Implementation and Evaluation of STEM Education Lessons to Develop Appreciation for Electricity in Japan and the Philippines

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1. Introduction

STEM "Science, Technology, Engineering, and Mathematics" education is an educational approach that transcends subject-, school-, and grade-level frameworks and involves inquiry activities, problem solving, creativity development, and collaborative research. Implementation methods for STEM education are presented in the K-12 Framework for Science Education (2012, hereafter referred to as the "K-12 Framework"), a theoretical pillar of STEM education in the United States. According to this K-12 framework, learning has three dimensions: domain core concepts, cross-disciplinary concepts, and practices. Specifically, it is a type of education in which new concepts are generated by weaving together fragmented concepts, in which questions are resolved and new questions are generated, and in which highly comprehensive concepts are acquired through continuous learning, including self-learning. In fact, it is quite meaningful to engage in the practice of deepening discussion and ultimately self-learning in the course of inquiry activities. Within these processes, it is necessary to generate cognitive conflicts while utilizing scientifically incorrect concepts as a clue to answer questions arising from the learners and to further generate new creative questions by resolving the students' questions with the help of the professors. According to Berlyne (1970), cognitive conflict can be described as being one of the following types: doubt, embarrassment, contradiction, cognitive dissonance, confusion, and inappropriateness. Novak (1998) states that, when integrating and making sense of school knowledge and everyday knowledge, a situation occurs in which two or more incompatible ideas cannot fit together in the mind. In science education, the term naive concept is used to describe a concept that is different from a scientific explanation but can be explained in a child's own reasonable way of thinking. In such situations, different students' thinking processes are often similar even when there are considerable differences in age and learning experiences. It is very interesting to note that similar trends can be obtained even in different upbringing environments, including those in Japan and abroad. Yamaoka et al. (2022), based on the results of a survey of national science university students, reported that the most common time to embrace naive concepts was during elementary school for both girls and boys.

Since around 2015, we have been developing teaching materials for elementary school students and implementing them in classes while referring to STEM practice methods and utilizing cognitive conflicts. Specifically, we have been developing and implementing a number of teaching materials for elementary and secondary school students through a trial-and-error process, using permanent sesame and LED-

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based IC crafts as examples. In June 2022, first Author encountered a winding machine from Osumi Educational Support Institute (hereinafter simply referred to as "OES Institute"), and in July of the same year, he received an order from the OES Institute (1). The OES Institute was established by Dr. Osumi, a professor emeritus at Kyoto University of Education, on land adjacent to his home. In 2007, Dr. Osumi was assigned to the Institute for the Promotion of Science and Technology Education (IPST), Ministry of Education, Thailand, as a senior overseas volunteer dispatched by JICA, where he worked for two years on cooperative activities. Based on the results of these activities, after returning from Thailand, he established a community contribution-type institute that has continued to conduct educational activities, such as holding science classes for teachers and children in the Kansai region and other nearby areas, in cooperation with the Faculty of Information Science and Technology of Kansai University, the Faculty of Industrial Sociology of Ritsumeikan University, and others. At the institute, they introduced to many teaching materials used in the "Power Up" STEM education training program for teachers in Thailand, as shown in Figures. 1 and 2.

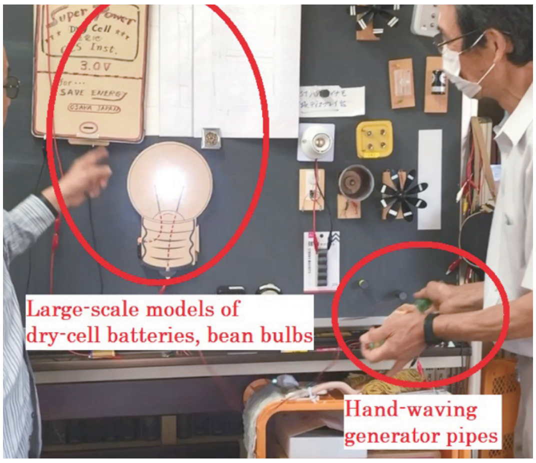

Figure 1 Handmade teaching materials

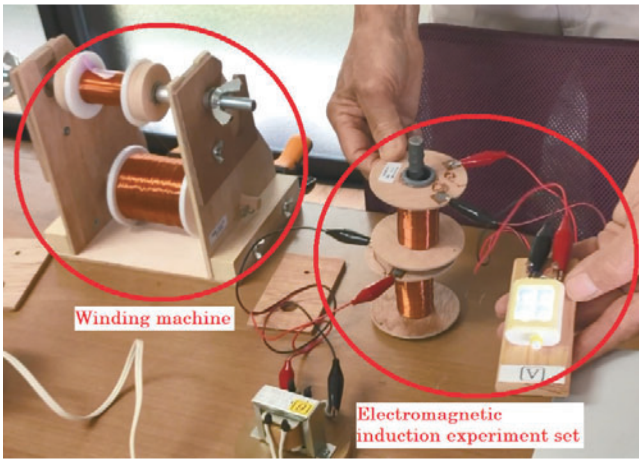

Figure 2 Handmade teaching materials

The contents I learned there were already being put into practice overseas (in Thailand); in addition, I was very much stimulated by the fact that information was being continuously exchanged with overseas experts during the COVID-19 disaster through the use of online systems. In July 2022, first Author used the teaching materials that learned at the OES Institute to teach a class at the university where he works, and in August of the same year, he visited a school in the Philippines to introduce the teaching materials to university teachers there. In this paper, we would like to introduce what we have done at universities in Japan and abroad after planning lessons using the OES Institute's STEM teaching materials.

2. Purpose of the Study

The purpose of this paper is to develop a lesson plan using the OES Institute's STEM teaching materials and then to practice and evaluate the lesson to verify the level of appreciation for electricity at universities in Japan and abroad.

3. Method

(1)Time of implementation and participants of the study

In late July 2022, 53 second-grade elementary education teacher candidates (39 men and 14 women) enrolled in the Faculty of Education at a private university in Aichi Prefecture were asked to practice teaching using materials learned at the OES Research Institute.

(2)Lesson design to examine the degree of appreciation for electricity as a function of the experience of working with windings

The purpose of the class was to examine the degree of appreciation for electricity that is brought about by the experience of winding work. We divided the class into two groups: Class α (n=29), in which the students were asked to fill in the worksheet after the winding experience, and Class β (n=24), in which the students were asked to fill in the worksheet before the winding experience. The classes were designed using the implementation method shown in Table 1, and the program was implemented in late July 2022. The worksheet created for the purpose of verifying the effectiveness of this class design will be explained in the next section.

Table 1 Class Design

	Class Implementation Process		
	June 2022	July 2022	
Class α (n=29)	Simple motor production	Winding experience	Worksheet description
Class β (n=24)		Worksheet description	Winding experience

As shown in Table 1, Class α was given the hands-on winding experience and then asked to light the LED with a hand-held generator pipe of their own making. The class was then asked to describe the process on the worksheet. Class β had the students fill out the worksheet after the teacher had them light up the LED with the hand-waving generator pipe (the finished hand-waving generator pipe) that they had already completed. After that, the students were given hands-on experience in the winding process. When creating two classes like this and comparing the effects of the two groups, Ross and Morrison (1995) state that the conditions must be exactly the same except for the specific teaching strategy that seeks to verify causal inferences. Therefore, from the standpoint of fairness, in the classes conducted in this study, both groups were taught by the same teacher, and the content was identical except for the timing of having the students complete the worksheets. Based on the above class design, although the class was divided for convenience, we made sure that there were no gaps in the class content and teaching methods in both Class α and Class β.

(3)Worksheet to verify the degree of appreciation for electricity brought about by the presence or absence of the winding work experience

In order to test the degree of appreciation for electricity that comes with the experience of winding, we decided to analyze the students' impressions when they experimented with LED lighting. As a hypothesis for the lesson design, we attempted to create a worksheet as shown in Figure 3 assuming that the level of appreciation for electricity would be higher in Class α.

What we learned from our experiments.	What I want to know more about	What I wanted to know more about
①	②	③
Thoughts (Did completing this worksheet help you organize your ideas?)		

Figure 3 Worksheet used in class

Specifically, Class α was conducted after the students had made their own hand-held generator pipe and engaged in experiments, whereas Class β was conducted after the students had engaged in experiments with a finished hand-held generator pipe and then made a hand-held generator of their own design. In addition, the worksheet was completed after the following explanation was given.

[Class α] Let's conduct an experiment using a hand-waving power generator pipe of your own making. Can you then explain the principle of this experiment?

[Class β] Let's try an experiment using a hand-waving power-generating pipe. Can you then explain the principle of this experiment?

(4)Practices for University Teachers in the Philippines

In August 2022, the company visited a university in the Philippines to introduce this teaching material to Filipino university teachers. After the practice, feedback was given to the Filipino university teachers.

4. Results and Discussion

(1)Class practice of winding work experience

Class α experienced the winding operation, and Class β experimented with power generation using the completed hand-waving power generator pipe. Figure 4 shows the winding experience of Class α . An acrylic pipe was cut with an acrylic cutter to a length (about 30 cm) that was easy to use in the experiment, and enameled wire was wound around the acrylic pipe 1,000 times using a winding machine. Figure 5 also shows an LED lighting experiment using a self-made hand-waving power generator pipe.

Figure 4 Experiencing winding work

Figure 5 Experiments using a self-made generator pipe

Class α had winding work experience and conducted experiments with a self-made hand-waving power generation pipe before completing the worksheet. Class β , on the other hand, conducted experiments on power generation using a finished hand-waving generator pipe, followed by a winding work experience, and then completed a worksheet. The results are summarized in Tables 2 through 5.

Table 2 Worksheet Results【No.1】

Response column	Description	Class α (n=29)	Class β (n=24)
What we learned from our experiments and found out	The number of turns is relevant	20	0
	LED lights up	6	8
	The principle	3	0
	The brightness changes depending on the swinging	0	12
	Difficulty	0	3
	Grateful for electricity	0	1

Table 2 shows that Class α, who experienced the winding process, described that they understood the number of windings and the principle of the winding process. In contrast, Class β, which used the completed hand-waving generator pipe, focused on the experimental result in which LEDs were lit up and described how the LEDs became brighter depending on how they were swung, or that the swing itself was difficult, but did not describe their consideration of the principle. The fact that the students actually made their own experimental device using a winding machine and saw the LED light up may indicate that they became more conscious of the principles of the hand-waving power generator pipe itself.

Table 3 Worksheet Results【No.2】

Response column	Description	Class α (n=29)	Class β (n=24)
What I want to know more about	What happens when you change the number of turns	21	1
	The principle	3	5
	The upper limit of brightness	2	0
	How to use	2	3
	Is continuous lighting possible	1	3
	The most efficient power generation	0	6
	How brightness changes depending on how it is swung	0	2
	The history of power generation	0	2
	The technology of energy storage	0	1
	The material of enameled wire	0	1

Table 3 shows that many of the Class α students expressed an interest in further research on what happens when the number of windings is changed. In contrast, Class β participants seemed to be interested in finding out more about efficient power generation, the principle of power generation, and whether there is anything else other than hand-waving power pipes. In response to the question of what they wanted to know more about based on the results of the experiment, some of the Class β students wrote that they wondered what the principle was.

Table 4 Worksheet Results【No.3】

Response column	Description	Class α (n=29)	Class β (n=24)
What I wanted to know more about	The principle	12	6
	What happens when the number of turns is changed	8	1
	How to use it	4	0
	Winding machines	2	0
	The method of continuous lighting	2	5
	The winding method	1	0
	The difference in brightness by swinging	0	8
	How to make it brighter	0	3
	How to use	0	1

Table 4 shows that, with regard to the questions, Class α often described things related to the principle of the hand-waving generator pipe and what would happen if the number of windings were changed. In contrast, Class β often responded not to the principle but to the experimental method, such as the idea that the brightness changed depending on the way the pipe was swung. Note that Osumi (2019) stated that, with a coil of 1000 windings, a faint LED was confirmed at 600 windings when a ferrite magnet was used. Based on this, we also tried a case using a neodymium magnet, and the lighting was confirmed after 450 windings. These are subjects that can be implemented as free research in junior high schools and in research projects in high schools. In this way, the attitude of making one' s own experimental plan and challenging oneself based on newly arising questions can be considered to be applicable to the process of inquiry, which is required in STEM education.

Table 5 Worksheet Results【No.4】

Response column	Description	Class α (n=29)	Class β (n=24)
Thoughts (Did completing this worksheet help you organize your ideas?)	I would like to do more experiments	7	0
	Interesting	7	2
	Great sense of accomplishment	6	0
	I could understand the principle	6	0
	I could understand the importance of electricity	2	0
	Raised many questions	1	0
	Worksheets are good	0	10
	It was difficult	0	4
	It took a lot of effort	0	2
	About how to use the system	0	1
	I want to think about efficient ways of generating electricity	0	1
	Would like to find out about the number of windings	0	1
	No answer	0	3

Table 5 shows that, regarding their impressions, many of the Class α students said that they wanted to do more experiments and that it was interesting. In contrast, Class β focused more on the worksheet itself, not on the experiments. In sum, the experience of working on the winding machine was described in terms of the principles but also in terms of the experiment itself. In other words, the experience of working on the winding machine is a teaching strategy that can lead to the next class in that the content of the experiment is likely to leave a lasting impression, and new questions will arise based on the desire to understand the principles.

(2)Practices for University Teachers in the Philippines

(2-1) STEM Education in the Philippines

In August 2022, we visited Wesleyan University Philippines and Bulacan State University in Cabanatuan City. The students were told that the university is working on STEM education in relation to the SDGs. Specifically, they were conducting research on dried food using the experimental apparatus shown in Figure 6 to examine food issues. Using the experimental apparatus shown in Figure 7, they were studying energy issues by conducting research on using tidal currents to create a power generator.

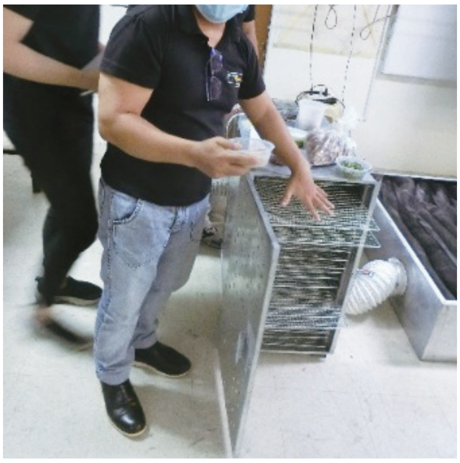

Figure 6 Research on food issues

Figure 7 Research on energy issues

Next, we visited the Bulacan State University in Malolos. Figure 8 shows the laboratory, which was devised to promote STEM education while creating handmade teaching materials, as shown in Figure 9.

Figure 8 The laboratory

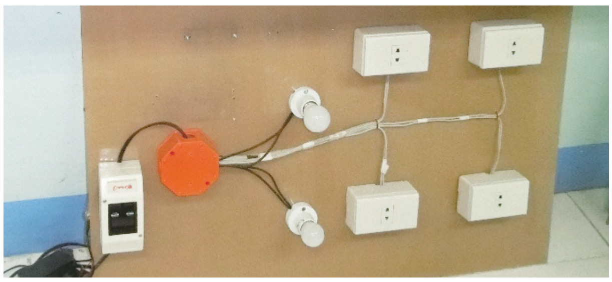

Figure 9 Handmade teaching materials

In the Philippines, science is formally taught from Grade 3 until Grade 10. In addition, specialization in science is offered for students under the STEM track. English is used as a medium of instruction for all levels. The science curriculum recognizes the important role of science and technology in everyday human activity. The science concepts are grouped into different themes and geared toward the development of scientific, technological, and environmental literacy.

(2-2) Practices for University Teachers in the Philippines

At Bulacan State University, an experiment on STEM education was conducted with six Filipino university teachers specializing in science education, science and technology education, and early childhood education. Figure 10 shows the simple motor fabrication. The experiment consisted of a simple motor and a hand-waving generator pipe after outlining the practices described in Table 1 in the previous section.

Figure 10 Experiment with a simple motor

The simple motor and the hand-waving generator pipe used in this practice were both equipment distributed by the OSE Research Institute and were brought to the Philippines from Japan, and Figure 11 shows the experiment using the hand-waving generator pipe.

Figure 11 Experiments using a hand-waving power generation pipe

As shown in Figure 10, the simple motor was completed, and some university faculty members applauded when the enameled wire rotated. After the creation of the simple motor, which required batteries, experiments were conducted using the hand-waving generator pipe shown in Figure 11. Some teachers commented that these experiments could be used to teach students about the importance of electricity, and some teachers specifically wanted their students to experience these experiments. Therefore, a plan was made to conduct the experiments with secondary school students and university students in the next fiscal year and beyond. Table 6 below shows some of the comments from Filipino university teachers after the experiment.

Table 6 Post-Experiment Impressions by Filipino University Teachers (partial)

A. Simple Motor	B. Hand-Waving Generator
I believe that a simple motor can be used by teachers at both elementary and secondary levels in teaching science even in the Philippines. Through the use of the simple motor, learners can easily understand the concept being taught. However, there is a need for the teacher to explain which side would be fully rubbed by sandpaper and which should be half only. Additionally, the materials used to make the simple motor are easy to find and available here.	I think this practical instructional material can be useful in teaching science concepts at the elementary and secondary levels. It promotes inquiry and critical thinking among learners. It is very interactive to use. It can be used even without a battery.

5. Conclusion

Based on the above study, understanding the content of the research through a hands-on experience with basic experiments in electricity is different from learning from textbooks and videos and is expected to generate new questions to invite further exploration, ultimately leading to the development of learners who are capable of self-learning. Therefore, focusing on the electrical field will be useful in promoting STEM education not only in Japan but also in Asia.

Note

1) The OES Institute was established by Dr. Norikazu Osumi, Professor Emeritus of Kyoto University of Education, who was appointed to the Institute for the Promotion of Science and Technology Education (IPST), Ministry of Education, Thailand, and has been engaged in cooperative activities.

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