FOSTERING ENGINEERING THINKING THROUGH INTELLIGENT ELECTRONIC PRODUCTION PROGRAM AT NIT SENDAI COLLEGE

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ABSTRACT

NIT Sendai College offers a practical training course called Intelligent Electronic Production program that has been conducted in its own curriculum since 2013. Senior students are supposed to develop a self-propelled robot which runs a certain course tracing a line and performs different assigned tasks. Basic components are provided but students have to design the rest of the necessary parts to realize various functions within the fixed budget. This program is the compilation of what the students have learned so far. Each robot is shown at the final contest on the college festival day. They compete for run time, accuracy of movement, stability, and appeal of their own robots in front of public spectators. Through this project-based learning program, students are expected to foster skills of managing the project work with other members in a group, applying their technical knowledge, and demonstrate application of engineering thinking to practice.

KEYWORDS

Project-based learning program, engineering thinking, self-propelled robot, group work, Standards: 4, 7, 10, 11

INTRODUCTION

Colleges at National Institute of Technology (NIT) in Japan are well-known as institutes that produce leading engineers with high skills and have long-term experience with PBL (Project/Problem Based Learning) education systems. These NIT colleges offer 5-year intensive education programs to foster engineers with practical skills. Students enter the college at the age of 15 and continue developing his/her technical skills for 5 years. The importance of practical trainings is emphasized in the curriculum of every NIT College. NIT Sendai College has also been offering spiral-shaped training programs with lectures followed by PBL type practices and has recently adopted more Active Learning methods in classes

(Fujiki N.M. et al 2016). Engineers in the next generation are required to have more and more flexible thinking and heuristic approaches to solve various issues. PBL is one key program at the NIT colleges to train students in various abilities so that they can adapt positively to society with complex economic structures, global competency, and rapid development of technology in the 21st century.

In the Department of Intelligent Electronic System at NIT Sendai College, the practical training program, called the Intelligent Electronic Production program, has operated with its curriculum since 2013. This program is offered to our senior students and the core objective of students is to develop a self-propelled robot which traces a line and completes different specified tasks (CDIO standard 5). Through the work on this practical project students are expected to conceive how to solve the given assignment, design various functions based on their ideas and implement their ideas to develop processes of a robot. At the same time they also learn cost and time management, how to work efficiently in a group, and how to apply knowledge that they have acquired previously in various lectures and experiments. Through this integrated learning experience, students could develop important skills required for future engineers such as engineering design implementation, ability to manage budgets, working in a team, and integrating all type of knowledge that they have(CDIO standard 4 and 7). The teaching staff acts an advisor who keeps an eye on students' progress on the project and properly identifies what may be blocking their progress. The enhancement of faculty teaching competence is also required.

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INTTELLIGIENT ELECTRONIC PRODUCTION PROGRAM

The main objective of Intelligent Electronic Production program is to provide students an opportunity to learn how to integrate practical knowledges about electric and electronic circuits, mechanics and software and to experience to creating their own machine through this PBL type project. We expect that students will struggle and work hard to find solutions for problems they will face during the program and acquire not only engineering thinking skills but also generic skills from their failures and trials. All these skills are surely required in their future when working as engineers.

An on-board microcomputer controls various sensors such as an infra-red sensor or a position sensor and motors to enable a self-propelled robot to trace a line successfully and to accomplish different tasks on its way. This program is offered to students of the 4th grade in the Department of Intelligent Electronic Systems. Three or four students form one group and work on the project 6 hours per week for one and a quarter semesters that takes roughly over 20 weeks.

The list of previous themes since 2013 is shown in Table1. The theme “Open up the positive gate” in 2017 is that a robot traces a black line and/or runs along a wall controlled by the data from a position sensor, counts markers on the field, and decides which gate to open. The maximum budget for robot production is limited, but students are free to select mechanisms to achieve assigned robotic tasks and design of the robot’s frame as well. How to pursue the development of a robot or assign the specific role of each student in a group is left to students. In this way, students learn not only technical knowledge and characteristics of electric devices, but also how to manage group work and/or realize their own ideas within a limited budget.

Table 1. Previous themes since 2013

FY	Themes	Key Elements
2013	Find gold mines	Metal detector and photo reflector
2014	Shoot balloons like William Tell	Position sensor and photo reflector
2015	Find and Deliver Chi-Ele. delivery service	Metal detector and photo reflector
2016	Chi-Ele Treasure hunter	Color sensor and photo reflector
2017	Open up the positive gate	Position sensor and photo reflector

Evaluation of results for each student is determined comprehensively based on points according to the required performance of the robot from each group at trails, and contribution to group work, and the presentation observed by the teaching staff.

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MODULE DESIGN

The module design is summarized in Table 2. The first part of instruction is designed to introduce students to the concepts of this program and to explain the theme picked for that year. After a few weeks of preliminary lectures and experiments students start working on their own robot production. A progress report is requested to submit every week and core functions of the robot are checked periodically. The whole operation is delivered in the project-based learning (PBL) style and the teaching staff acts as facilitators to encourage, risk taking, to correct errors and to support smooth operation of their work. On the other hand, students consider what kind of technical requirements they need to realize the tasks and design the proper mechanisms of a robot with certain electronic devices, motors, and other parts. SOLIDWORKS is an application for 3D CAD provide to the students to design the main frame of the robot. The basic kit includes a TAMIYA Inc. Remote Control Robot Construction Set (Fig.1) and a programmable microcomputer LPCXpresso LPC1769 board as the development platform (Fig.2) is provided.

A sample course for the production program in 2017 is shown in Fig.3. The black line disappears in the middle of the course, and walls are placed instead of the line. There are gates on the course and robots must decide which side of the gate to open based on the number of horizontal short lines drawn before the gate.

Table 2. Module Design

Week1	Guidance and announcement of a theme for the year Explain the tasks and the rules
Week2 -Week3	Lecture and workshop about infrared sensors, power circuit and DC motor Fundamental exercises on basic elements
Week4	Lecture on electronic circuits and preparatory experiments and design of a robot
Week5	Lecture about position sensor and RC servo motor, the micro-computer Fundamental exercises on basic elements Submission of project protocol
Week6 -Week17	Production of a self-propelled robot in a group Submission of a weekly report
Week8	Check line trace capability of each robot
Week13	Presentation to assess the progress of each team
Week16	Check basic movements of each robot
	Root competition at the college festival
Week18 -Week20	Final adjustment Submission of final reports

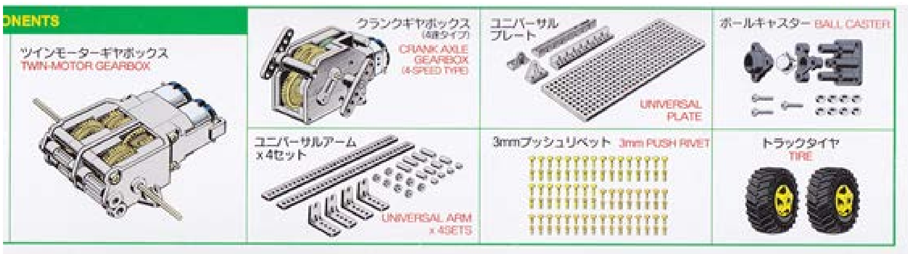
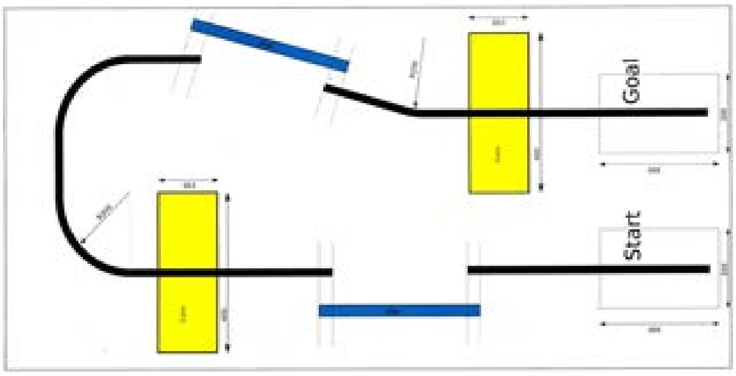


Figure 1. Basic development kit of TAMIYA Inc. Remote Control Robot Construction Set

Figure 2. Microcomputer development platform



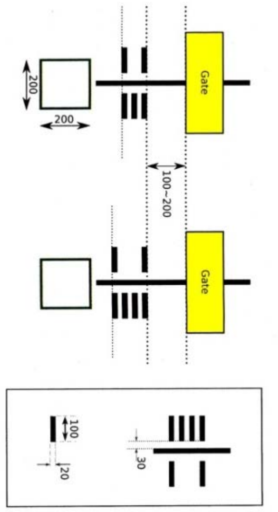


Figure 3. A sample course shown at the guidance

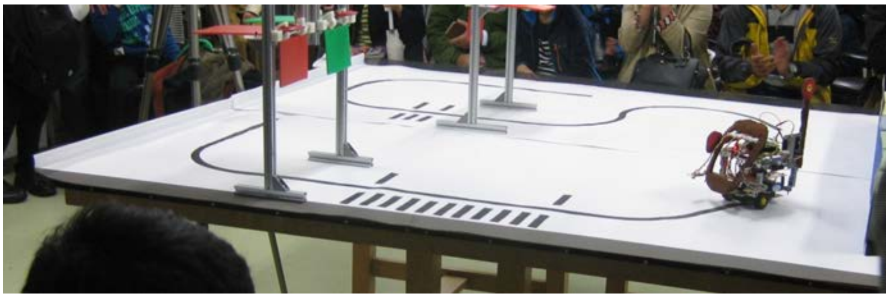


Figure 4. The actual course used in the final round of the contest in 2017

Figure 5. Robots entered in 2017 contest

STUDENT MOTIVATION

According to similar analysis on the effect of learning DE(digital electronics) by doing approach by Siong and Thow from Nanyang Polytechnic (Siong, G.E.and Thow, V.S. 2017), we used the Intrinsic Motivation Inventory(IMI) to evaluate the effect of this PBL program on students' motivation. Motivation is based on Self-determination Theory (Ryan & Deci, 2000) and is related to various activities such as target setting, planning and designing and/or execution of projects and plays an important role in any learning program. The IMI developed by Ryan (1982) and his colleagues from the Rochester Motivation Research Group is a multidimensional measurement device intended to assess participants' subjective experience related to a target activity in laboratory experiments. It yields six subscale scores and has been widely used in studies related to intrinsic motivation and self-regulation. We adopted the same expression but the words "digital electronics" were substituted with "developing a robot" in 45 items corresponding to 6 subscales used by Siong and Thow and translated into Japanese. Students were asked to describe their experience on a Likert scale from 1 (not true at all) to 7 (very true).

We think that the IMI enables quantitative evaluation of the effect of this program on students' motivation. The 45 items for 6 subscales are shown in Table 2. Interest/Enjoyment, Perceived Competence and Effort/Importance are related to students motivation toward the activity. Value/Usefulness is an aspect that is related to one's internalization of an experience. Pressure/Tension is theorized to be negative predictor of intrinsic motivation, and Relatedness is used in studies having to do with interpersonal interactions or friendship formation.

The same survey was issued to 2 groups of students, IE4 is the group that finished this PBL program a few months ago, and IE5 completed the same program last year. The average scores for each subscale and standard deviations are shown in Table 4. Younger students answered that they enjoyed the program very much whereas senior students scored their enjoyment lower. We might conclude that group IE4 evaluated the program in a more subjective manner with sensory impressions, and group IE5 answered based on a slightly more objective point of view.

Overall, the items in Effort/Importance subscale received high scores and Value/Usefulness received the highest average score in this survey. Perceived Competence was relatively low and Pressure/Tension had the lowest score. However, the expression of each sentence in the Pressure and Tension scale seems to be ambiguous and the students' selections may depend on how they interpret the items.

Table 3. Selected Subscales of Intrinsic Motivation Inventory

Interest/Enjoyment	Perceived Competence	Effort/Importance
• I enjoyed doing this activity very much • This activity was fun to do • I thought this was a boring activity(R) • This activity did not hold my attention at all(R) • I would describe this activity as very interesting • I thought this activity was quite enjoyable • While I was doing this activity, I was thinking about how much I enjoyed it	• I think I am pretty good at this activity • I think I did pretty well at this activity compared to other students • After working this activity for a while, I felt pretty competent • I am satisfied with my performance at this task • I was pretty skilled at this activity • This was an activity that I couldn't do very well	• I put a lot of effort into this • I didn't try very hard to do well at this activity(R) • I tried very hard on this activity • It was important to me to do well at this task • I didn't put much energy into this(R)
Value/Usefulness	**Pressure/Tension**	**Relatedness**
• I believe this activity could be of some value to me • I think that dong this activity is useful for promoting my interest in learning engineering • I think this is important to do because it shows me how to build, test and package a prototype of developing a robot • I would be willing to do this again because it has some value to me • I think doing this activity could help me to sharpen my thinking and problem solving skills in group works and presentation • I believe doing this activity could be beneficial to me • I think this is an important activity	• I did not feel nervous at all while doing this(R) • I felt very tense while doing this activity • I was relaxed in doing these tasks.(R) • I was anxious while working on this task • I felt pressured while doing these tasks	• I felt really distant to my teammate (R) • I really doubt that my teammate and I would ever be friends (R) • I felt like I could really trust my teammates • I'd like a chance to interact with my teammates more often • I'd really prefer not to interact with my teammates in the future (R) • I don't feel like I could really trust my teammates (R) • It is likely that my teammates and I could become friends if we interacted a lot • I feel close to my teammates

Note: The item marked (R) are negative statements. To calculate the item score, subtract the item response from 8.

Table 4. Results of Survey using IMI

IMI Subscales	IE4(35)		IE5(29)	
	Average	Standard Deviation	Average	Standard Deviation
Interest/Enjoyment	5.30	1.56	4.76	1.62
Perceived Competence	4.32	1.51	4.07	1.45
Effort/Importance	5.16	1.41	5.06	1.41
Value/Usefulness	5.37	1.44	4.95	1.48
Pressure/Tension	3.90	1.78	3.83	1.64
Relatedness	4.61	1.65	4.51	1.71

DISCUSSION

We introduced the PBL program called Intelligent Electronic Production program to foster engineering thinking of students. The IMI subscales were used to evaluate students' motivation on this program and to capture how they had felt about the activity in this program. From detailed results of the survey using IMI, we could see the items "I think doing this activity could help me to sharpen my thinking and problem-solving skills in group work and presentation", "I believe doing this activity could be beneficial to me," and "I think this is an important activity" in the subscale Value/Usefulness were marked higher than others. IE4 said they enjoyed doing this activity very much. On the other hand IE5 denied the item "I thought this was a boring activity (R)," so both groups seem to have worked this activity with certain interest at least. Relatedness might indicate a typical feature of college students. One feature at colleges of National Institute of Technology is that each department has only one class at each grade level. Consequently about 40 students have been studying together for 5 years in the same class. The students have been close to each other for the last three or four years. Most of the students could assume their own role in the group quite naturally and accept the manner of putting the right person in the right position.
Analysis of the IMI survey results suggests that most of students think the program was useful and motivated them to learn engineering. On the other hand, they think their skills were insufficient to complete this program without help.

We took another survey asking students about subjects that they had considered useful for this project work. NIT colleges adopted the spiral-shaped curriculum style that offers many lectures followed by related exercises or experiments and basic course lectures followed by advanced course lectures. We obtained answers from 49 of IE4 and IE5 students. The majority of students (77%) answered the microcomputer basic, advanced I, and II lesson were useful. Three-fourth of students (75%) said the electric circuit (basic, and advanced) was useful, and 42% answered electronic circuit basic, advanced A, and B, 44% chose programing basic, advanced and applied, and 27% voted for fundamental experimentation. These results indicate that this program is well designed to integrate students' knowledge obtained from various lectures and exercises taken previously.

Some of students were also interviewed about the most useful experience they obtained from this program. They emphasized the usefulness of getting to know the reality of engineering work such as what will exactly happen if too much current flows into a microcomputer or electronic device, why they should not apply higher voltage than the acceptable range and/or also the importance of solid connection between cables.
The teachers who organized this PBL program observed that students were more confident after completing the program and applied the valuable experience obtained from this PBL

program to their graduation research projects. However setting a proper theme consisting of various levels of challenges is still a big problem to the teaching staff. It is highly expected that the teaching staff should respond properly to a variant of unique challenges with different and often multiple causes. Continuing this PBL program more effectively is certainly a big challenge for us.

In order to reach any concrete conclusion if this PBL program does foster students engineering thinking, we may need to conduct a similar survey of graduates already working as engineers. It is hoped that those valuable experiences of the students will be viewed equally useful to their careers as engineers.

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