Chapter 10
Characteristics of Learning Environments and Teachers' Support for Children's Creative STEM Enquiry in Japan

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10.1 Introduction

In recent years, interest in science, technology, engineering, and mathematics (STEM) in pre-school, primary, and secondary education has increased in Japan. As a result of this academic trend, the *Japan Society for STEM Education* was established in 2017. In addition, other science education-based academic associations have increased their amount of related research on the basis of competitive research grants, such as *Grants-in-Aid for Scientific Research* as supported by the *Japan Society for the Promotion of Science*. Moreover, an increasing number of books and toys oriented towards STEM for pre-schoolers and early elementary students are now displayed at bookstores and toy stores. However, some of them merely focus on a single STEM discipline, such as counting, resulting in fewer opportunities for children to be creative. It is expected that STEM enquiries in multiple STEM disciplines would provide learning opportunities for children when they try to combine different ideas to solve a problem and make something new.

The purpose of this chapter is to discuss important elements of STEM enquiries that can foster creativity (hereafter called creative STEM enquiries) from the perspectives of both environments and teachers' support by using a curriculum analysis, meta-analysis, and practice record analysis.

This study presents Japan's case for creative STEM enquiries, which emphasises comprehensive instruction under its curriculum. A report on how creative STEM

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enquiries in early childhood are being taught under this kind of curriculum could be useful for countries with similar curricular characteristics.

10.2 Background

To provide context for creative STEM enquiries in early childhood education in Japan, we discuss the major characteristics of both the curriculum and STEM enquiries, as well as situations wherein creativity has been interpreted. These situations will be used as markers of creativity in this chapter.

Historically, comprehensive instruction has been emphasised in early childhood education in Japan. Based on children's interests and curiosities, instruction is provided through children's play and activities, which are not directly related to set disciplines. Although the *National Curriculum Standards for Kindergarten* (i.e. the national pre-school curriculum; hereafter called the National Curriculum) stipulate five content domains, such as 'health', 'human relationships', 'environment', 'language', and 'expression', these domains should be treated holistically. For example, the *National Curriculum Standards for Kindergarten* explains that the learning of the curriculum's content is "delivered in a comprehensive manner through the specific activities which are developed in relation to the children's learning environment" (Ministry of Education, Culture, Sports, Science and Technology (MEXT), 2017, p. 11). That is, teachers must bear in mind that comprehensive instruction should be used for activities. This approach is a major curricular characteristic of early childhood education in Japan.

In the context of Japanese primary and secondary schools, STEM learning aims to solve complex issues in contemporary society by utilising multiple concepts and ways of thinking that originate from each of the STEM disciplines (Matsubara, 2020) rather than using a single discipline. STEM enquiries can be understood as the use of multiple perspectives or ways of thinking; namely scientific enquiry, engineering processes, and mathematical thinking (Matsubara, 2020; Otani, 2020). While each discipline-based way of thinking is important, the engineering process is focused on in this study's analysis. This is because engineering involves the extraction of an optimal solution via trial and error for a specific purpose, and is more closely related to creativity than other ways of thinking.

The definition of creativity varies, to some extent, depending on the academic field. In this study, we refer to Takahasi Makoto's general definition of creation from the *Japan Creativity Society*. Takahashi issued a questionnaire to members of the Society that asked "What is creation?" in 1983, and received definitions from 83 members. After referring to these definitions, he came up with the following: "Creation is to solve problems when people put together and integrate different kinds of information and produce a new value at the society or individual levels" (see http://www.japancreativity.jp/definition.html; translated by the authors). Regarding early childhood, children can 'solve' problems through their activities, which naturally involve play at the ECEC centres. Most children typically try to

solve a problem by using creativity during early childhood. Generally, the level of creativity that can be seen in the ECEC centre setting is quite basic. Thus, in relation to creativity, children's actions that we see are expected to be simpler and the utterances we hear are expected be shorter and more limited in meaning. Considering Makoto's definition and adaptation to children's activities in the ECEC centre setting, we assume that creativity can be cultivated when we witness children's actions and/or utterances regarding the following:

1. Trying to solve a problem individually or with a group, often using different types of information.
2. Producing new things or ideas.

In the following sections, we use situations (1) and (2) as markers of creativity to determine whether or not activities that children are involved in can be regarded as activities fostering creativity. It is important to note that teachers can provide the right environment and support for such situations through STEM enquiries. In particular, engineering, which deals with trials and errors, goes well with creativity.

10.3 Elements of Creative STEM Enquiries and National Curriculum for Kindergartens

This section conducts a brief curriculum analysis to identify important elements of both environments and teachers' support that are thought to help creative STEM enquiries in early childhood education in Japan. In the curriculum analysis, our focus was on creativity and the ways of thinking about STEM enquiries, particularly those related to engineering processes. The interpretation of creativity and the major characteristics of the curriculum and STEM enquiries, as discussed above, were utilised as lenses to view descriptions of the curriculum. Regarding the procedure, a qualitative analysis was conducted to identify important elements of both environments and teachers' support that are thought to enhance creativity or STEM enquiries in descriptions of the curriculum. Two experts in STEM education and the curriculum, and one expert in early childhood education participated in the analysis. Reference was made to statements from the National Curriculum provided by the *Ministry of Education, Culture, Sports, Science and Technology* (MEXT).

10.3.1 Creativity in the Curriculum

The National Curriculum uses the term 'creativity' only once and describes it as "developing rich feelings and the ability to express oneself, and enhancing creativity by expressing experiences and thoughts in their own words" (MEXT, 2017, p. 17). This is intended to explain the meaning of the 'expression' domain, which is

one of the five domains defined in the National Curriculum. The 'expression' domain's content uses the term 'creative' to signify "[children] being familiar with various materials and making use of them creatively in play" (MEXT, 2017, p. 17). The Ministry guidelines on the National Curriculum explain that this kind of experience during play is the source of creative activities (MEXT, 2018). From these descriptions, we can see that the curriculum emphasises the importance of an environment that contains various materials alongside the teachers' support to allow children to make use of these materials during play. The National Curriculum also stipulates that the seeds of creative thinking should be cultivated during early childhood (MEXT, 2017). The guidelines further state the importance of expanding children's interests through experiencing various surrounding things, and that they should keep thinking and trying, even when these things do not work well (MEXT, 2018). From these descriptions, we can see that the curriculum emphasises the importance of an environment that attracts both the children's interests and the teachers' support so as to allow the children to continue to try. For example, teachers can support children by providing enough space and time for them to keep trying when they are involved in an environment that is relevant to their interests.

Regarding environments and teachers' support, we have seen that, with a focus on creativity, the curriculum emphasises:

- Environments that contain various materials as well as teachers' support to allow children to make use of these materials during play.
- Importance of environments that attract children's interests.
- Teachers' support that allows children to continue to try.

These points will be used to organise the important elements of the creative STEM enquiries later in this chapter.

10.3.2 STEM Enquiries in the National Curriculum

STEM enquiries are not commonly understood in the field of early childhood education in Japan. One reason could be that the concept of STEM education is a relatively new idea for teachers in this field in Japan. A more important underlying reason could be that comprehensive instruction is valued, as previously explained. Many practitioners and researchers would disagree with the idea that activities in ECEC centres focus on specific disciplines such as science, arithmetic, and languages. However, while they are not explicitly described, some ways of thinking that are related to STEM enquiries can be found in the National Curriculum. They are often embedded as parts of comprehensive instruction since content is not separately described as specific disciplines.

The latest National Curriculum has incorporated perspectives and ways of thinking within pre-school education. These include becoming aware of one's environment and its significance as well as ways of engaging with it, exploring it in a trial fashion, and thinking about it (MEXT, 2017). These kinds of thought processes in

early childhood education demonstrate correspondence with the seeds of engineering processes—namely, 'thinking by means of trial and error'. We can also see that the curriculum emphasises the importance of teachers' support, which allows children to explore and think by trial and error when focusing on the way of thinking shown. In addition, the descriptions of 'becoming aware of one's environment' and 'engaging with it' (one's environment) show how the curriculum emphasises the importance of the environment that children engage in as a learning content that should be relevant to both their interests and the real world.

Regarding environments and teachers' support, we have seen that, with a focus on STEM enquiries, the curriculum emphasises that:

- The environment in which children engage in as a learning content should be relevant to their interests and the real world.
- Teachers' support allows children to explore and think using trial and error.

Table 10.1 summarises the two perspectives with a focus on creativity and STEM enquiries.

This chapter uses the points emphasised by the curriculum—the various environments that are relevant to children's interests and the support for children's trial and error during play—to explore both environments and teachers' support, which are thought to help with creative STEM enquiries in early childhood education in the context of Japanese ECEC centres.

These two important elements of creative STEM enquiries will be used in the next section of the meta-analysis to review the studies that have dealt with STEM and early childhood education.

10.4 Learning Environments and Teachers' Support for Creativity in STEM

We conducted a meta-analysis of the existing studies to see how they dealt with the two aforementioned elements and explored whether they contributed to fostering creativity. One thing to note here is that the reviewed studies were not necessarily

Table 10.1 Environment and teachers' support for creative stem enquiries extracted from the national curriculum

	Environment	Teachers' support
Creativity	The environment should have various materials and teachers' support to allow children to make use of material during play. The importance of the environment attracts children's interests.	Teachers' support allows children to continue to try.
STEM enquiries	The environment that children engage in as a learning content should be relevant to both their interests and the real world.	Teachers' support allows children to explore and think by trial and error.

those that were intentionally prepared to show the relationship between the environment and/or teachers' support and creativity. To determine whether creativity is cultivated, rather than directly searching for the term 'creativity', we inferred from descriptions in the literature when we found information about children's actions and/or utterances regarding the following:

- Trying a problem individually or with a group, often using different types of information.
- Producing new things or ideas.

The analysis was conducted using the following academic journals: 1) those that cover STEM education fields in Japan; namely, *The Journal of Science Education in Japan* and *The Journal of Research in Science Education*; and 2) those that deal with pre-school education, namely *Research on Early Childhood Care and Education in Japan*, *The Journal of the International Association of Early Childhood Education*, *The Japanese Journal of Infant Care and Early Childhood Education*, and *The Japanese Journal of Historical Studies of Early Childhood Education and Care*. The analysis period was from 1989, the year of the first major revision of the National Curriculum for early childhood education, to 2019. This was because the 1989 revision was the first time that pre-schools were released from a kind of preparatory education for elementary school, which was a format that existed to a certain extent within childcare and similar facilities. The aim of the major revision was to launch independent, autonomous pre-school education. The core of the revision was the 'comprehensive instruction through play and the daily life of pre-school children' at childcare facilities and so on. While minor curriculum changes have occurred approximately every ten years since then, the 1989 revision entailed a transformation of the fundamental principles of ECEC in Japan.

A search was made for titles and subtitles in the aforementioned journals, as follows. In the journals that cover STEM education fields, the keywords were 'pre-school', 'pre-schooler' or 'child', 'kindergarten', 'day-care' or 'childcare', and 'young child'; 11 related articles were extracted from these journals. In the journals that deal with pre-school education, 43 articles that included keywords related to the STEM domain were extracted. Next, the contents of the extracted papers were reviewed, and a selection was made of those that included statements related to 'learning environment' and 'support provided by ECEC teachers' (i.e. day-care centre teachers, kindergarten teachers, etc.) within Japanese pre-school education. Thus, 25 papers were selected for analysis. There were two out of the 25 papers that included some ideas regarding the fostering of creativity, and one of them describing the 'various environments relevant to children's interests and the real world' and the other describing the 'support for children's trials and errors during play' were identified in the curriculum analysis. Each of them was given additional information provided by another paper out of the 25 papers They were summarised into two case studies: the playground environment and origami (paper folding), as shown below. Only ten out of the 25 papers mentioned one of the two important elements without describing creativity.

10.4.1 Various Environments and Trial and Error During Play for Creativity

10.4.1.1 Playground Environment

Tajiri and Takashi (2005) questionnaire survey showed that there was a relationship between the natural environment that surrounded a facility (e.g. trees to climb, trees that produced fruit or nuts) and activities involving production play and related natural phenomena. The production play here produces a new activity related to creativity. Their results showed that the various natural environments that attracted children's interest and intentional environments, such as biotopes, were effective in fostering creativity. In addition, Inoue & Takashi (2006) identified that less than ten per cent of the playground had areas such as biotopes or composting piles where natural diversity and the natural cycle could be readily displayed to children. The facilities were faced with the issue of finding ways to improve its environment in order to engage with nature as a daily sustained activity.

10.4.1.2 Origami (Paper Folding)

Origami is a traditional play activity in Japanese homes and is a typical activity at ECEC centres. Children use trial and error during origami play while teaching each other how to fold with friends and teachers, and they imitate how to fold from early childhood education-related books. In his research on origami, Fukui (2003a) stated that as children fold paper, they experience changes in shapes and dimensions (e.g. from two to three dimensions) while exploring activities that are similar to trial and error. Accordingly, children appear to set their own goals and experiment with new styles and developments during play. Fukui (2003a) proposed the need for motivation within a childcare education setting to encourage creativity. Fukui (2003b) also found that early childhood education-related books on play involving origami stressed the importance of teachers helping children to gain perspective on shapes and their construction based on an understanding of children's physical abilities and their technical and mental development.

The first case study shows that various natural environments that attract children's interests and intentional environments are effective in fostering creativity. The second case shows that when children fold paper (origami), their activities could include the use of trial and error with new goals or styles during play. Furthermore, the Fukui (2003b) study proposed the need for motivation within the childcare education setting to encourage creativity.

From the two case studies, it can be interpreted that various environments that are relevant to children's interests, as well as support for children's trial and error during play, can contribute to fostering creativity.

10.4.2 Teachers' Provision of Intentional Environments and the Use of Trial and Error

10.4.2.1 Relevant Environments to Children's Interests and the Real World

It is known that nurseries and childcare facilities with biotopes or compost piles have important educational effects including the fostering of a scientific mind, raising awareness of the importance of nature, and improving mental health and motivation (Osawa, 2006). A study on sandbox facilities discovered that a variety of play activities were performed in accordance with the component amounts of clay and silt in the sand (Takei, 2012). In a study on the relationships between facility equipment and natural materials, it was demonstrated that the characteristics of natural materials and equipment defined children's expressive acts as they played with water, sand, earth, snow, ice, and so on (Ishikura, 2012). Another study reported how the construction of a wooden deck at a facility enabled children to circulate among multiple spaces, and led to specific changes in the way that they played (Kawabe, 2006). From these studies, it can be interpreted that teachers' provision of intentional environments, such as biotopes and sandboxes, are effective for stimulating interest.

Hosaka et al. (2009) focused on activities that showed the development from the cultivation of cotton and indigo plants used for the dyeing process, which is a familiar activity in Japanese traditional lifestyles, and noted the positive use of a variety of sensory experiences. Kubo (1996) focused on the Japanese game of *Sugoroku* (a variation of 'Parcheesi'), and summarised that it aided the development of concepts regarding numbers and probability, and cultivated social skills and other such elements of educational significance. Takahashi and Kiuchi (2000) conducted a survey of illustrated children's books. They found an extremely large number of books that could give children a 'virtual' experience of interacting with nature. As such, these studies reveal how various environments are relevant to the real world.

10.4.2.2 Support for Children's Trial and Error During Play

As a study related to the support for children's trial and error, Saito (1999) focused on the importance of providing sites for children's spatial representation and expression styles. Another study examined the careful preparation of sites to stimulate thoughts and viewpoints that could serve as a basis for novel awareness (Yuzawa & Torimitsu, 2004). Minowa (2006) clarified differences in teacher intervention regarding 'hill-building', where teachers gave three- and four-year-old children specific instructions on the task, while no such instruction was provided to five-year-olds. Here, it was thought that since 'co-operative learning' could be seen among the five-year-olds, the teachers' support became harder to manifest. These studies show the importance of preparing situations for children to use trial and error.

This section shows how the two important elements of creativity have been dealt with among the existing studies and explores whether they actually contributed to fostering creativity. It can be summarised teacher's provision of various environments, as well as children's trial and error can contribute to fostering creativity.

10.5 Analysis of the Practice Record

This section presents a practice record that includes an activity that fostered children's creativity. As previously discussed, this chapter takes the position that creativity can be cultivated when we see descriptions of children's actions and/or utterances regarding two things: trying a problem individually or with a group, and producing a new thing or idea. The following practice record demonstrates that children make new things. Using the actual practice at the ECEC centre, the purpose of this section is to provide a real example of how teachers can prepare various environments that are relevant to both children's interests and the real world, and how teachers can support children's trial and error during play.

The practice record of 'pretend train play', conducted by teacher Komatsu Hukuzou and five-year-old children at Wako Kindergarten, is presented below. This practice record concerned the activity of making a train that the children could ride. After a holiday, the children came up with some ideas during a classroom discussion and shared experiences of their holiday travels, where they had the opportunity to ride various kinds of vehicles. Although this practice record is from 1975 and is relatively old, it has often been used as a good example of a holistic project activity that demonstrates pretend play (Asai, 2012; Kato, 2008; Shishido, 2008). It is reasonable to use this practice record because the activity allowed the children to engage in making something new. It is also widely recognised as a practice record that includes comprehensive instruction: a major curricular characteristic in early childhood education in Japan.

10.5.1 Practice Record at Wako Kindergarten (Komatsu, 1975)

The children asked, "How can we make a train that we can actually ride?" They started their creation through a group discussion. They came up with the idea of making trains out of cardboard and apple crates, but when they made them and got on them, the cardboard train immediately broke. The train made from the apple crate had door rollers and ran very well inside the pre-school, but when it was put out in the yard, the door rollers dug into the ground and would not move.

The children then devised an improvement plan: "Let's use something bigger, like a tricycle wheel". The teacher then went to a local waste collection company to get a tricycle and pram that had been thrown out. The next day, the children watched

the teacher remove the wheels from the items. The wheels were handed over to the children, who managed to install and complete the train without the teacher's help.

The children enjoyed riding and playing with the train for a while, but their interest in playing started to seek a more realistic form, and expanded into them wanting 'to make a train that four or five people could ride together'.

Therefore, the teacher prepared three planks of wood of approximately 2 m × 30 cm. In order to make a carriage larger than the apple crate, the planks of wood had to be cut and put together. Thus, the teacher first disassembled a paper box and showed it to the children, who then realised that they needed five planks of wood, and they had several discussions about what shape they should cut the planks into. In addition, the teacher taught them how to cut the wood with a saw, and in four days, the larger train that they had longed for was complete. The story ends when the wheels were attached to complete a large, slender train. Then, using the completed large train and three other single-seater trains that had already been completed and developed into a large-scale 'pretend train play' that used the entire yard (Komatsu, 1975).

10.5.2 The Teacher's Provision of an Environment and Support for Creativity

The children initially made trains using cardboard and apple crates, which had some limitations, and then made better trains by utilising bigger wheels from abandoned items. Eventually, they completed a three-seater train that met their needs for play, thus demonstrating their creativity. This could have occurred in the environment that the teacher had intentionally prepared and supported.

The teacher had prepared some environments that were relevant to the children's interests and the real world in both the early part and the development part of the activity. As can be seen from the beginning of the practice record, the train started from the children's interest. Most probably, their holiday experiences of riding vehicles helped to grow their interest in making something that they could ride. The teacher then intentionally utilised their real experiences during the holidays, which worked well. Furthermore, when the children wanted "something bigger, like a tricycle wheel", the teacher prepared the junk tricycle and pram which they could use for the wheels. One important point to be noted here is that the preparation of the environment was conducted quickly enough before the children's interest or desire diminished. The children went through much trial and error during play while riding and making the train. Their first train made from cardboard broke when they got on it, while the apple crate train got stuck out in the yard, although it worked very well inside the pre-school. They solved the problem by utilising bigger wheels, but the train's capacity was not sufficient until they had crafted the three-seater train. In those scenes, the teacher provided support for the children's trial and error during play in good time. When the children wanted bigger wheels, the teacher not only

prepared the used tricycle and pram but also provided support by removing the wheels. When they wanted to make a bigger train, the teacher showed them a basic configuration by disassembling a paper box. In addition, the teacher told them how to cut wood with a saw. One important point to be noted here is that the teacher did not teach them how to make a box but waited until the children had realised by themselves that they needed five planks of wood.

This practice record is regarded as a problem-solving project. Ohta and Asai (2012) stated that this was because the children had their own purpose and continued their creative activities due to their earnest desire and authentic interest about their own play (Ohta & Asai, 2012, p. 152).

The practice record displays how the teacher could prepare various environments that was relevant to the children's interest and the real world and shows how the teachers could support the children's trial and error during play, which lead to creative activities.

10.6 Discussion and Conclusion

This chapter discussed important elements of STEM enquiries that can foster creativity from two perspectives: environments and teachers' support. These perspectives involve various environments that are relevant to children's interests and the real world and teachers' support for children's trial and error during play, which are points that were found to be emphasised by the curriculum. These perspectives are thought to help creative STEM enquiries in early childhood education in the context of Japanese ECEC centres. The meta-analysis determined whether these points contributed to fostering creativity, and two case studies showed that various environments that were relevant to children's interests or support for children's trial and error during play could contribute to fostering their creativity. It found that some studies have stated that the intentional environments that teachers provide are effective in stimulating interest, while other studies have focused on the various environments that are relevant to the real world and seemingly implied their importance in early childhood education. The importance of preparing situations for children to use trial and error has also been addressed by several studies.

The analysis of the practice record displays a real example of how teachers can use the two perspectives successfully. One important point to be noted here is that in the practice record, the preparation of the environment had been done quickly before the children's interest or desire diminished. Therefore, providing an environment in a timely manner will increase children's chances of being creative. Another point is that the teacher waited until the children realised by themselves that they needed five planks of wood when they wanted to make a new type of train. This reminds us that the teacher's strategy of waiting for the children is very important when it comes to STEM enquiries for creativity. The teacher who implemented the practice record's activity reflected upon the practice and wrote that, "As a ECEC teacher, I needed to secure ample time and environments that enable children to

repeat their trials and errors, in order to make the activities educational play not mere play, which does not sustain children's interests". (Komatsu, 1975, p. 72). Conducting STEM enquiry activities, especially when making things using trial and error, is time-consuming. However, securing ample time for children's trial and error during play is something we need to remember if we want to make children's STEM activities more creative.

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