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Developing Young Children's Scientific, Technological, and Social Competency through "Pendulum" Play Activities at Japanese Kindergarten

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Abstract. There is growing recognition that young children are familiar with naïve physics, and construct their own theory about the natural world from early childhood. The research reported in this study focuses on intellectual play activities involving pendulums carried out by young children at a kindergarten in Japan. Over the course of three weeks, five-year-old children participated in these pendulum play activities. They made pendulums by themselves, tried them out, compared them with others, identified variables in moving, controlled these variables, and communicated their findings with others in the context of free guided play. Throughout these activities, the children changed their sense making of pendulums as objects of art to objects for investigation. Simple equipment, such as weight balances and counters, seemed to develop their scientific and technological competency. Their findings were displayed on a communication board so that they could appreciate and discuss them with each other. Socio-cultural aspects of science and technology in our global society are coming into the spotlight in the field of science education. Drawing on recent reviews, this paper proposes some implications in relation to the theory and practice of science activities for young children that aim to develop their scientific, technological, and social competency in early childhood.

Key words. Pendulum; STS (Scientific, Technological, and Social) Competency

In recent years, many new views have been aired on cognitive development, and many of them challenge Piaget's theory on children's acquisition of scientific knowledge and conceptual changes in science. Study findings revealing the high scientific competency of children in what Piaget considers the concrete operational, preoperational and sensorimotor periods have been successively presented around the world since the 1980s. In fact, problems have been noted regarding several of Piaget's development tasks from a methodological point of view (Siegal, 1991). It has been found that in experiments in which a task is used in a way that is clearly understandable to children, a "correct" response can be observed even at a much lower age than Piaget supposed. Also, as found in reviews (Inagaki, 1996; Ochiai, 2000; Wellman & Gelman, 1998), a large number of research results citing specific data have been reported to justify assumptions of naïve physics and naïve biology as innate constraints or "domains," in which infants acquire scientific knowledge and change their understanding in science. In other words, research findings available today enable us to assume broad "domains," such as naïve physics and naïve biology in children's early cognition and thinking. Children are able to do abstract scientific thinking in specific domains from a very early phase of their development.

However, the high competency in the domain of physics is not always reflected in science curriculums and science teaching for young children. Sprung (1996) deplores that science, particularly *physical* science, is not given equal importance to other areas of the curriculum in most classrooms. The pendulum, which Matthews (2004) claims to be a most suitable topic for discussing science studies, cognitive science and science education, was selected as the topic of this study. It has also been reported that 5-year-old children could predict and answer questions relating to pendulum motions correctly (Sumida, 2004). DeVries (2002) defined "physical-knowledge activities" as those in which children act on objects and observe their reactions, and pointed out that such activities appeal to children's interests, inspire experimentation, and usually involve cooperation.

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It is a notable feature of the past few decades that many of the boundaries between the natural sciences and their associated technologies have been dissolving before our eyes. Technoscience is an essential component of economic development (Ziman, 2000). In 1998, National Curriculum Standards for Japanese Kindergarten were revised, and the newest and existing version has been implemented. One of the new content inclusions in the new Standard involves a technological aspect, "*Developing an interest in surrounding things and play equipment, and through thinking about them, coming up with creative ways to make the best use of them.*" History of Pendulum (Matthews, 2000) shows the strong relationships between progress of science and innovation in technology as Navigation and Timekeeping in society.

Social points of view in the field of science are being expressed in science education research around the world (e.g. Cobern, 1999). Science is now identified as a culture emerged from the Western Modern Age. Like any other culture, "Science" has a history of development and change. It emerged in essentially its modern form in Western Europe in the first half of the nineteenth century. Since then it has evolved into a coherent and elaborate social activity, and is being increasingly integrated into society at large. Indeed, science has grown and spread throughout the world as a characteristic of modernity. Science, Technology, and Society (STS) Education is the new transformation of science education and such an integrated way of teaching science will ascertain the validity of science education for early childhood. Pendulum activities for young children will be useful for developing their social and technological competency as well as scientific competency.

The purpose of this study was to test the effectiveness of pendulum activities, as developed for this study, in enhancing the scientific, technological, and social competency of children.

Methods

Subjects

This study involved a total of 67 five-year-old Japanese children attending a kindergarten ("yochien" in Japanese) attached to a national university in a city location. The subjects were 30 boys and 37 girls. The kindergarten provides half-day education for children aged between 3 and 5. Facilities include one classroom per class, a meeting hall, a large schoolyard, a library, a staff room and several other rooms. All class members come together at meal-time and have a class meeting before leaving. The remainder of the time is for free play. Children can choose their favorite play activities inside and outside their classroom.

Research Design

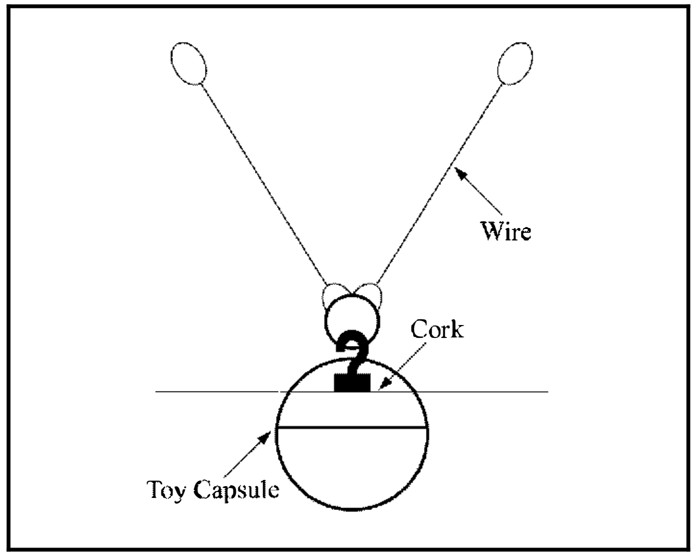
Pendulum activities were conducted for 18 days from November 15 to December 19, 2005. The children were free to participate in these activities and spent about 3 hours on them daily. Therefore, both small group activities and large group activities were included in the context of free-guided play. These activities were set up in both the science area inside and the outdoor area. Pre-organized parts of activities were very limited. The teacher acted as a warm and nurturing guide for carrying out each activity using a holistic approach to develop children's scientific, technological and social competency. The experiments proposed by the children during the course of the activities were abundant and challenging. Data was collected during the activities using audio recording, video recording and a digital camera.

At the beginning of the activities, the pendulums were displayed at face height so experiments could be carried out easily and safely. These demonstration pendulums were created using materials found in everyday life (Figure 1). Toy capsules were fixed by a piece of cork to stainless steel wires, which do not stretch even when suspending a heavy bob. Two wires were used to prevent any spinning. This type of pendulum was beneficial for this study because it is:

(1) Easy to make and easy for young children to use
(2) Very stable and accurate
(3) Easy to change the weight of the bob and observe the weight of the capsule
(4) Easy to change the length of the pendulum
(5) Easy to display and compare with others

DeVries (2002) proposed four criteria for good physical-knowledge activities in early childhood. These are: (1) the child must be able to produce the phenomenon by his or her own action, (2) the child must be able to vary his or her action, (3) the reaction of the object must be observable, and (4) the reaction of the object must be immediate. The pendulum used in this study allows for the fulfillment of all the criteria. Kamii and DeVries (1993) introduced the pendulum as a physical science activity for pre-school children, but the design of the pendulums did not allow for easy changes in the variables, unlike the pendulum used in this study.

Figure 1. Pendulum Designed for This Study



Results

The pendulum play activities carried out during the 18 days of this research were divided into three parts:

The first part of the pendulum play activities (4 Days)

Before the first day of the activities, the teacher prepared 18 pendulums suspended under the eaves of the classroom. All pendulums were the same length and weight, with sand used as the weight. The teacher observed how the children played with them.

At first, many children gave the pendulums names such as "Dream Ball" and "Monster Ball." Next, their focus of interest shifted to (1) the matter inside the capsules (which elicited comments and questions, such as "There is sand in the capsule," "How did you put sand in the capsule?" etc.), and (2) the properties of their weight ("Light," "Hard," etc.). One child put water in one of the capsules and introduced the new capsule to other classmates. Others added more sand to them.

One girl began to count the swings of one of the pendulums. The teacher encouraged her to continue but she stopped counting at around 170 when she became tired.

The second part of the pendulum play activities

An increasing number of children wanted to make pendulums by themselves in the latter half of the first part. The teacher created Pendulum Institute (Special Science Corner for Pendulums) for the children and invited them to make their own pendulums there (Figure 2). They prepared a variety of matter to put in their capsules (sand, beads, and cotton, etc.), decorated them in various ways (Figure 3) and worked well with each other.

Figure 2. Pendulum Institute (Special Science Corner) at the kindergarten

Figure 3. Children's Pendulums

Those who made their own pendulums began having a pendulum swing competition (Figure 4). At first, the competition was based on the speed of the swings. It was very difficult for them to judge which pendulum was swinging faster. Nevertheless, some discovered that the swinging speed was related to the weight of the pendulum. One boy said, "I lost when I didn't put sand in the capsule, but won when I added sand and made my capsule heavy."

Figure 4. Competition in Pendulum Swings

The focus of the pendulum competition then changed from the speed of the pendulum swings to the number of pendulum swings. The boy who suggested having the competition had already tried these experiments relating to the number of pendulum swings using a pendulum at home. The higher the number of pendulums used in the competition, the more difficult it was to compare their weight. Next, the teacher introduced weight balances to the children. They easily understood their purpose and used them to compare the weight of many things, e.g. stones (Figure 5).

Figure 5. Weight Comparison Using a Weight Balance

Some children asked the teacher to have a competition. One girl had a competition with the teacher 5 times. When she lost the first competition, she said, "I lost because the stones in my capsule are heavy." She often changed the weight of her pendulum by taking stones out of the capsule and adding sand, etc. However, she still could not win. She thought about different ways to make her pendulum swing faster and came up with an idea. She said, "The big ears on my capsule (decorated like an elephant) are disturbing the swinging!" She removed the big ears and finally won the competition with the teacher. The activities became more sophisticated as the children began to accurately measure the weight of their pendulums. One boy tried using different weights in his capsule to find the most suitable one to create the fastest swing. He discovered "neither heavy nor light are good."

In competing for the highest number of pendulum swings, it was difficult for most of the children to count over 100 even though they already knew a number of three figures. The teacher introduced a simple counter to them (Figure 6). It involved pushing a button with swings and could be easily used to measure the number of pendulum swings. They enjoyed using it and then recorded the number of swings of their own capsule (Figure 7). Some of them measured more than 1,000 swings.

Figure 6. Counter to Measure Pendulum Swings

Figure 7. Number of Pendulum Swings

The children became more competent in carrying out experiments after they mastered using the weight balance and counter. The more sophisticated their experiments became, the more cooperation needed among them and the more social interaction that developed. As the activities continued, they worked efficiently and cooperatively with each other, and were well behaved. Some children cautioned others who cut in on activities. They also took care with handling of common equipment and apparatuses, and shared their use among friends.

The third part of the pendulum play activities

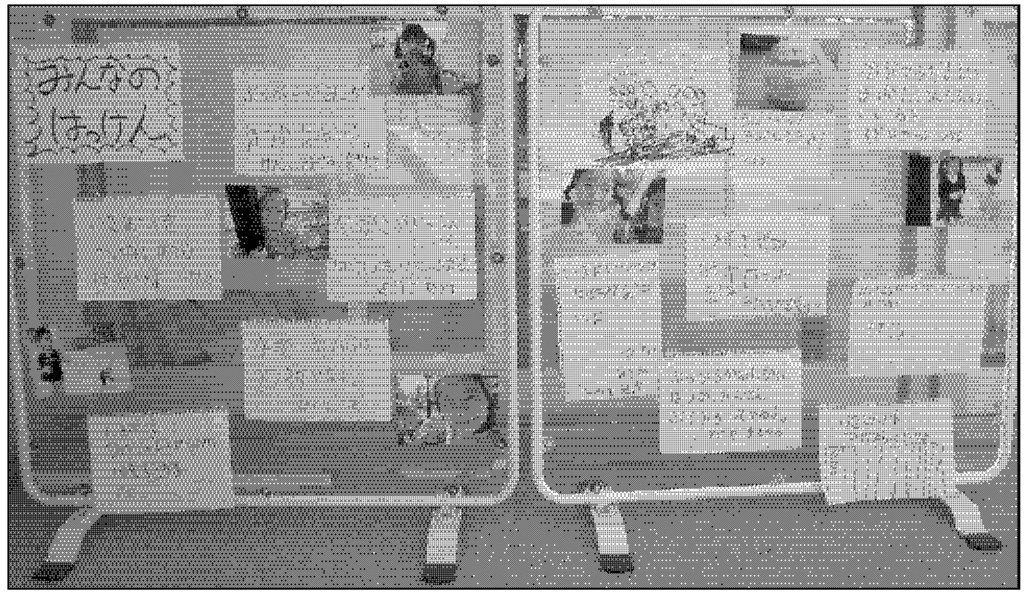
At the end of the second part, some children predicted that a higher starting point would create more swings. In the third part of the pendulum play activities, the teacher prepared pendulums of various lengths and suspended them from the eaves of the classroom (Figure 8). The scale was shown on a pole next to the pendulums.

Figure 8. Pendulums of Various Lengths

The children looked for a more simple way of comparing the pendulum swings. With the teacher, they created a new method of measuring and comparing the time for ten swings to occur, taking the speed and number of swings into consideration. This way of measuring achieved a consensus among the children. It made their pendulum experiments very simple and easier to carry out properly.

The children's products and the pendulum activities were photographed using a digital camera. These photos showing their ideas and findings were displayed on the *Discovery Board* for others to see (Figure 9). This encouraged the children to express their own ideas, find self-fulfillment, pay attention to the findings of others and acquire literacy. Some had a keen interest in the new findings. Some claimed the same findings as others and added their names to the findings concerned.

Figure 9. Pendulum Discovery Board



Jones and Courtney (2002) pointed out that the documentation process itself helps teachers gain a deeper understanding of individual children in the class and enhances general knowledge of how young children make sense of the world. By engaging in the documentation/assessment process of collecting, describing, and interpreting evidence of young children's understanding in science, early childhood educators are able to provide more appropriate learning experiences and environments. In this study, the teacher delivered a short lecture with simple experiments on the basis of the children's findings on the *Discovery Board* at the end of the pendulum activities. The first experiment was based on the length of the pendulums. Three of the children discovered and reported on the board that shorter pendulums swung faster during the activities. The teacher showed pendulums of two different lengths and asked children to predict which would swing faster, the shorter pendulum or the longer pendulum, or if they would swing at the same speed. Most of the children predicted that the shorter pendulum would swing faster. Then the teacher carried out the experiment to compare the two pendulum swings. The children's claim was proven correct.

The second experiment was based on the amplitude of the pendulums. There were two opposite findings on the *Discovery Board* about the effect of amplitude on pendulum swings. Three of the children reported that pendulums with a large amplitude swing more slowly while another child reported the opposite. The teacher carried out an experiment to compare both findings. However, the purpose of this experiment was not clear enough for the children to identify the effect of amplitude on pendulum swings.

There were three different findings on the board about the effect of weight on pendulum swings. Two of the children reported that if the length of two pendulums is the same, the speed of swings is also the same regardless of weight. Another child reported that if the length of two pendulums is the same, the lighter one swings faster. These findings differed from each other but both included two variables, *length* and *weight*, in reference to pendulum swings. For the third experiment, the teacher used different weights to compare the swings. After the third experiment, an increasing number of children agreed that pendulum swing speed does not depend on weight.

Figure 10. Science Lecture and Experiments on Pendulums

Flow of the children's thinking during the pendulum activities

The pendulum activities in this study were conducted in the context of free-guided play so that the children could choose to participate in the activity of their own will. Some children only chose to participate in the activities for some of the 18 days. The number of participating children differed daily. Therefore, it was very difficult to analyze their behavior longitudinally and statistically. The three children who most often participated in the activities during the 18 days were focused on to outline changes in their thinking during the activities. Table 1 summarizes the flow of their thinking at specific points during the 18-day pendulum activities on the basis of their protocol data.

Table 1. Flow of Three Children's Protocols during the 18-Day Pendulum Activities

	First Part				Second Part									Third Part				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Characteristics of Pendulum	A	A			B		B		B		B/C							
Variable (1):Length							B				B	B		A/B/C	A/C			A/B/C
Variable (2):Amplitude												B/C		A		C	B/C	A/B/C
Variable (3):Weight													C	B/C		C		A/B/C
Measurement (1): Weight						A	B		B	A/B		B					B/C	
Measurement (2): Speed/Period											B	B/C	C		C	C	C	
Activity Regulations							B		B			B						

"A," "B" and "C" in Table 1 represent each child and refer to what each child mentioned at a specific point in the day. There were a few protocols only about the characteristics of the pendulums in the first part.

Protocol Example in Characteristics of Pendulum (Day 1 in the first part)
Child A: Is this "Yume Yume Ball" (that he used in Literary Exercise at the kindergarten)?

The children mentioned the measurement of the pendulums in the second part and then started to talk about variables in pendulum swings. It is clear that these three children controlled the variables used for investigating the pendulum swings in the third part.

Protocol Example in Measurement (Day 9 in the second part)
Child B: This is heavier.
Teacher: Is this heavier? How do you know this?
Child B: Because this arm (of balance beams) is higher.

Protocol Example in Variables (Day 14 in the third part)
Child C: This pendulum swings faster. I told you so! (He wrote "Shorter pendulum swings faster." on Pendulum Discovery Board).

Protocol Example in Activity Regulations (Day 12 in the second part)
Child B: Yes. Over 90.
Teacher: You got it! It'll be over 200, actually.
Child B: Over 200 times! Don't touch the pendulum! (to friends)

On some days, child "C" pursued a better way of measuring. The "activity regulations" included cautioning anyone who disturbed the experiments. The children investigated autonomously and cooperatively from the second part.

Discussion

Young children are generally enthusiastic about activities but may easily lose interest in carrying them out. Support and guidance from teachers, as well as a suitable arrangement of the learning environment, are needed to increase children's ability to learn. Children's social skills develop best when they have opportunities to learn and practice them in the context of meaningful activities (Conezio & French, 2002). Making the pendulums, organizing the competition, operating equipment, and reporting the findings in the second and third parts, were all interconnected to enhance the children's scientific, technological, and social competency.

Kotloff (1993) reported that the yochien teachers in Japan were able to establish a complementary relationship between the individual and the group in the classroom. One factor that accounted for this success was the way cooperative group-activity formats and individual-activity formats were integrated. This facilitated an exchange between the individual child and the classroom group that enriched and enlivened both. In the first part, the children played with the pendulums individually. They were unable to continue playing with them without the teacher's support at the end of the first part. The pendulum activities in the second and third parts changed their understanding of pendulums as objects of art to objects for investigation. The activities also became more interesting for them. They wanted to play with their own pendulum and to have competitions with others. Children did what was possible independently and experienced enjoyment and sadness together through establishing active relationships with friends. During these competitions, they studied the relationships between the properties of their pendulums and pendulum motion. Then, they spontaneously worked on their pendulums to allow them to swing faster and/or longer. This inspired some to collaborate with others. For example, a boy asked a girl if she would work with him. He counted the number of swings as she swung the pendulums. As the activities went on, the children continued to work well in groups, deepening relationships and showing awareness of others through the pendulum activities.

The optimal development of competency in science activities depends on a cooperative social context as well as technology. AAAS (1999) attempts to discuss science, mathematics, and technology holistically in early childhood education. Modern science, technology and society are interdependent. Technology is not equivalent to only computers. The use of simple equipment such as weight balances and counters in making the pendulums helped encourage the children to become more involved in the activities and to develop their higher order thinking. They compared the weight of the capsules and looked for something to equal the weight of their own capsule. This activity also promotes an interest in and understanding of density. Counting was used by children in measuring many different kinds of phenomenon in everyday life. They count the time to go downhill, to finish cleaning the rabbit house, etc. By using the counter, *numbers* became an integral part of their pendulum activities. The use of numbers made the carrying out of the children's experiments more efficient and the findings recordable. Children developed an interest in measurement equipment, came up with creative ways to use them, and increased their understanding of quantity and numbers in nature.

Hoisington (2002) pointed out that using photographs in children's science activities is to help children to (1) revisit and extend their experiment, (2) reflect on their experiences and articulate their strategies, and (3) analyze and synthesize data. The *Discovery Board* in this study encouraged the children to express their findings, achieve self-fulfillment and pay attention to others' findings. In this way, the Discovery Board also helped to create a sense of togetherness and "community." There were some opposing findings on the *Discovery Board.* However, in the field of science, this type of situation is as healthy as achieving a consensus. The strength of science is tolerance of difference of opinion (Ziman, 2000). The OECD group proposes three Key Competencies. These are the ability to: (1) interact in socially heterogeneous groups, (2) act autonomously, and (3) use tools interactively (Rychen & Salganik, 2003). The pendulum activities in this study included (1) interacting in different groups and ways, (2) acting autonomously and collaboratively, (3) using tools properly and making things, and (4) creating and appreciating new ideas. It may be concluded that science activities are effective in enhancing young children's social, technological, and scientific competency. Future research needs to be carried out to investigate the effectiveness of science activities in developing multiple competencies in early childhood.

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