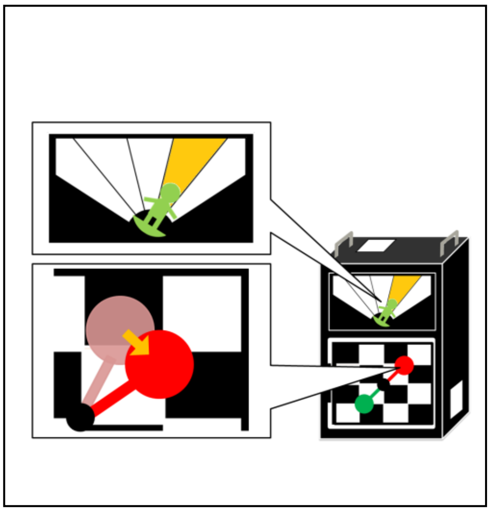

Figure 4: Explanation of the main body

Research Design

- ***Planning***: First, the students visited the special needs school. They interviewed the teachers at the school and observed a class. Then they returned to the university, and brainstormed, writing and making notes and sketches on paper. Under the special coordinator's guidance, they came up with a direction for the new exercise equipment.

- ***Design***: Based on their notes and sketches from the planning stage, the students worked on designing the equipment's outside dimensions, force transmission mechanism and electronic control circuitry. Figure 5 was a design drawing of the gear system made by the students in 3D CAD.

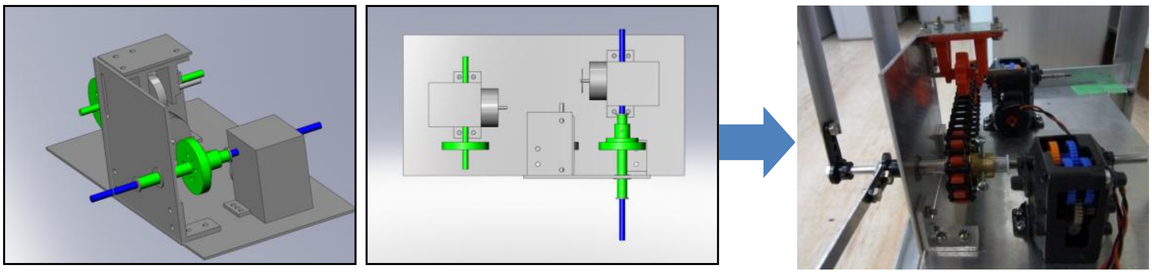

Figure 5: Blueprints of gear system and gear unit made by students

- ***Production*****:** Using their designs, the students worked to construct the equipment parts under the guidance of the senior supervisor (see Figure 6). The tools used by the students included a general-purpose lathe, a milling machine, an NC drilling machine, and an arc welding machine. The students had used these machines in shop class when they were first- or second-years. Figure 7 shows the structure of the main body.

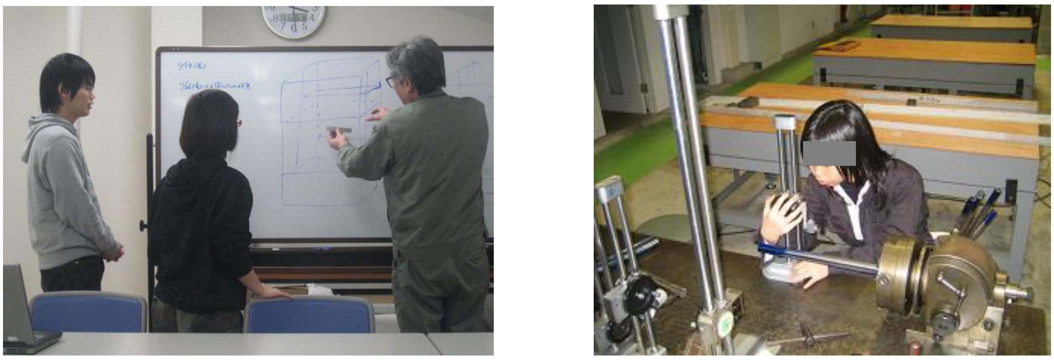

Figure 6: Production

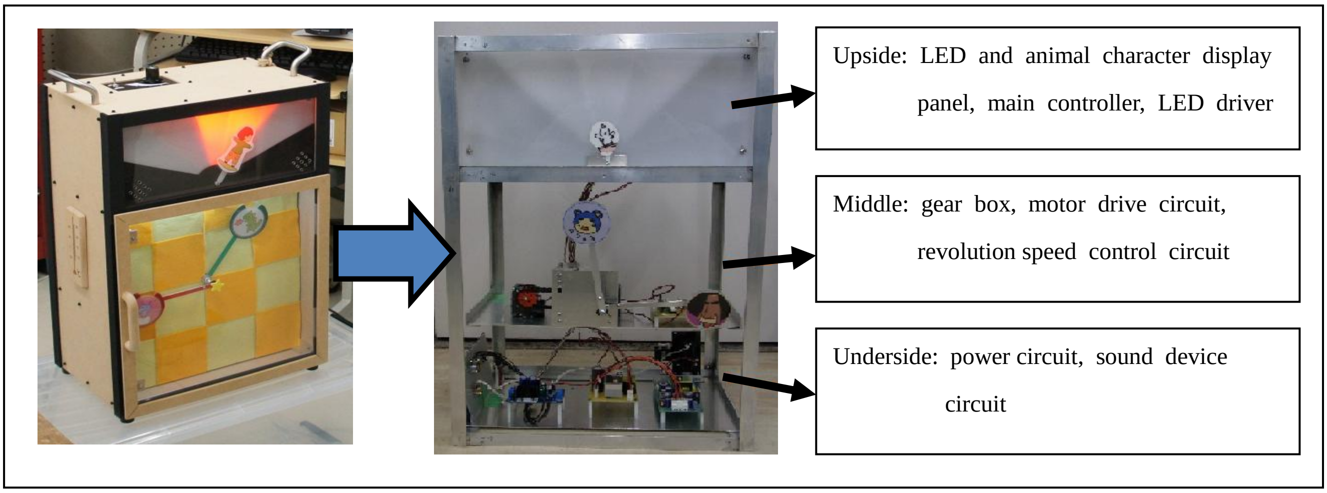

Figure 7: Structure of main body

- ***Product Assessment and Feedback*****:** Students reported to the special needs teachers about the equipment they had developed. They also lent it to the school for the students to try out for one month. One month later, the teachers told the students how to improve the equipment in terms of safety, stability and mechanical strength. Based on the teachers' advice, the students returned to the production and design stages. This was not their first setback. For example, the test model they made had many problems and did not work, requiring a return to the design stage. However, after many failures, the students completed the project and improved the product quality by trial and error.

- ***Final Presentation*****:** The students held a final presentation for the special needs teachers (see Figure 8). They presented their experience during the project and the exercise equipment they had developed. The teachers confirmed that the equipment had improved from the test model, and they evaluated the presentation and the equipment. This was the end of the students' project.

Figure 8: Final presentation

EVALUATION OF PBL PROGRAM

External Evaluation of Exercise Equipment

Students entered a contest for a product announcement. As a result, they were awarded two prizes.

- The President of Tottori Prefectural Chamber of Commerce and Industry Prize, The 52nd Tottori Invention and Innovation Contest, Tottori Institute of Invention and Innovation, 2010.
- The Academy President Prize, The 6th Technology Education Invention and Innovation Contest, in the "Development of Teaching Materials" category, The Japan Society of Technology Education, 2011.

Effect to students through the PBL Activity

In this project, one professor led the class. Furthermore, a special coordinator who is a retired engineer and two senior supervisors of engineering at the university provided technical assistance and training. They helped the students to carry out the PBL program as "facilitators" and taught the students machining techniques. The researchers learned the educational effect of PBL from interviewing these educators.

The special coordinator said, "The students learned the ability to solve problems by making a plan. At first, they often designed with more ideals than reality in mind. They experienced failures due to lack of planning. However, after many failures, they came to be able to make a feasible plan." The senior supervisor said, "I thought that PBL allowed the students to learn how to do real work. For example, engineers must visualize the actual production process at the each design step. However, many students often create a design that is difficult or impossible to execute; a mere desk plan that is hard to put into practice. Through PBL, the students gained the ability to visualize production when they design." One of the students said, "*I think that the PBL program will be of use to me in the future. This experience is not provided in my other classes. I will recommend the PBL program to younger students*." Based on these comments, it is concluded that a PBL program with a flow of planning, design and production is beneficial to the students.

CONCLUSION

This article reported a case study of the collaboration between engineering majors and a special needs school using PBL. The purpose of the project was to develop exercise equipment for special needs learners. The students have succeeded to develop the equipment. PBL is currently in use at many universities with strong engineering programs. It is hoped that more universities and Engineering departments will use PBL programs in the future.

ACKNOWLEDGMENT

We would like to thank special coordinator Mr. Torahiko Kato and senior supervisors Mr. Masahiko Akiyama and Mr. Satoshi Takeda for their help with this study. Their advice is gratefully acknowledged.

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