Cross-Disciplinary Learning Through Manufacturing: Toward Student-Centered STEAM Education

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Abstract

In recent years, with the importance of cross-disciplinary educational programs such as STEAM education, it has become necessary to provide mathematical education at the early stages of elementary and junior high school to prevent the increase in the number of students who have dropped out of science. As a result, educational institutions are also becoming more active in efforts such as robot-themed education as part of their contribution to the local community. In this study, we propose a method for students to decide their own theme about mechanics, obtain a production budget, and engage in cross-disciplinary learning through extracurricular activities. with support outside and inside the school.

Keywords: Cross-disciplinary learning, Student-centered educational activities, STEAM education, Pendulum clock

1. Introduction

In recent years, there have been classes, etc., that use LEGO parts, etc., in teaching "mechanics" as the mechanical aspect of robotics so that students can learn intuitively through experience [1]. This may be particularly effective when the target audience is elementary school students, and it is becoming increasingly important to conduct this as a regional collaboration. Such efforts are important to create interest in science at an early stage among elementary and junior high school students, to motivate them to study science-related subjects, and to stop young people from turning away from science and engineering.

As for spontaneous projects by university students, a sumo robotics class for elementary school students is planned [2], and a robotics class for elementary and junior high school students is planned to provide science and technology education [3].

In addition, as part of the development of teaching materials for robotics education, a programming teaching material was created using a commercial product called View trover, in which the theme was set as "maze exploration" and the final mission was successfully completed in 90 minutes [4]. In addition, we hosted a workshop and evaluated the usefulness of the lecture by taking pre- and post-questionnaires [5].

In addition, using a commercial product called Butte Balancer, we are developing teaching materials that can be used to convey the mechanism of inverted control, the relationship between mathematics and physics, and how it feels around us, in a cross-disciplinary manner [6]. Furthermore, a workshop was planned, and a class was conducted and evaluated so that participants could touch the robot and experience not only control engineering but also basic programming techniques, etc., with the aim of having them understand the concepts of control engineering and become interested in mathematical subjects in general, which are the basis for these subjects [7].

In this study, we will promote independent manufacturing activities for second-year students at technical colleges to enable students to engage in independent creative activities for Steam education.

1.1. *Curriculum of Department of Electronic Control Engineering*

Table 1 shows the curriculum for years 1-3 of the school's Department of Electronic Control Engineering.

In the first year, students learned control and programming using existing microcomputers in Basic Electronic Controls. In drafting, students learned design skills necessary for design. In mathematics and physics, students acquire the skills to identify phenomena and the basic knowledge to express engineering phenomena such as functions, which are necessary to study specialized subjects in the second and subsequent years.

In the second year, in CAD, students learn the skills to incorporate their own envisioned designs into their designs. In the Fundamentals of Electric Circuits course, students learn the basics of direct current and alternating current, and in the Engineering Experiments course, they re-learn their knowledge of electrical theory through measurement and measurement.

In the third year, there is a class for building creative robots called "Creative Design Exercise," and students are likely to be bound by time restraints even after school, The second year is considered to have relatively more time.

For the following reasons, it is considered appropriate to conduct such activities in the second year. Need to learn CAD ahead of time. Students who are highly motivated can study basic mathematical subjects on their own.

Table 1 Records of Out-of-School Activities

Date and Time	Special subject	Mathematical subjects
First year	Drafting Basic Electronic Control	Mathematics 1 Physics 1
2nd year	CAD Engineering Experiment Fundamentals of Electric Circuits	Mathematics 2 Physics 2
3rd year	Creative Design Exercise	Mathematics 3 Physics 3

1.2. *Toward the Challenge and Adoption of Shimane Mono*

Motivated students (second-year college of technology students) formed their own organization and set a goal of producing a clockwork mechanism. They made a production plan and created an application form for the Shimane High School Students' Monozukuri Challenge, and submitted it under the application theme of "Reproducing the mechanism of a mechanical clock using a 3D printer, etc. - Tourbillon production.

The proposal included a production plan toward a spring-loaded watch as a step toward tourbillon production. The plan included items to be mastered, such as skills in using CAD software, mathematical knowledge of mechanics, and material processing techniques necessary to design the watch.

This initiative was adopted and received a funding grant from the JST EDGE-PRIME Initiative Program at Shimane University. In addition, the Matsue Business Ecosystem, a MATSUE entrepreneurial ecosystem consortium, provides advice and technical assistance during regular monthly meetings at Shimane University.

2.3. Environmental maintenance and planning in the school

A workspace will be set up in a part of the laboratory where the fifth-year students belong, and the budget will be used to purchase a 3D printer and materials to improve the environment (money will be managed by the faculty member in charge). Students learn how to operate printers and learn CAD ahead of time, starting in the 5th grade. Basically, a 15-minute meeting once a week. The activity time is basically once a week, and students are responsible for their own activities after school.

Table 2 shows the required knowledge and skills corresponding to the plan and timeline for production.

Table 2 Production Plan and Required Knowledge and Skills

Date and Time	Contents	Knowledge and Skills
May	Toward the Theme "Karakuri Clock"	Group Work and Emphasis
June	Using a 3D printer for teaching graduate students	How to design parts with a printer and CAD
July	Pendulum Mechanics Research Group Study Group on Mechanisms and Technology	Mathematical knowledge of mechanics
August	Gear design and assembly gear meshing considerations	Simulation Skills
September	Design of teaching materials	
October	Material processing work and assembly	Leather cutter and lathe work
November	assembly	-
December	operation test	-

2. Correspondence with STEAM Education

2.1. *Mechanism Study (SM:Science,Math)*

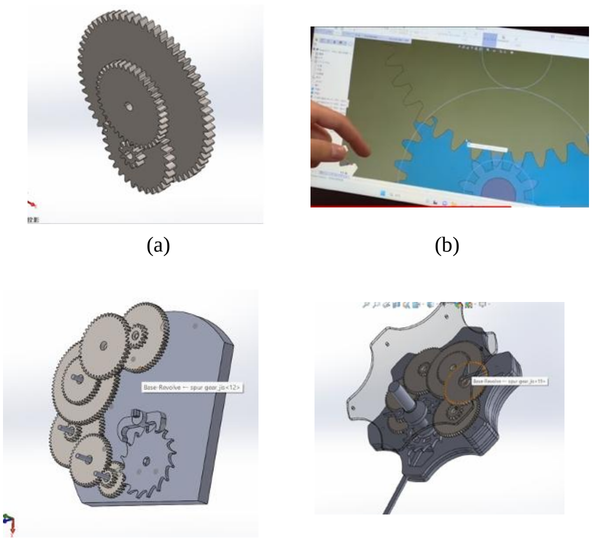
(a) (b)

Figure 1 Extracurricular activities centered on Mechanics (a). Rotational presentations (b) Organization of learning content in mechanics

As shown in Figure 1, after school, the students share their knowledge with the group by giving presentations on what they have learned in a rotational format. Students are also required to study "mechanics" to understand how gears work. While studying this field, the students will realize the need for knowledge in the areas they have not yet studied in "physics" and "mathematics" and will be motivated to learn more.

2.2. *Design of Mechanism Materials (T: Technology)*

The design for producing a Karakuri clock was made by setting up gear parts in Slid Works (Figure 2(a)), fitting the gears produced through trial and error for gear meshing, and simulation (Figure 2(b)). The assembly was also completed by assembling the gear (Figure 2(c)(d)) (in the "CAD class," the students did not take assembly or simulation, so they taught themselves).

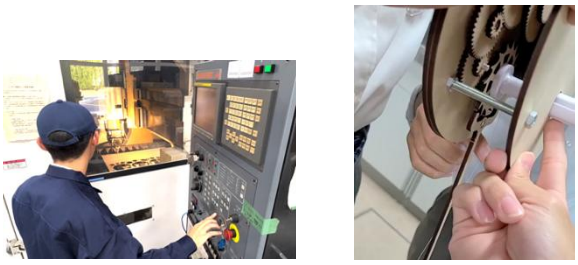


(a) (b) (c) (d)

Figure 2 Process of creating the mechanical material (a). Gear design in SolidWorks (b). Simulation of gear meshing (c). Assembly (d). Completion of assembly

2.3. *Machining and fabrication of mechanical materials (E: Engineering)*

The CAD design data is converted to MC data and processed using a machine (Figure 3(a)). The completed parts are assembled. Finally, the operation is checked (Figure 3(b)). Since the students had not yet completed the "Practical training for machining in a factory", they fabricated parts using a laser cutter and a lathe with the assistance of technical staff.



(a) (b)

Figure 3 Fabrication process (a). Laser cutting board (b). Assembly completed and Operation check

2.4. *Pre-emptive learning and Steam compatibility*

In sections A-C, we describe the correspondence between the skills gained and the Steam items. Table 3 shows the knowledge and skills gained across disciplines in the process of learning mechanics. Thus, it shows that knowledge and skills were gained across disciplines, including physics, mathematics, CAD design and machining operations.

Table 3 STEAM Elements and Anticipatory Learning and Correspondence

STEAM Items	Skills gained
S: Science	Oscillation and period, equation of motion of a pendulum
T: Technology	Use of simulation software required for assembly and operation checks necessary to design, and MC data conversion necessary for machining
E: Engineering	Lathe, laser cutter processing, assembly work, hand finishing work
A: Art	Design as Design
M: Mathematics	Curves expressed in terms of parameters (involute curves), integration methods, infinite series, differential equations

In Science (S), students gained knowledge of basic physics to understand the phenomenon of pendulum oscillation; in Mathematics (M), students learned trigonometric functions to describe pendulum motion and differential calculus of involute curves through the rotational motion of gears. The students learned differential and integral calculus.

In Art (A), students designed a pendulum clock, and in Technology (T), they learned how to use a simulator to design and check its operation.

In Engineering (E), the participants gained machining operations and assembly skills in the fabrication of components.

2.5. *Self-assessment*

Table 4 shows the evaluation of the initiative from the perspective of the students and mentors of this activity.

As described above, the students gained a lot, as indicated by the mentors' comments. 1

Table 4 Student and Mentor Opinions

From the students	Mentor
Broadened my horizons. More weapons (skills) I have a stronger sense of responsibility.	Starting with a pure desire to "make something," the perspective was broadened to see how their own manufacturing could affect those around them (giving birth to a workshop project that will be the subject of a future issue).
I am now able to act in a team-oriented manner. I learned the importance of trusting people.	The team consulted and collaborated well, and everyone participated independently. Technical skills such as 3D CAD and 3D printers grew remarkably.

3. Conclusion

In this study, the students themselves were able to obtain a budget by respecting their strong desire to build a pendulum clock and by carefully preparing a production plan by the students. They also used support from outside the school to complete the manufacturing process. In this series of processes, the students learned across disciplines (mathematics, physics, CAD, and fabrication techniques) and improved their skills with a sense of STEAM education. This can be evaluated from the questionnaires from the students and the mentors who provided external support.

For future research, we would like to design a short and abbreviated version of the pendulum clock we produced and plan workshops for elementary and junior high school students to conduct classes with STEAM education in mind.

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Authors Introduction

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