A Study of Experiential Learning Activities using Model Materials for the Kicking Motion

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Abstract

In order to develop human resources for the realization of Society 5.0, it is necessary for students to acquire the ability to solve problems that transcend the frameworks of subjects. For this purpose, cross-curricular learning is attracting attention. In this study, we examine teaching materials that connect the content of measurement and control in technology education with studies in science, health and physical education. A simple mechanism model teaching material is proposed to allow students to learn about ball operation through experiential learning by conducting motion experiments on a model that simulates the kicking motion.

Keywords: a simple mechanism model, technology education, teaching material, cross-curricular learning

1. Introduction

In 2018, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) released “Human Resource Development for Society 5.0—Changes to Society, Changes to Learning— (Summary)”. [1] In the summary, the MEXT indicated that the direction to be taken in the future is to transcend the humanities/sciences divide. Then, the Cabinet Office issued the “Science, Technology, and Innovation Basic Plan” for 2021.[2] In this plan, the realization of Society 5.0 is indicated. In order to develop human resources for this purpose, it is said that it is important to give them direct experience of the real thing through STEAM (Science, Technology, Engineering, Art(s), Mathematics) education. In these ways, it can be said that learning is required for students...
to acquire the ability to solve problems that transcend the frameworks of subjects.

In Japan, technology education is mainly conducted in junior high school technology and home economics (technology field). The Lower Secondary School National Curriculum Standard, which sets standards for organizing the curriculum, calls for cross-curricular learning. On the other hand, it also calls for the development of information literacy. In addition, many teaching materials and classes have been developed for learning related to measurement and control. [3], [4] Therefore, we decided to examine teaching materials that allow students to learn about measurement and control as part of their technology education and that are connected to the content of their studies in science, health, and physical education.

In this study, a simple mechanism model teaching material was proposed to enable experiential learning of ball operation by conducting motion experiments on a model that simulates the kicking motion.

2. Composition of Teaching material

The proposed teaching materials include the learning contents of technology, science, and health and physical education shown in Table 1. The proposed teaching materials are shown in Fig. 1. The mechanism model was created with the hip joint motion in the kicking motion as servomotor_A and the knee joint motion as servomotor_B. This motion has connections to the study of football. The hardware was fabricated using a servomotor (SG90, Made by Tower Pro Pte Ltd), a stainless-steel frame (Made by Yamazaki), and plywood as materials. The fixture for attaching the servomotor to the plywood was made by myself using a 3D printer. To operate the servomotor, Studuino was used as an educational microcontroller board.[5] Three AA batteries, 4.5 V in total, were used to power the servomotor.

### Table 1. Learning content of each subject.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Learning contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology</td>
<td>Mechanism, Model</td>
</tr>
<tr>
<td>Science</td>
<td>Force, Point of action</td>
</tr>
<tr>
<td>Health and physical</td>
<td>Football, Ball operation</td>
</tr>
<tr>
<td>education</td>
<td></td>
</tr>
</tbody>
</table>

3. Motion of Teaching material

The proposed teaching material can be operated in two patterns. The first pattern (kick_A) is to operate the servomotor_A. The force to poke the ball in kick_A is obtained from the torque relation in Eq. (1) below. Where $T[N \cdot m], F[N], r[m]$. 

$$ T = F \cdot r $$  \hspace{1cm} (1)

Stall torque listed in the data sheet of the servomotor used is $1.8kg \cdot cm$. The turning radius $r_1$ shown in Fig. 2 is $240mm$.

From Eq. (1), the value of $F_1$ is Eq. (2).

$$ F_1 = \frac{T_1}{r_1} = 0.735[N] $$  \hspace{1cm} (2)

The second pattern (kick_AB) operates servomotor_A, servomotor_B. servomotor_A can apply force $F_2$, shown in Fig. 3. However, due to the operation of servomotor_B, the turning radius $r_2$ is less than $240mm$. servomotor_B can apply a force of $F_3$, as shown in Fig. 4. However, the radius of rotation $r_3$ is $140mm$. 

![Fig. 1. Mechanism model teaching material](image1)

![Fig. 2. Radius of gyration of servomotor_A in kick_A](image2)
From Eq. (1), the value of $F_2$ is Eq. (3).

$$F_2 = \frac{T_2}{r_2} \geq 0.735[N]$$  \hspace{1cm} (3)

From Eq. (1), the value of $F_3$ is Eq. (4).

$$F_3 = \frac{T_3}{r_3} \div 1.26[N]$$  \hspace{1cm} (4)

From Eq. (2)-(4), the forces on kick_A and kick_AB are related in Eq. (5).

$$F_1 < F_2 + F_3$$  \hspace{1cm} (5)

As shown above, kick_AB can apply more force to poke the ball than kick_A. Thus, there is a connection with the learning of the force applied to the point of action.

4. Experimental method

Learners will experiment with the proposed teaching material in action in order to learn experientially the relationship in Eq. (5). The positional relationship between the proposed teaching material and a plastic ball ($\phi = 51.5mm$) is shown in Fig. 5. In kick_A and kick_AB, the angle $\theta_A$ of servomotor_A was set at 45° as shown in Fig. 6. As shown in Fig. 7, the angle $\theta_B$ of servomotor_B was set at 110°. In order to measure the velocity of the ball poked by kick_A and kick_AB, a video was recorded using an iPad. Each was operated ten times and the average velocities were compared.

5. Experimental result

The measured velocity of the ball for kick_A and kick_AB are shown in Table.2. The average velocities were 1.09m/s for kick_A and 1.22m/s for kick_AB. The results showed that the ball velocity was higher when two servomotor_A and servomotor_B were used. Thus, similar results to Eq. (5) obtained from the torque relation
equation are obtained from the motion experiments of the proposed teaching material. These results suggest the possibility of having students learn that the ball velocity can be increased by linking the hip joint motion with the knee joint motion when kicking a ball.

6. Conclusion

In this study, a simple mechanism model was proposed that can be made to learn about the kicking motion from the motion experiments of the model. Then, it was shown that the difference of kicking motion can be discussed from the relational equation and the motion experiment of the mechanism model. In the future, it will be considered to be practiced by learners as cross-curricular learning. This work was supported by JSPS KAKENHI Grant Number JP21K02951.

References


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