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

Teruyuki Tamai
Faculty of Education, Ehime University
3, Bunkyo-cho, Matsuyama, Ehime 790-8577, Japan

Shoki Takeuchi
Faculty of Education, Ehime University
3, Bunkyo-cho, Matsuyama, Ehime 790-8577, Japan

Yoshihiro Ohnishi
Faculty of Education, Ehime University
3, Bunkyo-cho, Matsuyama, Ehime 790-8577, Japan

Kazuo Kawada
Graduate School of Humanities and Social Sciences, Hiroshima University
1-1-1, Kagamiyama, Higashi-hiroshima, Hiroshima 739-8524, Japan
E-mail: tamai.teruyuki.xq@ehime-u.ac.jp, g230072c@mails.cc.ehime-u.ac.jp, ohnishi@ehime-u.ac.jp, kawada@hiroshima-u.ac.jp
www. ehime-u.ac.jp, www. hiroshima-u.ac.jp

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 sarvomotor_A and the knee joint motion as sarvomotor_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.

Subject	Learning contents
Technology	Mechanism, Model
Science	Force, Point of action
Health and physical education	Football, Ball operation

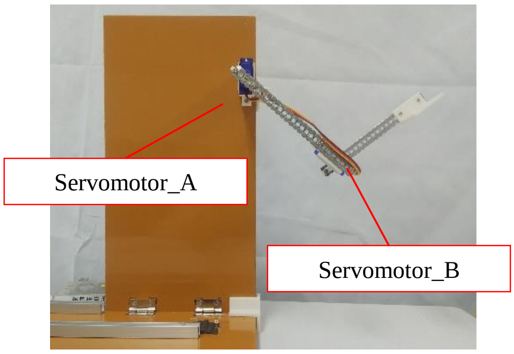

Fig. 1. Mechanism model teaching material

3. Motion of Teaching material

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

$$T = F \cdot r \tag{1}$$

Stall torque listed in the data sheet of the sarvomotor used is $1.8kgf.cm$. The turning radius r_1 shown in Fig. 2 is $240mm$.

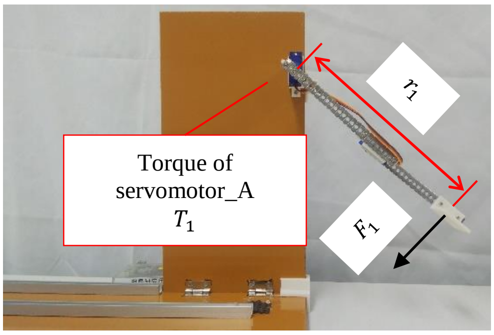

Fig. 2. Radius of gyration of servomotor_A in kick_A

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

$$F_1 = \frac{T_1}{r_1} \fallingdotseq 0.735[N] \tag{2}$$

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

From Eq. (1), the value of F_2 is Eq. (3).

$$F_2 = \frac{T_2}{r_2} \geq 0.735[N] \tag{3}$$

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

$$F_3 = \frac{T_3}{r_3} \doteqdot 1.26[N] \tag{4}$$

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

$$F_1 < F_2 + F_3 \tag{5}$$

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.

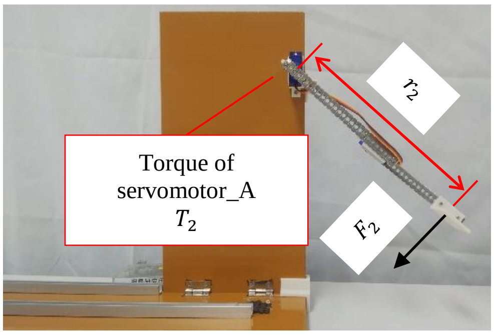

Fig. 3. Radius of gyration of servomotor_A in kick_AB

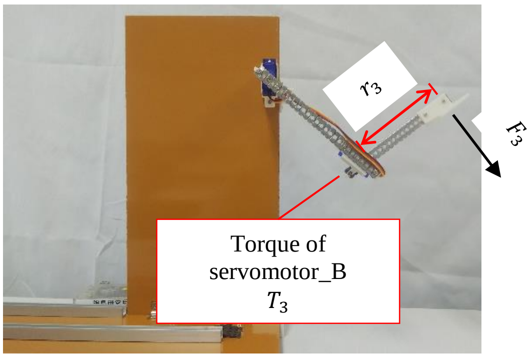

Fig. 4. Radius of gyration of servomotor B in kick_AB

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 θ_A of servomotor_A was set at 45° as shown in Fig. 6. As shown in Fig. 7, the angle θ_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.

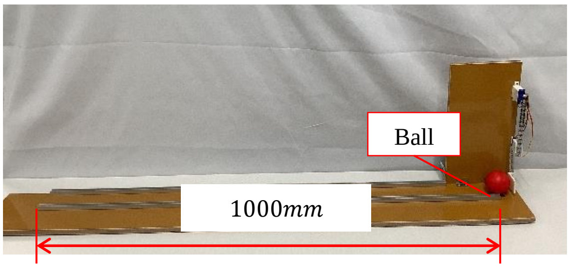

Fig. 5. How to measure ball speed.

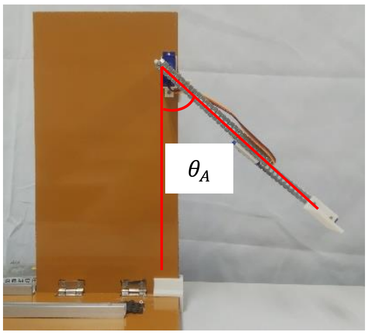

Fig. 6. Servomotor_A angle.

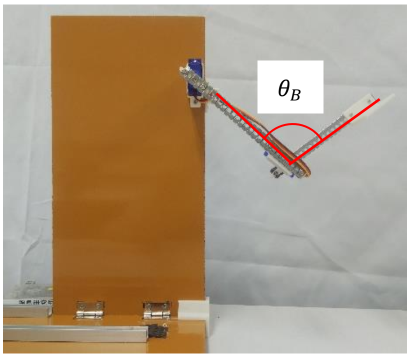

Fig. 7. Servomotor_B angle.

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 sarvomotor_A and sarvomotor_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.

Table 2. Measurement result.

	kick_A		kick_AB	
	time[s]	velocity[m/s]	time[s]	velocity[m/s]
1th	0.90	1.11	0.82	1.22
2th	0.92	1.09	0.82	1.19
3th	0.92	1.09	0.82	1.22
4th	0.93	1.08	0.82	1.22
5th	0.92	1.09	0.84	1.19
6th	0.93	1.08	0.83	1.20
7th	0.90	1.11	0.81	1.23
8th	0.93	1.08	0.81	1.23
9th	0.93	1.08	0.80	1.25
10th	0.92	1.09	0.82	1.22
average	0.92	1.09	0.82	1.22

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

1. MEXT(Ministry of Education, Culture, Sports, Science and Technology), " Human Resource Development for Society 5.0～Changes to Society, Changes to Learning～(Summary)", 2018
2. Cabinet Office, " Science, Technology, and Innovation Basic Plan", 2021 https://www8.cao.go.jp/cstp/english/sti_basic_plan.pdf [Accessed December 10,2022]
3. Y. Ohnishi, K. Honda, R. Nishioka, S. Mori and K. Kawada, "Robotics Programming Learning for Elementary and Junior High School Student", Journal of Robotics and Mechatronics, 29(6) 2017, pp. 992-998
4. S. kabemune, S. Shirai and S. Tani, "Informatics and Programming Education at Primary and Secondary Schools in Japan", Olympiads in Informatics, Vol.11, pp.143-150, 2017
5. K. Omata and S.Imai, "Practice of Programming Education using Finger Robot", Journal of Robotics,Networking and Artificial Life, Vol.6, No.4, pp.262-264, March,2020

Authors Introduction

Dr. Teruyuki Tamai

He received his Ph.D. at Graduate School of Education in Hiroshima University. He is an Assistant Professor in the Faculty of Education, Ehime University.

Mr. Shoki Takeuchi

He is acquiring the B.Ed. in the Faculty of Education in Ehime University.

Dr. Yoshihiro Ohnishi

He received his Dr. Eng. from Osaka Prefecture University in 2002. He is a professor at Faculty of Education in Ehime University.

Dr. Kazuo Kawada

He received his Ph.D. degree at Graduate School of Education in Hiroshima University. He is an Associate Professor in the Graduate School of Humanities and Social Sciences, Hiroshima University.