Tetsuo Isozaki
Manabu Sumida *Editors*

Science Education Research and Practice from Japan

Springer

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Foreword: Academic Life in Retrospect: Being Marginal

As a science education researcher, I have committed my time to several research topics since 1981. They can be categorized into seven groups: (1) cultural studies in science education, including the Japanese traditional view of *shizen* (nature); (2) Science, Technology, and Society (STS) education; the interaction among them, not teaching science through STS. (3) science literacy (not necessarily scientific literacy); (4) science communication; (5) policy studies on scientific and technological human resource development, including science teacher education; (6) foundations, rationales, and goals of science education; and (7) science teaching and learning in school settings. Some of the works were published in English, whereas others were in Japanese. Looking back on my 40-year journey, I realize that a principle guided my research activities; that is, being marginal to the conventional status quo. How could I take and enjoy such a positioning?

Starting Career as a Science Education Researcher

While training as a plant physiologist in 1974–1981, I had the opportunity to teach high school sciences (biology, chemistry, and physics) at an academically low-ranked, but athletically higher ranked, high school for 4 years (1976–1979). I was a graduate student at the time. The students with low academic performance had little interest in learning science. Indeed, learning, in general, was quite different from that of my own experience as a high school student. It was really another world. I tried to cope with the students and the classroom climate, but most of it was in vain.

My central concern gradually shifted from the question: How do I teach science effectively? Why do they need to learn the sciences? I realized that this is a very fundamental question. It has motivated my science education research activities throughout my academic life.

In 1981, I was in the last year of my doctoral program, having already published several plant physiology papers in international journals, and I had just started my job search. I found two academic positions of interest. One involved plant sciences and the other was a science education position. I applied for both university positions. I received the first appointment phone-call from the university of the latter position and accepted it immediately.

A university with elementary and secondary teacher education programs had asked me to serve as an assistant professor of science education. This was my official start as a science education researcher. I figured that it was a great challenge for the university to give this opportunity to a young researcher whose academic background was plant physiology, without any marked academic performance in science education research.

On the very first day, the Dean mentioned that I was expected to concentrate on science education research and teaching. I agreed. The university gave me several years without teaching duties to become a quality science educator. They also gave me the opportunity of a one-year study leave program (funded by the Ministry of Education) and I spent the year at a certain national university of education so that I could concentrate, and catch up on, my capacity and performance as a science education researcher and science educator.

I found it very instructive to learn from, and have discussions with, both my host science education professors and fellow students. They helped me to better understand science educators' ways of doing and thinking, which were rather unique compared to those of natural scientists. Also, I spent a lot of time at the university library learning about the history, policy, and research trends of science education, domestic as well as international. Specifically, I found it very fruitful to check almost all of the articles published in *Science Education* and the *Journal of Research in Science Teaching*. But at the same time, I also felt these research findings were rather irrelevant to the status quo of Japanese science education. Then, I tried to read domestic articles published mainly in university bulletins, which at that time were the main means of publication, although domestic academic journals had already been launched.

Finally, I realized that Japanese domestic science education research had its own rationales and terminology, but it was sometimes difficult to translate them into English. Of course, major academic influences from the Western world (e.g., the curriculum reform movement such as the post-Sputnik alphabet curricula) were prominent, but in most cases, they were Japanized through the lens of traditional Japanese science education. Also, I spent my time reading books and articles on history, philosophy, sociology, psychology, and anthropology, in general, as well as those on science, in particular. Among them, the most impressive authors included Paul Feyerabend (1975), Yehuda Elkana (1971), and Robin Horton (1967).

Adopting My Positioning: Being Marginal

When I began to concentrate on science education research and teaching, I recognized several things:

1. The Japanese school system with its established curricula, textbooks, and subject matter was perfectly predetermined by the policy of the national government. As a result, teachers had little freedom to develop their own curricula and teaching practices. Furthermore, students themselves had no influence on what they wanted to learn.
2. Two major schools, the Tsukuba and Hiroshima groups, enjoyed their leadership in science education research, national curriculum development processes, and domestic science education research associations.
3. Science education researchers outside of the two schools could not help but take a marginal or peripheral standpoint within the research community.

Strategy for Surviving as a Science Education Researcher

Thus, I decided to take a stance toward being marginal within the Japanese science education research community. Later, I transferred this stance to the international setting where Western science education researchers had dominated science education research and thereby had established a conventional status quo. The ideas and accomplishments of Japanese science education researchers were at that time not visible, mainly because they wrote in Japanese.

It was not easy to survive as an active science education researcher (i.e., to publish quality academic papers and present conference papers), while at the same time, to keep my marginality meaningful. I realized that I needed to develop a research strategy for survival that could demonstrate uniqueness within the research community, internationally as well as domestically. Therefore, I adopted a habit of mind to examine critically the dominant research programs: (a) fundamental frameworks, (b) tacit or hidden presuppositions, and (c) methods of thinking. I also tried to develop possible or probable alternative frameworks, presuppositions, and ways of thinking. Otherwise, being marginal could have immediately lost its value as a research program.

Of course, most attempts were not successful because the ideas themselves were poor in most cases, but sometimes they were not accepted by reviewers of academic journals in the Western world. So, the number of my publications (especially in English) was small. My hope was to publish, almost every 5 years, an English academic paper on these new ideas that would impact the dominant groups. I would watch to see how these papers were cited within the major science education research arena. Among such ideas were: “family-based STS education” (Ogawa, 1989a), “indigenous science in a science education context” (Ogawa, 1989b), “multiscience perspective” (Ogawa, 1995), “neo-science” (Ogawa, 1996a), “four-eyed fish”

(Ogawa, 1996b), "science-educationalizing school" (Ogawa, 2011), and "science educator as consultant-researcher" (Ogawa, 2019).

Regarding the impact of these ideas, Google Scholar's citation analysis showed that Ogawa (1986) has been continuously cited up to today (over 30 years), even if the number of citations in each year were small. I found that Ogawa (1995) was cited constantly over the course of 25 years. These articles have been recently cited by researchers working in geologically and linguistically peripheral areas, as well as by Ph.D. students. I feel satisfied with such findings.

Beyond: Unfinished Works

The positioning of being marginal inevitably allowed me to be sensitive to people being marginal in terms of science and/or science education. In my early days, Wilson's (1981) review work and Maddock's (1981) anthropological approach in the context of Papua New Guinea were pertinent to my deliberation on marginality. Later on, my concern was expanded to the so-called socially vulnerable, including Indigenous people, ethnic minorities living in Western countries, persons with disabilities, women, and even children. This guided me from positivistic toward critical perspectives or orientations.

Sometimes, I was angered by the hidden assumptions shared within the major schools of science education research: (a) science is worth teaching and learning for all students, and this means nobody has the freedom to reject or avoid attempting to learn it and (b) science educators and teachers should represent science and primarily serve (or stand for) science.

Learners with poor performance in school science are regarded as the target of remedial treatment. I remember how irritated I was by this kind of arrogance. See, for example, Ogawa (2004). From then on, I have been looking for an alternative framework of social goals for enterprise science education in our contemporary world. At the end of my 40-year academic journey, I finally reached a tentative framework as follows (Ogawa, 2019):

> One of the ultimate goals of science education practice can be identified so as to develop a better relationship between science (scientific enterprise) and society (people living there). Also, the ultimate goal of science education research should be contributing to make science education practice better through its research activities. (p. 271)

An important question here is: For whom is it "better?" Of course, it is neither for the betterment of the science educators nor the science education researchers. It should be "better" for the people living there.

Another unfinished deliberation on science educators' social roles engages me. I presented a preliminary approach on this issue at a Japanese domestic conference (Ogawa, 2017), in which I argued that the science education research field should expand its goal from only educating students, to supporting the coexistence of humanity and science. As the expected social roles of science educators have been expanding in our contemporary society from traditional roles such as teaching, it is better to develop a more comprehensive category consisting of several sub-roles (including teaching). Ogawa (2017) presented a preliminary idea on this category based on Edger Schein's (2009) conception of helping, which includes 27 verbs: assisting, aiding, advising, caregiving, catalyzing, coaching, consulting, counseling, doing for, enabling, explaining, giving, guiding, handing, improving, mentoring, ministering, offering, prescribing, recommending, showing, steering, supplying, supporting, teaching, and telling (p. 7). In this sense, the social role of a science educator or teacher, at the present time, could be identified as a science supporter or science helper in our contemporary society.

Thus, the social role of science supporters (helpers) should be supporting people (perhaps as clients) living in our society in terms of science and technological issues. The ethical role would entail doing so based upon the people's own values and needs, not those of the science supporters.

While the idea is preliminary and hence unfinished, a dramatic paradigm shift in science education practice and research could be available if such radical ideas were seriously developed and vividly examined. Otherwise, science education research could remain unchanged in terms of old-fashioned and fundamental presuppositions. I believe young scholars in science education research (not only from Japan but also from all over the world) can brave the presuppositions and develop several new research paradigms. In the near future, someone may write, "In its early days, a research field called science education had flourished, but now …" I do hope such a day comes.

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Introduction

Western science education research societies, such as the National Association for Research in Science Teaching (NARST) and the European Science Education Research Association (ESERA), have fewer Japanese members attending their meetings and conferences compared to other Asian countries, such as South Korea and Taiwan. This is despite Japan having one of the highest proportions of members in the East-Asian Association for Science Education (EASE). This is a longstanding Japanese issue. Professor Emeritus of Kobe University and Tokyo University of Science, Masakata Ogawa, has led a decades-long fight to involve more Japanese science educators (researchers, practitioners, and so on) to collaborate with their Western counterparts and science education societies.

We can think of Professor Ogawa's research as a commemorative historical position that made Japanese science education independent of Western science education. Professor Ogawa's (1986) proposition is that "science must be a foreign culture for non-Westerners," and yet Westerners have a significant impact on science education researchers in both non-Western and Western societies. His work has led to the concept of the "pluralities of sciences" among cultures in science classes, investigated by Western and non-Western science education researchers (Ogawa, 1995), and his framework for the critical review of Western science education has gained ground worldwide. His research advances awareness of the cultural pluralities of science education itself.

There have been many excellent Japanese researchers and practitioners since the scientific subject *rika* (in Japanese) was institutionalized in the second half of the nineteenth century. Professor Ogawa's contributions to Western publications and thought—his insights into the teaching and learning of science from anthropology, and his questions about the cultural pluralities of science to the actual study of science education—have placed him at the forefront of his peers as the most eminent researcher in the cultural study of science education.

When the concept of *rika* was introduced to Japanese science education, its distinctive characteristics were markedly different from science education in the West (Ogawa, 2015; Isozaki, 2014). For readers interested in this topic, such as curriculum developers, policymakers, researchers, practitioners, and young scholars, this book provides the historical context for Japanese students' success in international science tests, such as those administered by the Trends in the International Mathematics and Science Study (TIMSS) and the Programme for the International Student Assessment (PISA). The historical context of science education in Japan is why we believe that the Japanese case has unique and valuable insights to offer to science education research worldwide, and it is why we use "from" and not "in" in the title of this book.

Professor Ogawa's research has not been limited to the pluralities of science education in non-Western culture, as it promotes mutually beneficial collaboration in science education research and practice around the world. He writes that the cultural pluralities of science education can be compared to the four-eyed fish, *Anableps*, whose eyes are raised above the top of its head and divided into two parts to enable visibility underwater and above water simultaneously (Ogawa, 1996). This analogy demonstrates Professor Ogawa's desire for reciprocal coexistence beyond the dichotomy of Western and non-Western science education. Japanese science education gained worldwide attention because of his pioneering research. He is a founding member of the East-Asian Association for Science Education, and has since continued to act as an indisputable leader in the development of science education; his ideas have transformed many areas of science education research. For example, Professor Sumida (2010) has proposed, based on the influence of Professor Ogawa, the concept of "twice exceptional children in science" through the combination of theories on science education, gifted education, and special education, which has made waves in the discussion of gifted education research based on elite education in diverse settings.

This book has been written as a tribute to Masakata Ogawa, to acknowledge and mark his contribution to the development of science education. It also poses two challenges to Japanese researchers in our field: to better propagate their science education research and findings and to work toward maintaining the quality of Japanese science education that Professor Ogawa has helped to establish. This book's account of the history of Japanese science education also presents a unique opportunity for researchers to continue the field's development along these Japanese lines, and to make fundamental changes in their approaches and practices. For this purpose, we take care to highlight "Japan," "Japanese," and "Japanized" in the body of the text.

Two of this book's authors, Dr. Larroder and Dr. Kimura, are former Ph.D. students of Professor Ogawa at Tokyo University of Science. Professor Otsuji is a former colleague of Professor Ogawa at Ibaraki University. Other chapter authors were informally educated by Professor Ogawa. Two colleagues of Professor Ogawa from outside of Japan contributed to this book: Professor Emeritus of the University of Saskatchewan in Canada, Glen Aikenhead, and Professor Jinwoong Song of Seoul National University. Special thanks go to Professor Aikenhead; without his discerning feedback, this book would never have been published. As editors, we appreciate the encouragement and comments given by Professor Emeritus of Monash University in Australia, Peter Fensham, in editing this book.

To the science educators and researchers interested in Japanese practices, we hope that this book explores the field's findings satisfactorily. Ultimately, our hope is that this book will tap into the potential of the younger generations of researchers, and introduce them to the methods, designs, and people that have laid the groundwork in the field of science education.

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Why Research the History of Science Education/Teaching (*Rika*) in Japan?

Tetsuo Isozaki

Abstract This chapter is written for science educators and students faced with the question: Why do we research and learn the history of science education/teaching (*rika* in Japanese)? In order to answer this question, two precursor questions are first addressed: What is history? How do we research it? DeBoer (1991) argued that an inquiry into the history of science education can provide a context for developing a sense of what is important and why. The chapter unfolds in three sections. The first section describes the emergence of *rika* in Japan and its historical players. In doing so, the section analyzes sources of evidence. Historians test such evidence for coherence and consistency to protect against personal bias. Even for the same historical events, interpretations will differ depending on which research approaches are used to acquire and analyze the evidence; such as in a comparative study or local history study. In the second section (What Is a History of Science Education? Why and How Do We Study It?), the author briefly reviews previous research on the history of science education in Japan, from an international perspective. The final section is an historical case study that deals with an era of surging science curriculum development in the late 1950s to the 1970s in three countries—the UK, the US, and Japan. Its historical analysis identifies characteristics of *rika* (Japan's science education), thereby developing a sense of what is important to Japan and why. Because this case study is an historical study, it does not predict the future of science education. All three sections accumulate answers to the basic research question, "Why do we research and learn the history of science education/teaching?"

1 Introduction

> *Japanese people have been readily confusing science and Rika (especially the spirit of science that of Rika), even though in the secondary level Rika has never included the component 'love of natural things.' This is an example of indigenized understanding of science through school science in [a] non-Western cultural context.* (Ogawa, 2015, p. 840)

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This chapter is written for science educators and students faced with the question: Why do we research and learn the history of science education/teaching (*rika* in Japanese)? In order to answer this question, two precursor questions are first addressed: What is history? How do we research it? DeBoer (1991) argued that an inquiry into the history of science education could provide a context for developing a sense of what is important and why.

Concerning the study of history, K. Jenkins (1991) wrote that "all history is theoretical and all theories are positioned and positioning …. The point is this: that those who claim to know what history is, is for them (as for me) to have always already carried out an act of interpretation" (p. 70). This perspective offers a key insight into not only researching but also interpreting a historical event. This chapter identifies some historical features of *rika* (i.e., a type of science education practiced in Japan), including similarities and differences with the teaching of science in Western schools. The chapter comprises first, a description of the several essential historical characteristics/features of science education as related to *rika*; second, a review of the purposes and methods of research used in undertaking a history of science education; third, a discussion of a case study discussed and a presentation of the conclusions.

2 The Emergence of *Rika* in Japan and Its Historical Players

Japan has shown itself to be one of the rare states that was able to undergo a successful process of modernization over a relatively short period of time in the second half of the nineteenth century. At that time, the Japanese government's intervention was as strong and effective in education as it was elsewhere in the economy, the civil service, and the armed forces (Shipman, 1971). There was resistance to the British government's intervention in education due to its *laissez-faire* liberalism of the time (Green, 1997; Layton, 1973; Shipman, 1971). Shipman (1971) stated, "[T]he simple technology and early industrialization and immediate economic and military advantages that were gained owned nothing to education" (p. 263). Japan willingly embraced Western modern "science," which was institutionalized throughout Japan from the mid-nineteenth century, and scientific subjects were introduced into the school curriculum from the level of elementary education through higher education levels. However, approximately 20 years after the Meiji Restoration period in late 1860s to 1870s, scientific subjects underwent drastic alteration, and a newly established single scientific subject, known as *rika*, was put into practice in elementary schools, due to various political and educational pressures. From historical and sociocultural perspectives, according to Ogawa (2015) and Isozaki (2014), this new subject of *rika* broadly corresponded somewhat to "school science" or "science education," as understood in Western countries, particularly in the Anglophone world.

The integrated scientific subject *rika* was established in 1886 for learners at higher elementary schools, but not at compulsory ordinary elementary schools, even though the government had introduced a modernized Western-modeled school system into Japan in 1872. Subjects in compulsory ordinary elementary schools chiefly consisted of reading, writing, arithmetic, and moral education, following debates and decisions taken by Japanese political leaders (Passin, 1965). The history of *rika* teaching covered a period of approximately 150 years. It was not taught in the lower grades of elementary education in Japan for the two-thirds time of its history, as an 1886 education reform had led to the disappearance of *rika* at lower grades elementary schools until a later reform introduced it.

The Ministry of Education promulgated its policy concerning elementary school formation and set out the primary objectives of elementary school science as follows (Monbusho, 1972: translated by the author):

> The major purpose of *rika* is to enable precise observation of common natural things and phenomena, to develop an understanding of their inter-relations and their relationship with human lives, and to educe [educate] a love of nature (*shizen*) in the minds of children. (p.100)

The wording, “to educe [educate] a love of nature in the minds of children,” was used in a report of the Department of Science and Arts in England written by the Department Secretary, Lyon Playfair (Department of Science & Art, 1857, p. xxxi). It was set out as only one objective of science teaching in primary schools, especially for children of the labor class. In Japan, however, this affective domain “to educe [educate] a love of nature in minds of children” was promoted in 1891 as one of the most important characteristics. Furthermore, the key objective of *rika* was determined by the government, not by science teachers themselves. This indicates that the Japanese government intervened in education more strongly than in Western countries. Consequently, Japan’s science educators, including teachers, professors, and scientists interested in education, became engaged in interpreting relevant education regulations and how to implement them in classrooms. They also responded to subsequent regulatory changes (Isozaki, 2014).

However, science education at the secondary school level had different characteristics than at the elementary school level. When secondary schools for boys were regulated in 1872, several separated scientific subjects, such as physics, chemistry, botany, and geology, were taught without the integrated science subject named *rika*. *Rika* was established as a subject in secondary schools for boys when *ippan-rika* (general science) was introduced into the science curriculum, following the example of general science teaching undertaken in the US and in the UK (Isozaki, 2016a). However, when secondary schools for girls were regulated in 1895, *rika* was a part of the school curriculum.

Ogawa (2015) has asserted that *rika* provides an indigenized understanding of science, while Isozaki (2014) contended that *rika* involves a reorganization of Western school science in the context of Japanese educational and natural culture. Given that Young (1986) and Hodson and Prophet (1986) have claimed that school science has been constructed as a product of particular sets of choices made in a *noosphere* (Bosch & Gascón, 2006; Chevallard, 1989) which means a group of particular stakeholders engage at specific times, and given that Aikenhead (2006) has identified school science as involving culture transmission, it is possible to regard *rika*, as well as school science as practiced in Western countries, as historically and socially constructed productions, which can be analyzed from historical and sociocultural/indigenous perspectives.

From its inception, the principal historical features or characteristics of *rika* have been as follows:

1. the words "nature" (*shizen* in Japanese) and "science" (*kagaku* in Japanese) have remained key concepts within the objectives of *rika* from elementary schools (Grades 1-6) to upper secondary schools (Grades 10-12), despite regulatory revisions over time;
2. the affective domain of *rika* at elementary schools, concerning the need "to educate a love of nature in children's minds" (Monbusho, 1972, p. 100) has been one of the most important objectives, as well as a representative feature, of the teaching of school science since 1891 in Japan;
3. in Grades 1 and 2, *rika* was not taught for approximately two-thirds of its 150-year history as a component within the school curriculum; and
4. science educators (e.g., teachers, scientists, professors, and policymakers) have paid careful attention to trends in Western science education, particularly in relation to secondary school sciences, since 1872 when modernized education was introduced in Japan. As a result, *rika* has historical and sociocultural characteristics that are both similar to and different from school science education in Western countries.

Why have the historical characteristics of *rika* developed since the recontextualization of Western science in the mid-nineteenth century, and how can we identify such characteristics through the research in the history of science education in Japan? In this chapter, the relevant historical and sociocultural characteristics of *rika* are identified and compared with practices in Western science education, especially regarding curriculum development that occurred from the 1950s to the 1970s. Other than when clearly understandable in the Japanese context, the term "science education" rather than "*rika*" has been used to avoid confusion.

3 What is a History of Science Education? Why and How Do We Study It?

3.1 What is History? for Whom is It Intended?

From a post-modern viewpoint, K. Jenkins (1991, p. 26) defined history as "a shifting, problematic discourse, ostensibly about an aspect of the world, in the past, that is produced by a group of present-minded workers (overwhelmingly in our culture salaried historians)." This definition includes some aspects of research involved in producing a history of science education. Furthermore, Jenkins (1991) claimed that the question: "What is history?" becomes "Who is history for?" A related point made by Tyack (1976, p. 388) concerning researching a history of education, was that "one is likely to adopt a framework of interpretation that matches one's perception of reality and purpose in writing." As Keeves (1998, p. 1136) stated regarding sources of evidence that "could be interpreted in ways that reflect personal bias," it is necessary to be mindful of who an author is when reading an article on the history of science education.

Tyack (1976) also presented five different possible interpretations of the same historical events, and Briggs (1972) discussed six approaches, commonly used in social science fields at that time, that could be adopted when engaged in writing the history of education. The implication of these studies is that alternative ways of seeing or different approaches may entail drawing on diverse kinds of historical evidence in relation to education history and assist historians in gaining a wider, more complex, and more accurate perception of the past.

Generally, the government's perspectives or objectives on educational matters could not be expected to always coincide with those directly engaged in providing science education. This chapter's author is a Japanese historian of science education who does not work as a government official and who uses a comparative history approach.

3.2 Why Do We Study a History of Science Education?

Hargreaves (1996) considered whether teaching could be regarded as a research-based profession, and he concluded that it could not. He additionally contended that "there are few areas which have yielded a corpus of research evidence regarded as scientifically sound and as a worthwhile resource to guide professional action" (p. 2). Given that an evidence-based approach to improving educational practice would appear to be self-evidently desirable, Hargreaves' claims generated considerable debate regarding the nature and value of educational research and the relationship between educational research and practice.

On the other hand, Jenkins (2001) claimed that research in teaching and learning was of critical importance but that too narrow a view of research prevailed in science education. He accordingly advocated the importance of more broadly based research, involving the use of sociological perspectives in science curriculum reform, as well as the need to undertake related historical and political studies. Jenkins's case focused on the situation within European societies in relation to science education. In the case of Japan, Ohtaka (2017) analyzed a Japanese science education journal from 2001 to 2010 and found that the subject matter of the most frequently published articles concerned "lessons and instruction" (50%), while the percentage of articles concerning "history and philosophy" articles was only 5%. The views of the British researchers noted above can also be seen to have some resonance and parallelism in the developments in educational research in Japan.

Recently, to improve the quality of subject teaching, including science, educational research has been clearly encouraged to provide evidence-based educational practice. As a result, the academic Master's programs in education at Japanese national universities now have more input from teaching professionals and have a greater focus on educational practice. However, it appears to be rare in Japan for research to draw on what can be learned from past experience (and even rarer for it to involve English publications), with the exceptions of Huzimoto and colleagues (1937), Nakagawa (1968), Ogawa (1995, 1996, 1998, 2015), and Isozaki (2014, 2016a, b, 2017). There are two primary reasons for these phenomena: a lack of researchers whose research interests involve the history of science education, and the fact that historical research is less commonly pursued as it appears to be a less interesting research field for Japanese researchers, particularly those who are younger, as is the case in Europe. For example, the author has been asked several times by science educators, "What does it mean to do historical research? What is the value of historical research for science educators? Does historical research contribute to improving practice in classrooms?" These critical questions exemplify the uncertainties surrounding the place and role of historical research in science education in Japan.

Kliebard (1995) claimed that educational professionals need a historical background or a historical perspective on their work. Referring to the influential philosopher and educational researcher John Dewey's (1910, 1916, 1938) ideas familiar in Japan, Kliebard (1995) concluded as follows:

> History provides us with a record of our cumulative experience and suggests how that experience may be interpreted. The renditions of certain traditional questions provided here are undoubtedly subject to other interpretations that may lead to quite different conclusions; nevertheless, if the study of the history of education unearths old and often-buried assumptions imbedded in the questions we ask and thereby exposes them to critical scrutiny, it could be of some real use after all. (p. 198)

Consequently, it is plausible to consider that historical research may have some potential in contributing to a more informed understanding of various educational issues and in helping to address various challenges. For example, Ohshima (1920) and Kanbe (1922, 1938) identified three prerequisites for successful science teaching that they considered to be equally applicable in the past: (a) adequate facilities, (b) an efficient system comprising relevant regulations and effective operational authority, and (c) well-educated teachers. These prerequisites remain critically important today.

3.3 How is Research on the History of Science Education to Be Undertaken?

There are excellent publications on the history of science education in the UK, for example, Turner (1927), Layton (1973), and Jenkins (1979). Turner's research was a pioneering study of the history of science education, using a diachronic analysis approach that has become common in studies of the history of science education worldwide. Layton (1973) explained how and why science had failed to find a place in the elementary school education provided to the laboring classes in England. His approach showed how a historically informed problematic analysis could identify specific issues that arise in the provision of science education. Jenkins (1979) made further advances on Layton's work and explored various complex factors, such as gender issues in relation to designing laboratories for practical work, as well as varying commitments to the provision of general science education that shaped school science curricula dynamics in the social context of science education in the first half of the twentieth century. Jenkins's work (1979) integrated Turner's (1927) and Layton's (1973) approaches. In the US, DeBoer (1991) explored the struggle to place science in the US school curriculum and analyzed the multiple debates around what a science curriculum should consist of.

In Japan, there have been few books or articles written in English on the history of science education in the country apart from works by Huzimoto and colleagues (1937), Nakagawa (1968), and Hashioka (1969). However, many more have been written in Japanese, such as works by Kanbe (1938), Hori (1961), Itakura (1968), and Gamoh (1969). The works by Kanbe (1938) and Hori (1961) involved a problematic analysis of the history of science education. It is also noteworthy that there have been publications on histories of science education in local contexts in Japan, such as Ogata (1978).

Following the contribution of revisionists concerning the study of history in the 1960s, a British historian, Briggs (1972), borrowing from other social science approaches, claimed that a historian of education needed to employ the following six "new" approaches, namely: (a) local history, (b) comparative history, (c) the study of quantitative history, (d) the study of "history from below," (e) a more analytical kind of political history, and (f) intellectual and cultural history. For example, using local history can provide insight into how the central government's educational policies affect local governments and schools (e.g. Sakai & Isozaki, 2005). Isozaki and Pan (2016) compared the cultural contexts of Japan (a non-axial civilization) and China (an axial civilization), as well as the West (comprising science exporting countries), and Asia (comprising science importing countries) using a comparative history approach. They concluded that their study would provide a reference point and comparative information on how to examine similar historical issues in other East Asian countries and more recent issues such as globalization, in a more precise manner than had been previously adopted in the field.

However, there is little literature of this type in Japan. There is considerable literature written in Japanese relating to the history of science education in foreign countries. However, almost all of it could be categorized as "area study" from a historical perspective as described by Bereday (1964), and is not readily comparable to comparative history. Therefore, undertaking a history of science education in Japan should embrace a broader approach, similar to approaches developed and employed elsewhere.

Kawada (2001, 2006, 2008) and Hirakawa (2010) developed a triangulation of cultures approach. Both the comparative history and the triangulation of cultures approach involve comparative investigations of cultures and societies. The triangulation of cultures approach concerns a comparison among three cultures (or countries) “in discontinuity, where the fundamental meanings of cultural items might be discovered by this ‘heuristic’ method” (Kawada, 2006, p. 346).

Science education is a historical activity modeled by the human mind and intellect in specific cultural contexts. *Rika* has been substantially influenced by Western ideas and practices, especially those from the US and the UK, since the mid-nineteenth century when Japan underwent a period of modernization (Isozaki, 2014). Using the triangulation approach with Japan, the US, and the UK, Isozaki (2017) investigated the institutionalization of laboratory work within historical perspectives and concluded that in conducting practical work, emphasis should be placed on its purpose; (a) encouraging students to consider why they were conducting practical work, (b) emphasizing what they could gain from the experience of learning science, rather than (c) primarily focusing on the required steps in practicing it. Therefore, a triangulation of cultures approach could be usefully adopted in relation to these three countries concerning the development of science education.

Bereday (1964) claimed that comparative education had traditionally developed as part of modern historical scholarship within the history of education. Referring to Bereday’s comparative model, Phillips (2006) contended that, while there can be no single approach to comparison, “[T]here should be attempts to produce a systematic framework for analysis which uses techniques of what Bereday called ‘juxtaposition’” (p. 315). Bray and Thomas (1995) developed a systematic framework to achieve multi-faceted and holistic analyses of educational phenomena using a three-dimensional cube model, comprising: (a) an axis of nonlocal demographic groups, (b) a geographical/local level axis, and (c) an axis of specific aspects of education and of society within countries. The x-axis of non-locational demographic groups includes ethnic, age, religion, gender, and other groups, as well as entire populations. The y-axis of geographical/local levels consists of seven levels: world regions/continents, countries, states/provinces, districts, schools, classrooms, and individuals. The z-axis focuses on curricula, teaching materials, educational finance, management structures, political change, the labor market, and other related aspects. Then Bray et al. (2007) further adapted the Bray and Thomas’s cube model for application across time to facilitate a historical comparison of education.

In the following section, the author will apply a triangulation of cultures’ approach within a historical context, using the Bray and Thomas’s cube model with Japan, the UK, and the US covering the period from the late 1950s to the 1970s. In using Bray and Thomas’s cube model, the x-axis is focused primarily on the secondary school level with occasional reference to the elementary school level in relation to co-education, the y-axis is focused on three countries, and the z-axis is focused on the science curriculum with occasional reference to teaching materials and educational finance. Three further factors are: the nation state; professional/academic learned societies and foundations; and science educators who exert a strong influence on teaching science, *rika*.

4 A Case Study of Science Curriculum Development: 1950s–1970s

4.1 The Promotion of Science in the UK, the US, and Japan

Japanese science education, or *rika*, has been substantially influenced by Western models, especially those derived from the UK and the US (Isozaki, 2014, 2016a, 2017). However, as previously discussed, the level of intervention by the central government in the field of education both in the UK and the US has traditionally been weaker than that in Japan.

The UK's *laissez-faire* doctrine that directed "financial aid from the centre was regarded as likely to weaken local effort and undermine private enterprise" (Layton, 1973, p. 162). This *laissez-faire* doctrine held a long and dominant position in the field of education. Layton (1984, p. 279) also observed that "various explanations have been offered to account for the lack of central control over the content of secondary school education in the post-war years." A lack of engagement characterized the central government's approach to education in the UK. Curriculum development was fostered elsewhere, as shown by the proposal for external examination syllabi put forward by the Science Masters' Association and the Association of Women Science Teachers (Science Masters' Association and Association of Women Science Teachers, 1962). In the UK, the Nuffield Foundation decided to provide financial support for the teaching science in the aptly named Nuffield Foundation Science Teaching Project. The project was represented as being "by teachers for teachers" (Nuffield Foundation, 1963, p. 2) and was also supported and influenced by "university scientists" (Black, 1993, p. 8).

In the US, National Science Foundation projects as well as a series of conferences on science teaching organized by the Organisation for Economic Co-operation and Development, accelerated the curriculum development era (Ingle & Jennings, 1981). Due to the success of the USSR's space exploration program in launching *Sputnik 1* in 1957, the US government began to back "initiatives of the scientists with enthusiasm and financial support" (DeBoer, 1991, p. 147). Trowbridge et al. (2000) also highlighted government initiatives concerning "curriculum reform" (DeBoer, 1991, p. 147). The American science curriculum projects were financially supported by the National Science Foundation, with theoretical rigor provided by the psychologist Jerome Bruner, the educator and scientist Schwab (1978). Deliberations at the famous Woods Hole Conference heard from 35 scientists, scholars, and educators who met to discuss how education in science might be improved in American primary and secondary schools (Bruner, 1960). Using the provided financial support and applying more recent theoretical insights, academic learned societies, such as the National Academy of Science and the American Chemical Society, proceeded to organize science curriculum projects.

However, the impetus to reorganize the science curricula in Japan came as an urgent issue from the government, as well as from business and industrial interests. As a result, legislation was introduced to promote technology and science education in the early 1950s before the launching of *Sputnik 1*, specifically the Industrial Education Promotion Law in 1951 and the Science Education Promotion Law in 1953. It became possible for all schools to apply for a national subsidy that would meet some or all of the costs of purchasing scientific equipment and establishing proper facilities. Business and industrial leaders in Japan had, in the meantime, become dissatisfied with science and vocational education. In 1956 the Japan Federation of Employers' Association (*Nikkeiren*) issued a proposal to promote science and technology education in schools, colleges, and universities. The launching of *Sputnik 1* was, therefore, a later impetus for promoting science education in Japan.

4.2 Why Does This Case Study Cover the Period from the Late 1950s to the 1970s?

Fensham (2016) claimed that, because of increasing scientific competitiveness during the Cold War, the need for skilled scientific experts became a national imperative for many countries. In the case of the UK, Ingle and Jennings (1981) contended that the root of the Nuffield Foundation Science Teaching Project could not be explained as being due to a single factor such as the launching of *Sputnik 1*. Other factors were also involved, including the influence of the North American science curriculum development, anxieties about the lack of scientific experts, and a climate favorable to science (Ingle & Jennings, 1981). Indeed, the Nuffield Foundation (1963) acknowledged the influence of American science curriculum projects supported by the National Science Foundation and by conferences on teaching science conducted by the Organisation for Economic Co-operation and Development. Layton (1984) stated that "a 'Cold War' climate had heightened concern about national shortage of scientists and technologists to an extent that allowed opponents of general science to attempt the *coup de grâce*" (p. 225, original emphasis). Connell and James (1958) criticized general science instruction up to that point and described the situation in the late 1950s as follows: "An improvement in the standards of school science teaching is now overdue and is a requirement for the continued existence of this country as a leading scientific and industrial nation" (p. 285).

In the US, Bruner (1960) stated that the aim of the Woods Hole Conference had been organized "at the beginning of a period of new progress in, and concern for, creating curricula and ways of teaching science" (p. xvii). DeBoer (1991) stated, "[P]rogressive education had turned its back on traditional intellectual values moved American education away from the theme of social relevance and toward a mastery of the traditional disciplines" (p. 146). This point of "social relevance" referred, in particular, to an enhanced perception of the value of general science.

Before *Sputnik 1*, there were various viewpoints on how to improve science teaching in relation to providing more progressive education. A report from the Rockefeller Brothers Fund (1958) discussed how education systems involving science education could be taught to create more informed citizens as they sought to live and work in a rapidly changing world, and the report asserted that science education was in a real crisis. The report maintained that "the U.S.S.R. is not the 'cause' of the crisis. The cause of the crisis is our breathtaking movement into a new technology era. The U.S.S.R. has served as a rude stimulus to awaken us to that reality" (Rockefeller Brothers Fund, 1958, pp. 27–28). Professor (later journalist) Silberman (1970) also made a similar point that the launching of *Sputnik 1* was only one important stimulus that accelerated the provision of curriculum development projects.

In Japan, Kurita (1981) argued that the "Alphabet phase [projects]" (Fensham, 2015, p. 276) or "trans-Atlantic products" (Fensham, 2016, p. 167), which were notable for their use of scientific concepts and principles, strongly stimulated Japan's renewal of science education, called *rika-kyouiku no gendaika* in Japanese, from the 1960s to the 1970s. Kurita (1981) considered that two factors, in particular, had fostered this renewal: changes in social conditions, such as greater economic growth, and the insights derived by science educators as they sought to explore ways to reconstruct *rika* in response to those changing social conditions.

Additionally, just after the Second World War, a more democratic education system and the idea of progressive education were introduced through the work of the Civil Information and Education Section of the Occupation administration from the latter half of the 1940s to the first half of the 1950s. The newly reorganized subject of *rika* was based on progressive child-centered education, known as *seikatsu-tangen gakushuu*, which means "topics based on students' lives." However, this type of *rika* was severely criticized as *haimawaru rika*, which means "science education at a snail's pace," from scientific perspectives. Consequently, the course of study for science in elementary schools and in lower secondary schools was revised. However, it is worth noting that this revision was less reflective of trends in Western science education compared with the revisions to come.

Therefore, it can be seen that in these three countries, a lack of staffing in the fields of science and technology during the Cold War led to the development of innovative science courses for study in schools after the launch of *Sputnik 1*. The development of science curricula was initiated with financial support from governments and/or foundations. It is worth noting that according to DeBoer and Layton, there was one feature of science education in the US and in the UK that did not transfer to Japan, which was the emergence of trans-Atlantic products based on both science educators' reflections and criticism of previous educational practices and emerging movements that promoted general science committed to the "social relevance of science" (Isozaki, 2016a) (see Appendix Fig. 1).

However, given conditions such as the lack of science and technology experts, science educators and other interested parties, such as the Nuffield Foundation and the Rockefeller Brothers Foundation, urged science education to take a different direction during the 1950s through to the 1970s. Hurd (1958) pointed out that the crisis in education was both immediate and far-reaching into the future. Hurd (1958) also observed that, to address these crises, scientists needed to be engaged in developing "scientific literacy in the young people of America" (p. 15), and that they needed to revise the curriculum and develop new teaching methods that would "give the academically gifted educational opportunities" (p. 52).

The Rockefeller Brothers Fund (1958) also reported that "we must insist that every scientist be broadly educated, so we must see it that every educated person be *literate in science*" (p. 28; italics added). The Nuffield Foundation (1963) stated that the central objective of their project was "'science for all'—not merely for the future specialist but for the future citizen" (p. 2). Bruner (1960, p. 10) claimed that the purpose of education was to help each student achieve his or her optimum intellectual development, and he stated that "if all students are helped to the full utilization of their intellectual powers, we will have a better chance of surviving as a democracy in an age of enormous technological and social complexity." According to the position statement on school science education for the 1970s from the National Science Teachers Association (1971, p. 48), the goal of science education was to develop scientifically literate citizens, and "science curricula must contain a balanced consideration among conceptual schemes, science concepts, and science processes including rational thought processes, the social aspects of science and technology, and values deriving from science."

Similarly, in the UK, the Association for Science Education (1971, p. 32) stated that "science should continue to be a component in the general education of all pupils." Additionally, the Association for Science Education (1973) published a statement policy for secondary school science that built up its previous statement policy of 1971 and claimed that "all pupils, up to the age of 16, should have learning experiences in school which provide foundations for a life" (p. 6).

Two trends are observable in science education from the late 1950s to the early 1970s: providing preparatory science courses for future scientists and developing courses that promote the scientific literacy of future citizens. However, the first trend received greater support, while the notion of scientific literacy was never clearly defined at the time. This chapter focuses on this period because these two trends were clearly discernable.

In contrast to the UK and the US, Japan has traditionally promoted "science for all" from elementary to upper secondary schools by making *rika* a compulsory subject. For example, in the curriculum development era, all students at the upper secondary school had to study *rika* as selective compulsory subjects, such as physics, chemistry, biology, earth science, and balanced/integrated sciences, based on their future career, aptitude, and interests *rika*/science.

4.3 Who Initiated the Development of the Science Curricula and for Whom?

Although Ingle and Jennings (1981) noted that only a small proportion of science teachers were actually involved in educational policymaking, and scientists were called on to comment only on draft proposals, professional learned societies, such as the Association of Public School Science Masters (later Science Masters' Association, and now the Association for Science Education) played an important role in educational reform. For promoting science education, these associations have published their policy statements since the beginning of the twentieth century. Layton (1984) said that the development in science education from the late 1950s through to the early 1960s could be seen as a "positive and responsible effort" (p. 237) that filled the vacuum in curricula matters created by professional learned societies of teachers. Therefore, the Nuffield Foundation Science Teaching Project was "by teachers for teachers" (Nuffield Foundation, 1963, p. 2).

In 1962, the Science Masters' Association and the Association of Women Science Teachers in the UK issued a policy statement arguing that science as a subject should be reorganized and taught as a major human activity. They recommended that all students should follow a balanced course of science subjects up to the end of fifth form, and in sixth form follow "a broader course which should enable pupils to attain the scientific literacy which the Crowther Report calls 'numeracy'" (Science Masters' Association & the Association of Women Science Teachers, 1962, p. 6). Layton (1984) claimed that taking the step of producing a statement was intended to ensure recognition of an authoritative voice on educational theory and practice, and it is clear that science educators were actively involved in the curriculum development of this period. While the Nuffield Science Teaching Project began with separated science courses, there remained a consensus that "a combined course was most desirable, especially in the first two years-for children between the ages of 11 and 13" (Booth, 1975, p. 28). Black (1993) pointed out that the Nuffield Foundation Science Teaching Project did in time involve two types of courses: those designed for the most advanced students and those designed for the average or less ability students. To deliver these courses effectively, balanced science courses, such as combined science and integrated science courses, were developed.

In the US, a speech by President John F. Kennedy to Congress in 1961 (Trowbridge et al., 2000) encouraged backing initiatives of "scientists with enthusiasm and financial support" (DeBoer, 1991, p. 147), although government and private support had been given prior to this time. In the case of Project Physics, financial support was provided by the Carnegie Corporation of New York, the Ford Foundation, the United States Office of Education, and Harvard University (Trowbridge et al., 2000). Bruner (1960) pointed out that this time:

> [T]here has been an unprecedented participation in curriculum development by university scholars and scientists, men distinguished for their work at the frontiers of their respective disciplines. They have been preparing courses of study for elementary and secondary schools not only reflecting recent advances in science and scholarship but also embodying bold ideas about the nature of school experience (pp. 2-3).

Back in 1954, the National Academy of Sciences-National Research Council began to discuss ways to improve the teaching of secondary school physics and biology (DeBoer, 1991). Conferences were held on physics education sponsored by several professional learned associations, such as the American Association of Physics Teachers, the American Institute of Physics, and the National Science Teachers Association.

In January 1959, the American Institute of Biological Science established the Biological Sciences Curriculum Study (BSCS) "as a means of contributing to the improvement of secondary school biological education" (BSCS, 1963a, p. ix). The BSCS steering committee was comprised of biologists, high school biology teachers, and other educators. In the case of chemistry projects, the American Chemical Society set up a body consisting of chemists and high school chemistry teachers to discuss how to promote more innovative and up-to-date teaching of high school chemistry (DeBoer, 1991).

The BSCS materials were designed for "all students in American high schools-regardless of aptitudes or career goals and they can be studied at a level of student sophistication that was heretofore thought completely unrealistic" (BSCS, 1963b, p. xi). The American science curriculum projects primarily involved scientists and science teachers supported by professional learned societies concerned with both academic science and science education, with financial support provided by foundations. The BSCS (1963a, p. x) stated that "perhaps the most significant feature in the development of the BSCS materials has been fruitful cooperation between research biologists on the frontiers of science and high school teachers on the frontiers of teaching."

Hurd (1958, p. 15) stated that scientists' role in engaging with curriculum development was "a professional responsibility they have too long neglected." Within 15 years of the *Sputnik 1* launch, a considerable number of science curricula had been developed in the US; named "alphabet-soup" courses by Shymansky et al. (1983, p. 388) because of the plethora of acronyms these programs from elementary to high school level accumulated.

The Western education reform movement, particularly its trans-Atlantic products, began to significantly influence secondary science education in Japan. The Japanese Ministry of Education adopted three ways of improving science education in the 1960s and 1970s (Isozaki, 2016b). First, the course of study determining the national curriculum was revised in 1969 and 1970 for the lower and upper secondary schools. The revised course of studies focused on the logical structure of the disciplines and the processes of science. Comparing trans-Atlantic products, the Central Council for Education, an advisory body to the Minister of Education, had proposed a new direction for Japanese education in the next generation. The science working group, which consisted of scientists, science education researchers, science teachers, and ministry staff, revised the course of studies based on the proposals from the advisory body to the Minister of Education.

Second, support for in-service teacher training programs and the establishment of prefectural science education centers were introduced.

Third, a special budget for scientific research, including science education, was established. The Ministry of Education generally backed these initiatives with enthusiasm and financial support. However, as Kurita (1981) and Isozaki (2016b) pointed out, professional learned societies, as well as the government, had played an important role in managing *rika-kyouiku no gendaika*, the modernization of science education. For example, Japanese professional learned societies, such as the Physics Education Society of Japan and the Japan Society of Earth Science Education, invited professionals who had been involved in developing trans-Atlantic products to attend a range of workshops for Japanese science educators. Furthermore, academic scientists and teachers translated some of the trans-Atlantic educational works into Japanese and positively engaged with such works to adapt them to the context of Japanese science teaching. Clearly, the revisions of the course of study for science in lower and upper secondary schools in 1969 and 1970 respectively was efficiently promoted through cooperation between the central government and professional/academic learned societies.

In the UK, the trans-Atlantic products were the result of initiatives by science teachers and learned societies supported by scientists and foundations. In the US, the strong initiative for the development of the trans-Atlantic products was primarily undertaken by the government and supported by scientists and academic societies. In Japan, however, a different approach was taken.

4.4 The Trans-Atlantic "Products" and Their Success

Leo Klopfer (1980) found that:

> [C]urricula and ideas spawned in the 1960s and early 1970s have been assimilated or ignored by teachers of science. Some have adopted the innovative methodologies and materials that stress scientific inquiry or disciplined structure or individualized instruction, but the instructional approaches used by many teachers have hardly changed at all. … important tasks remain to be accomplished in science education in the 1980s (p. 1).

Similarly, DeRose et al. (1979, p. 36) reported to the National Science Foundation that "total and final responsibility for what happens in science teaching does not rest solely on the shoulders of teachers, but a successful school program in science education is solely dependent upon what they do with their students. Unmistakably, the teacher is the key!".

Silberman (1970, p. 180) also evaluated the "alphabet-soup" courses in the US and similarly concluded that "the reformers were university scholars with little contact with public schools or schools of education…[T]hey also tended to ignore the harsh realities of classroom and school organization."

In the UK, Ingle and Jennings (1981) concluded that "twenty years of curriculum development have made a notable contribution to science education in Britain, but the business of bringing about worthwhile change in the classroom cannot be done by curriculum development alone" (p. 54).

All of these comments suggest that the most important component for successful curriculum innovation is teacher involvement. This had been recognized early on; for example, the Physical Sciences Study Committee (PSSC) (1960, p. ii) stated, "[T]he most important element of a successful PSSC course is the teacher." Nonetheless, as Silberman (1970) pointed out, the *P.S.S.C. Physics: Teacher's Resource Book and Guide* (PSSC, 1960) was produced by 12 physicists, a physics department, two high school teachers, and only one educator from the College of Education at the University of Illinois. The *Biology Teachers' Handbook* (BSCS, 1963b) was coedited by 11 college or university teachers, and involved only one teacher from a laboratory school attached to a university, and only one educational testing institute.

Why did science educators in Japan not review their approach to the modernization of science teaching, except in a few cases? Despite evidence of successful science learning, such as the International Association for the Evaluation of Educational Achievement's First Science Study, numerous challenges remained to bring about the modernization of teaching science. Kurita (1981) highlighted the challenges: (a) elementary science education had not been well developed, (b) growing fatigue with a discussion concerning the modernization of science education, (c) lack of research skills among university teachers, and (d) confusion between modernizing science education and improving educational technology.

As Japanese university and science teachers did not fully understand the philosophy or ideas behind the Anglo alphabet projects, many university teachers in science education lacked both the necessary research skills needed in the field of education and a clear vision of science teaching (Kurita, 1981). Furthermore, Isozaki (2016a, b) claimed that Japanese science educators had not engaged deeply enough with the significance of curriculum reform as implemented in Western cultures.

Using the Israeli experience, Ganiel (1995) pointed out that because the discipline of science education did not exist in Israel until the late 1950s, professors of education in science were not well equipped to train new science teachers, and thus, Israel's situation was similar to Japan's.

Despite the challenges, modernization of teaching science was carried out through the determined initiatives of the Ministry of Education with science educators (Isozaki, 2016b). This fruitful cooperation between the government and science educators helped to improve the teaching of science. Consequently, it would appear, as Fujita (2013) and Isozaki (2016b) claimed, that the 1950s to the 1970s could be considered the "golden age" (Fujita, 2013, p. 9) of science education in Japan. We can observe that the key factor for success of curriculum reform from the 1950s to the 1970s was science teachers, as stated by Ohshima (1920) and Kanbe (1922, 1938) about one hundred years ago.

In Japan, however, science curriculum projects like the trans-Atlantic products have never come to fruition because of the centralized nature of Japanese curricula. As Ito (1997, p. 217: translated by the author) observed, "[I]t is not desirable from the perspective of the nature of education to rapidly change the current education system, which has been organized in this way for a long time." This means that little change has occurred in the course of study for both lower and upper secondary schools, with their inquiry-based approach and structured content derived from the key scientific concepts of the pure sciences. This fact exemplifies the historical and sociocultural characteristics of *rika.*

In the case of primary science education, Ingle and Jennings (1981) in the UK pointed out that the major obstacle was the lack of "primary science teachers with expertise in teaching science" (p. 34). Fensham (2015) claimed that primary school teachers in the West generally had very weak science content backgrounds. As a consequence, they were asked to be more concerned with scientific processes. It is noteworthy that in Japan, trans-Atlantic products for teaching elementary school science were not investigated to the same extent as those intended to improve secondary school science teaching. Consequently, materials such as textbooks were not translated into Japanese.

Why did Japanese science educators and professional learned societies respond differently to elementary science teaching improvement than secondary science teaching? This can perhaps be explained by the character of the elementary school science teaching profession. Ever since the late nineteenth century, elementary school teachers and normal school (later university) teachers have (Isozaki, 2016b): (a) organized professional learned societies for research and practice of elementary science, (b) held conferences on matters related to improving their teaching, and (c) published periodicals and books based on practice. Therefore, they had accumulated wisdom and developed an expertise in the Japanese context. They were likely to have gained more confidence over time, based on research and practice through participating "lesson study" (Isozaki, 2015) research methods within their formal or informal professional learning communities. Consequently, there had not been an urgent need to borrow or consider new ideas from the West, although there was some engagement with academic research on trans-Atlantic products.

5 Conclusion

What can be learned from the history of science education? Why is it necessary to study the history of science education? In terms of historical context, Black (1993) and Millar (2011) claimed that science education has two purposes: to improve understanding and knowledge concerning everyday practices and artifacts and to prepare future scientists for scientific careers. Black (1993) pointed out that the tension between these two purposes continues "to bedevil school science to this day" (p. 7). Fensham (2002) also described these two aspects as involving a contrast between providing science education for all future citizens and providing science education for possible future scientists. Similarly, Aikenhead (2006) stated, "school science has traditionally attempted to prepare students for the next level of science courses" (p. 1), but that there have been alternative rationales for science curricula since inception.

When analyzed historically, this tension in the purposes of science education is apparent in relation to the various trans-Atlantic products that emerged throughout the 1950s to the 1970s. (Historical events related to this are described in Appendix Fig. 1.) Like a pendulum swings, two crucial and fundamental issues (i.e., who should be responsible for determining the science curriculum content, and conflicting purposes for students learning that content) have oscillated considerably over time, especially in the 1970s.

Fensham's (2002, p. 22: italics original) remark that "*[s]cientific literacy is too important to leave to scientists or to science educators!*" highlights this tension in relation to determining science curriculum and the values that should guide science educators.

In spite of the extensive literature on negotiating the tensions in the teaching of science in the UK and the US, Japanese science educators introduced components of trans-Atlantic products *with* only a superficial understanding of the philosophy and the sociocultural features that framed them, while at the same time, *without* a deep reflective critical review. As a result, there was little debate in Japan over the tensions experienced in the UK and US. Approaching the tensions from a different perspective, Japanese science educators successfully recontextualized the trans-Atlantic products into the Japanese context of *rika*.

As this case study shows, science education can be regarded as a historical and sociocultural product or phenomenon involving sometimes significant intellectual engagement within and between societies. Consequently, a study of the history of science education can provide useful historical insights with more informed sociocultural perspectives on how science education has been undertaken and might be better undertaken. Science education research should not only focus on technical rationales for practices to improve teaching and learning science, but it should also consider the history of science education in order to "reflect on our own tradition of science education that we take for granted" (Isozaki & Pan, 2016, p. 24).

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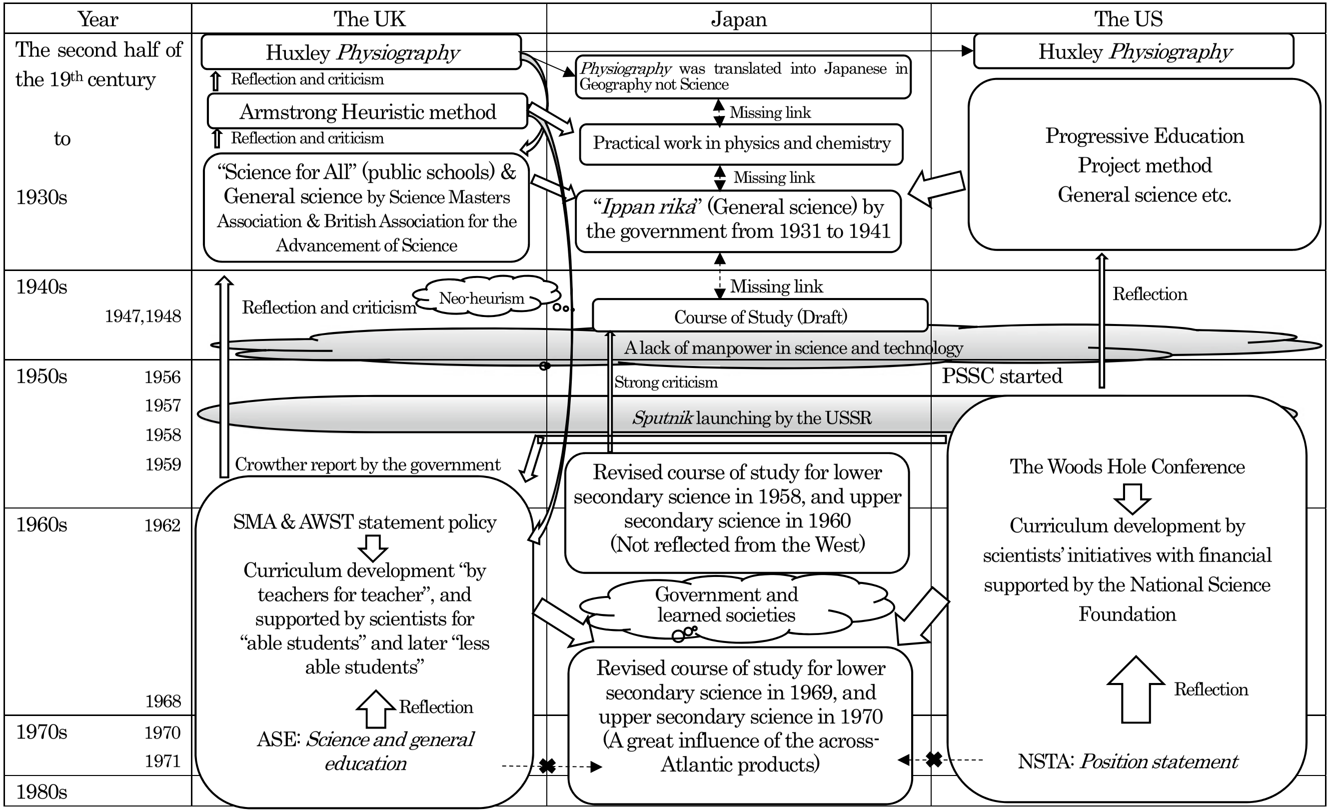
Appendix

[Appendix figure is shown on the following page.]



Appendix Fig. 1 A historical sketch of science education in three countries

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The Pursuit of Understanding Science Classroom Culture in Korea and East Asia

Jinwoong Song

Abstract There has been a growing academic interest towards East Asian education across the world, especially in science education (e.g., Ogawa, 1986, 1998). While so-called 'East Asian disparity' phenomena (Song, 2013), i.e. high achievement versus low engagement, became one of the key educational issues in the region, there have been several new developments in the community of science education, such as the establishment of EASE (East-Asian Association for Science Education) in 2007, the launching of the online journal of APSE (*Asia–Pacific Science Education*) by KASE (Korean Association for Science Education) in 2016, and a series of publication of books on East Asian science education (e.g., Science Education in East Asian (Khine, 2015); Science Education Research and Practices in East Asia (Lin, Gilbert, & Lien, 2016)). While the school is the specially designed place to be the locus of formal education, the classroom is the place where actual teaching and learning practices are taking place across different levels of socio-psychological cultures (e.g., society level, local level, school level, individual level). Despite the centrality of the classroom for actual teaching and learning activities, in the field of science education, it is true that we do not know much about what are actually happening inside the classroom: for example, how much is the interaction between teacher and students happening?; how and when do students participate in classroom discourse?; why are East Asian students silent inside classrooms? and does this mean that they participate less actively?; how many times do teachers say more compared to students?: when silent what do students do? and so on. Even although we (Korean and maybe East Asian scholars too) have imported and implemented so many educational theories which were developed in the Western culture, there has been almost no theories which were directly and properly applicable to local science classroom environments. In this chapter, I would like to address the importance of the socio-cultural approaches to understand what is really happening inside the science classroom and why it is so. Even although the contents (and more) of school science education might be rather universal or similar across the world, the way they (teachers and students) teach and learn school science can be very different. It is because the activities of teaching and learning cannot be beyond the cultural boundaries and independent on the values and

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traditions of the societies. If the East and the West are really different in educational interactions, the way they teach and learn also must be different accordingly. This has been the starting point of the ECCO-SM (East-Asian Classroom Culture of Science and Mathematics) project supported by Korean NRF (National Research Foundation). With this background, as the primary investigator of the project, I will (1) summarize the major features of East Asian science education, identified by a number of previous studies, (2) explain the backgound, structure and main findings concerning science classroom culture out of the ECCO-SM project, (3) introduce some potential explanations of the findings from the perspectives of other disciplines (such as, philosophy, communication, psychology), and (4) discuss the importance of the socio-cultural approaches to science classroom and suggest some directions of future researches on this topic.

It is probably true that we have accepted science as a product of Western culture and that we have done so as a matter of course. However, this must not prevent us from discussing the problems that are associated with the introduction of science (based on Western culture) into a non-Western society (Ogawa, 1986, p. 115).

1 Introduction

As late starters of industrialization, nations in East Asia as a whole have made great efforts to import and learn from Western sciences and Western cultures. One of the first efforts was to transform their traditional school system and science subjects, especially their curricula, to meld with the host country's culture. Japan would be the first nation to accomplish this important and perhaps inevitable task in the region of East Asia,[1] around the 1870s during the Meiji Restoration (Isozaki, 2014).

A well-known contemporary educational phenomenon of East Asian cultures is the distinctive mismatch pattern of students' high academic achievements with low attitudes toward school. This mismatch is often referred to as—"the paradox of Confucian Heritage Culture (CHC)" (e.g., Chan & Rao, 2009), the "Eastern learning paradox" (e.g., Lee & Sriraman, 2013), or the "East Asian disparity" (e.g., Song, 2013). However, among the three East Asian nations, Japan and Korea appear more in common. On the one hand, the Chinese cultures (i.e., Mainland China, Hong Kong, Taiwan, and even Singapore) show a pattern of high achievements and either less high or modestly low attitudes. On the other hand, Japan and Korea share a

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[1] In a narrow sense, East Asia usually refers to China, Japan, and (South and North) Korea. But these nations could be called "North East Asia" because geographically other nations (e.g., Mongolia and the Philippines) can also be grouped into East Asia. However, such studies as PISA (Programs for International Student Assessment) and TIMSS (Trends in International Mathematics and Science Study) categorize East Asia as being three nations: Japan, South Korea, and China (together with Hong Kong and Taiwan). This categorization is adopted for this chapter.

more contrasting pattern of high achievements with extremely low attitudes and participation (Lau, 2014; Song, 2013).

There has been a growing academic interest in East Asian science education (e.g., Lau, 2014; Ogawa, 1986, 1998) evidenced by several recent developments by East Asian science educators, such as—(a) the establishment of EASE (East-Asian Association for Science Education) in 2007; (b) the launching of an international journal, *Asia-Pacific Science Education (APSE)* by KASE (Korean Association for Science Education) in 2016 (Martin & Chu, 2015); and (c) a series of book publication on East Asian science education, for instance, *Science Education in East Asian* (Khine, 2015), *Science Education Research and Practices in Taiwan* (Chiu, 2015), and *Science Education Research and Practices in East Asia* (Lin et al., 2016). One recurring topic of interest has been East Asian classrooms.

Why do science educators need to understand science classroom culture in East Asia? Science has long been one of the core subjects in schools worldwide, and science education has become one of the most active areas in educational research. Science classrooms are the locus where teaching and learning practices actually take place across different levels of socio-psychological cultures: society, local, school, and individual levels (Chang & Song, 2016; Chang et al., 2018; Fiske et al., 1998).

Despite the centrality of science classrooms for teaching and learning activities, we still do not know much about what actually happens inside the science classroom. For example—What are the interactions between teachers and their students? How and when do students participate in classroom discourse? Why do East Asian students tend to be silent inside classrooms? Does this mean that they do not participate in the lesson? How can we compare teacher talk with what students say? When being silent, what are students really doing? Even though we Korean and East Asian researchers have imported and implemented so many educational theories developed in the West, there have been little or no theories that were directly and culturally applicable to local science classroom environments. These issues have been addressed for some time, but not properly resolved yet, as judged by Ogawa's definition of science education: "the discipline concerned with the interface of science and culture" (Ogawa, 1986, p. 115).

Based on my resolve to understand East Asian science classrooms as cultural interfaces with Western science, this chapter will unfold in four parts. First, I outline the East-Asian Classroom Culture of Science and Mathematics (ECCO-SM) project. Secondly, I introduce some features of East Asian science classrooms identified from the ECCO-SM project and related studies. Thirdly, I discuss the importance of the socio-cultural approaches to understanding science classroom culture. Lastly, I introduce Korean Science Education Standards (KSES) for the future generation, which was developed to meet and overcome some key challenges to Korean science education.

2 ECCO-SM Project

The East-Asian Classroom Culture of Science and Mathematics (ECCO-SM) was a research project supported by the National Research Foundation (NRF) of South Korea for three years (September 2013 to August 2016) under the name of Social Science Korea (SSK) research funding scheme. With the goal to understand East Asian science and mathematics classroom culture, the ECCO-SM's full research title is "Identifying the characteristics and mechanism of science and mathematics classroom cultures in East Asia through socio-cultural lens." The project was initiated by an anomaly. Despite their high performances and values towards science as assessed by the OECD, students of the East Asian region, most typically Korean, are well below the OECD averages in almost all attitudinal measures (Song, 2013; Lau, 2014). If students are not enjoying and are not confident studying science, how could they continue to study and use science once they finish studying their mandatory secondary school sciences?

Being science educators, one of our problems is not really knowing much about what happens during school lessons. If we do not know, we cannot solve the problem.

Another problem is the way we teach and how students learn science in schools has not changed much, despite applying new educational theories and strategies (mostly from Western cultures). What makes science and mathematics teaching so resistant to change? The passive or low participation by students in science classroom activities also appears almost unchanged. How can we respond to these on-going challenges?

With myself as the primary investigator, the ECCO-SM team consisted of several science or mathematics educators: Prof. Ohnam Kwon, a mathematics educator at the Seoul National University (SNU); Dr. Sonya Martin, a science educator at SNU; Dr. Yong Jae Joung (a primary science educator at Gongju National University of Education); and Dr. Jiyeon Na, a primary science educator at the Chuncheon National University of Education.

Throughout the funding period, these five regular co-researchers were supported by other members; one or two full-time post-doctoral researchers and several postgraduate students majoring in science or mathematics education at SNU. In order to accomplish the mission of "understanding East Asian classroom culture," the ECCO-SM team sometimes collaborated with other science or mathematics educators in Hong Kong, Japan, Taiwan, Indonesia, Thailand, and beyond.

The ECCO-SM project had two main research *areas*, each divided further into two *themes*:

1. Current situations and features of science and mathematics classroom culture:
    a. Features of communication of learning phenomena through socio-cultural approaches.
    b. Relationship between the types of classroom culture and teaching and learning activities.
2. Factors forming science and mathematics classroom culture:

a. Participation structure in the community of practice (CoP).
b. Nature and orientation of learning and disciplines.

In total there are four themes.

During the project's three-year period, the ECCO-SM team produced 23 peer-reviewed journal articles and 38 oral/poster presentations at various conferences, including one organized by the ECCO-SM team (i.e., the International Conference on the Understanding of Science and Mathematics Classroom Cultures in East Asia (7–8 January, 2015, at Seoul National University)). Table 1 shows the research areas and examples of published research papers from the project.

Table 1 Research in published journal articles from the ECCO-SM project

Research Area	Examples of Journal Papers
(1.a) Features of communication of learning phenomena	– Analyzing research trend of interaction in mathematics classroom in Korea (Cho, Kwon, Bae, & Lee, 2014) – Developing an instrument for analyzing students' behavioral engagement in school science classroom (Choi, Na, & Song, 2015) – A case study on the features of classroom norms formed in inquiry activities of elementary science classes (Chang & Song, 2015)
(1.b) Relationship between the types of classroom culture and teaching and learning activities	– Ho do elementary school students perceive science classroom? Developing a framework for cultural analysis of science classroom. (Park, Na, Joung, & Song, 2015) – Reinterpretation of learning environment instruments from cultural perspectives: Exploring the applicability for understanding science classroom cultures. (Chang, Na, & Song, 2015)
(2.a) Participation structure in the community of practice (CoP)	– Development and application of the measuring instrument for the analysis of science classroom culture from the perspective of "Community of Practice". (Chun, Na & Song, 2015) – Exploring the possibility of forming the strategic community of practice for science education: A case of Science Core Schools in Korea (Kim, Na, & Song, 2017)
(2.b) Nature and orientation of learning and disciplines	– Theoretical investigation on implications of "Community of Inquiry" for science education: Toward "Community of Inquiry in Science Classroom." (Joung, 2014) – Unintended learning in primary school practical science lessons from Polanyi's perspective of intellectual passion. (Park et al., 2016)

After the NRF's support period of three years as a small-scale SSK project, the ECCO-SM project was upgraded to a middle-scale SSK project, with a change of name to "GloCal[2] Social Changes and Educational Responses" (GCER). This occurred by joining with another small-scale team of mostly general education researchers. The GCER team's research title became "Innovations in Classroom Culture and Educational System for Low Fertility and Hyper-connected Society." I was its leader for a half of its funding period, working with ten co-researchers of university faculty members, two or three post-doctoral researchers, and several research assistants. The GCER project was supported by NRF for three years (September 2016 to August 2019).

3 Features of East Asian Science Classroom Culture

In this section, I briefly introduce some key findings and outcomes of the ECCO-SM project, organized within the following topics: silent participation in science classroom; norms in science classrooms; science classroom creativity; and instruments for investigating science classroom culture.

3.1 Silent Participation in Science Classroom

A well-known feature of Korean (and perhaps Japanese) students concerns their meager or passive participation and engagement (e.g., Leung, 2005), commonly known as "classroom silence." Some informative studies have explored this phenomenon.

Based on the TIMSS 1999 Video Study, Leung (2005) argued that the ratio of the average number of words spoken by teachers to those spoken by their students during a lesson showed a very evident verbal dominance by teachers of the East Asian countries. The ratios were calculated for the following countries: Hong Kong (16:1), Japan (13:1), the US (8:1), Australia and the Czech Republic (9:1), and the Netherlands (10:1). In a study of two Korean middle school mathematics teachers, Lee and Sriraman (2013, p. 163) found that "although they work towards constructivism in education and application of the current educational reform perspective which is based on constructivism, [they] continue to employ a traditional approach to teaching recognized as the 'pedagogy of silence.'".

As part of the ECCO-SM project, Choi (2015) and Choi et al. (2015) analyzed the behavioral patterns of a small group of Korean students' participation in science lessons. Their analysis required a tool named VABAP (Video Analysis of Behavior

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[2] It is a shortened expression of "global and local". In this project, hyper-connectedness and low fertility represent the most important global and local issues faced by current Korean society respectively.

and Participation in classrooms). It was developed to observe elementary and secondary science lessons in Seoul, Korea.

In these studies, students' participation patterns were classified into ten trans-subject behaviors (i.e., spontaneous speech, listening, reading aloud, reading silently, writing, paying attention, raising hand, moving, non-participatory motion, and activity motion) and four science behaviors (i.e., observing, classifying, measuring, and handling apparatus/specimen). And, based on whether or not a student had verbal participation and lesson participation, these behaviors were further grouped into four different participation patterns: participatory speech, non-participatory speech, participatory silence, and non-participatory silence. The classification and grouping of the observation records of the lessons were made every one second.

In a case study with elementary science lessons (Choi et al., 2015), two pupils were closely observed. As shown in Figs. 1 and 2, the main behavior patterns of the pupils and their teacher were identified as follows:

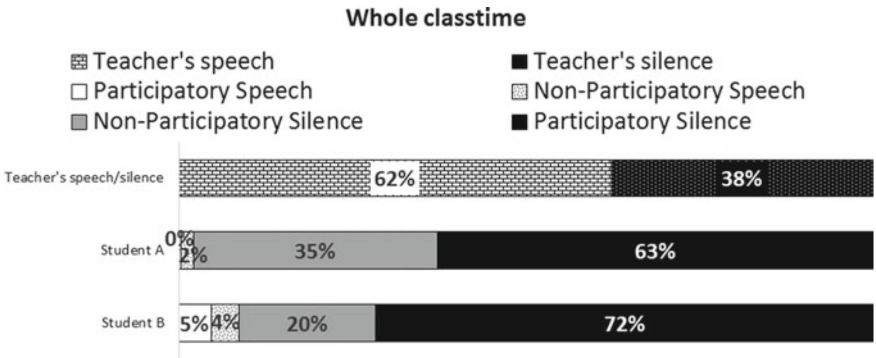

Fig. 1 Participation patterns in elementary science lessons (Choi et al., 2015)

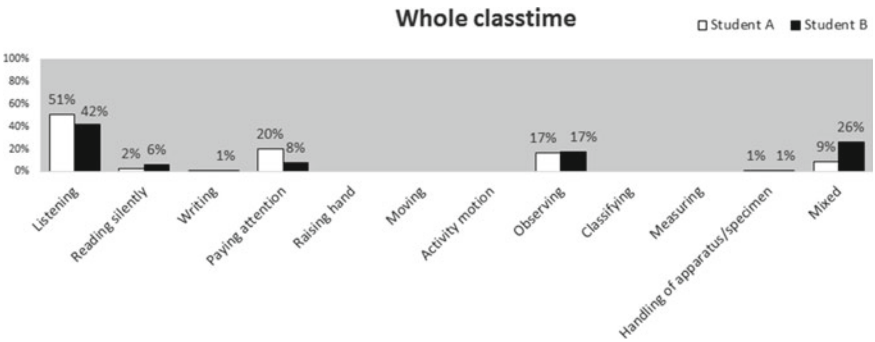

Fig. 2 Different activities of students' participatory silence in elementary science lessons (Choi et al., 2015)

- sixty-two percent of the whole lessons' time was used for the utterance by the teacher.
- pupil B made verbal utterances for nine percent of the lesson time, of which five percent was "participatory speech" and four percent was of "non-participatory speech."
- for pupils A and B, the longest time used was for "participatory silence," 63% and 72%, respectively.
- in the "participatory silence" category, the most common behaviors were—listening (51%, 42%), paying attention (20%, eight percent), and observing (17%, 17%).

The other case study concerned middle school students (Choi, 2015). Behaviors of seven students in a Grade 7 science class were recorded for three lesson hours with four cameras. The main findings were as follows: (a) All the students (except one who made verbal utterance for 19%) kept silent (i.e., they made verbal utterance only for 0–4% of the lesson time); (b) a verbal utterance (19%) made by the only student was non-participatory, meaning that it was not related to lesson; and (c) the most frequently observed behaviors of participatory silence were in the order of paying attention, listening, observing, and so on.

The main results of the above two observations of Korean science lessons could be summarized as follows:

1. more than a half of science lesson time is used by the teacher;
2. among students' activities in science lessons, most of the students remained absolutely silent. Only a few students made verbal utterances, most of which were non-participatory; and
3. more than a half of the lesson time was used for different kinds of "silent participation" such as, listening, paying attention, and observing. Therefore, even although Korean students appear to have very passive and little participation, they are in fact participating in science lessons in one of several forms of participatory silence.

Thus, it is important to notice that the lack of verbal communication by East Asian students during science classrooms should not be interpreted as the direct evidence of their lack of participation in the lesson.

3.2 Norms in Science Classrooms

During the ECCO-SM project, Chang and Song (2016) conducted a study to analyze what kinds of classroom norms are formed and practiced in inquiry activities of elementary science classes in Korea. Science lessons by two elementary teachers (one homeroom teacher and one science subject teacher) and their classes at different schools were observed for 20 science lessons throughout the first semester of an academic year.

The data were collected through classroom observations, student interviews, and questionnaires. First, based on the review of previous studies, they were able to classify three different kinds of norms formed during science lessons: (a) norms for behavior guidance; (b) general academic norms; (c) scientific inquiry academic norms.

Secondly, the classroom investigation of the norms for behavior guidance was observed to be formed for the purposes of time management, lesson preparation, classroom atmosphere, and basic rules for classroom behavior. “[T]hese rules are formed mainly under the influence of the teacher, and the features of these norms are quite different from classroom to classroom depending on the teacher’s value[s] and belief[s]” (Chang & Song, 2015, p. 196).

On general academic norms, the rules for learning attitudes, classroom presentations, and activity participation were observed, and it was found that “these norms were operating in relation with norms for behavior guidance and reflecting well teachers’ values and beliefs” (p. 196). On the other hand, scientific inquiry academic norms were observed as rules for participating in inquiries, for criteria of desirable inquiry performance, for laboratory safety, and appeared to be frequently shared with students rather than being monopolized by the teachers.

In a subsequent study, Chang and Song (2016) found that the classroom norms in different science classes were established differently and that the norms could be categorized into three types in terms of their sharing process in the classroom: teacher-initiated norms, teacher-student-negotiated norms, and students-initiated norms.

The teacher-initiated norms were top-down in their nature; for instance, “We should try to make our own interpretations of phenomena in inquiry activities” (p. 753) and “We should follow the normative standards suggested by the teacher to evaluate peer’s interpretations in group discussions” (p. 756). Here, it was found that there were three levels of acceptance of classroom norms: pretending to follow, selective acceptance, and internalization.

The only teach-student-negotiated norm observed was “We should not pollute the environment during experiments” (p. 761). Here, the teacher first established a norm related to environmental ethics (i.e., not polluting the environment during experiment activities) and explained the reasons why. Then students were willing to accept the core value of the norm and internalized the norm.

A students-initiated norm observed was “Nevertheless, we should produce the correct answers” (p. 758). Here, despite its negative nature, students established their own norm that is believed to be due to their preoccupation with correct answers.

Thus, most of the science classroom norms observed in this study were either teacher-initiated or teacher-student-negotiated (i.e., teacher-initiated but with student-accepted). This means that the role of the teacher is vitally important. Even in the case of the one student-initiated norm (i.e., producing the correct answers), it is basically influenced by sources of authority of science lessons (i.e., the teacher or textbook). Figure 3 shows an example of how the teacher-initiated norms are formed and shared in the classroom.

As illustrated by Chang and Song’s studies (2015, 2016), communications and interactions in Korean (and perhaps for East Asian) science classrooms seem rather

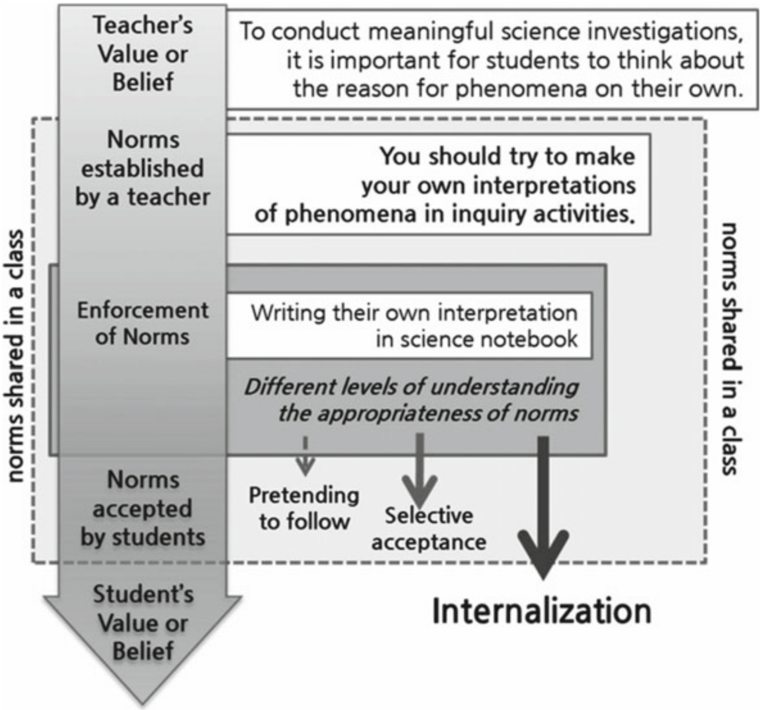

Fig. 3 The process of formation and sharing of teacher-initiated norms (Chang & Song, 2016)

teacher-centered. Teachers usually take the lead in classroom conversation and are actively involved in building up classroom norms. Nevertheless, this teacher-centered communication and interactions do not exclude students' participation and do not imply inefficient lessons, as Leung (2005) rightly pointed out:

> [M]eaningful learning can still take place in a teacher directed classroom. Teacher dominance with a lot of teacher talk does not necessarily lead to passive, receptive learning. Much depends on the content of the teacher talk and how it is delivered, and whether the talk can stimulate students to be engaged in the mathematics. (pp. 209–210).

3.3 Science Classroom Creativity

As in many other countries, creativity has been one of the key objectives of school education in Korea. Moreover, science is generally regarded as a core subject to achieve this goal. The 2015 National Curriculum of Korea declares five goals, one of which is a student-centered curriculum to improve learners' autonomy and creativity. The curriculum also defines science as "a subject to foster scientific literacy which makes possible for all students to solve personal and social problems scientifically and creatively by understanding scientific concepts and acquiring scientific inquiry abilities and attitudes" (Ministry of Education, 2015, p. 3).

The 2015 curriculum is not the first national curriculum to emphasize creativity as its goal. Creativity and integration (創意融合) have been the overall visions since the 2009 National Curriculum in Korea (Song & Na, 2014). In criticizing the confused interchangeable usage of the terms "creativity" and "integration," Song and Na (2014) argue that while creativity (創意) must be the goal, integration (融合) should be the way to achieve that goal.

In briefly reviewing studies on creativity and the adoption of socio-cultural approaches, Song and Na (2014) argued that there has been an increasing number of studies concerned with a *group of people*, not with individuals. This kind of creativity has been called group creativity, team creativity, or collaborative creativity (John-Steiner, 2006; Shalley et al., 2004; Surowiecki, 2005).

Considering a class as a group, Hong (2016) developed a componential model of Science Classroom Creativity (SCC) to explain creativity in science classrooms. Hong's model resulted from multiple research methods that included literature reviews, critical incidents techniques, classroom observation, focus-group interviews, and surveys with secondary school students in Korea. Hong conceptualized SCC to have nine factors: cognitive characteristics of students, affective characteristics of students, internal engagement in science class, external engagement in science class, science classroom environment, cognitive support of science teacher, emotional support of science teacher, individual creative experience, and group creative experience. Through the analyses of the data, these nine factors were grouped into five components of SCC: student characteristics, engagement in science class, creative behavior, science teacher support, and science classroom environment, as shown in Fig. 4. It is interesting to see that two of the five components constituting the SCC model (i.e., science teacher support and science classroom environment) are subject to classroom culture rather than to individual students. Furthermore, by applying the SSC model to four classes in a high school in Seoul, it was found that the supports (emotional and cognitive) of science teachers appear to be the most important factor contributing to SCC.

When science educators emphasized students' creativity, they tended to focus on students at the individual person level, for example—Who is talented with creativity? How do we select them? How can their creativity be improved? However, as seen from Hong's study (2016), to foster students' creativity, schools should provide a creative classroom environment. To accomplish that, the role of science teachers is essential. They need to support their students cognitively and emotionally. But the expected roles and teaching practices of science teachers in Korea are quite different from those in Western cultures.

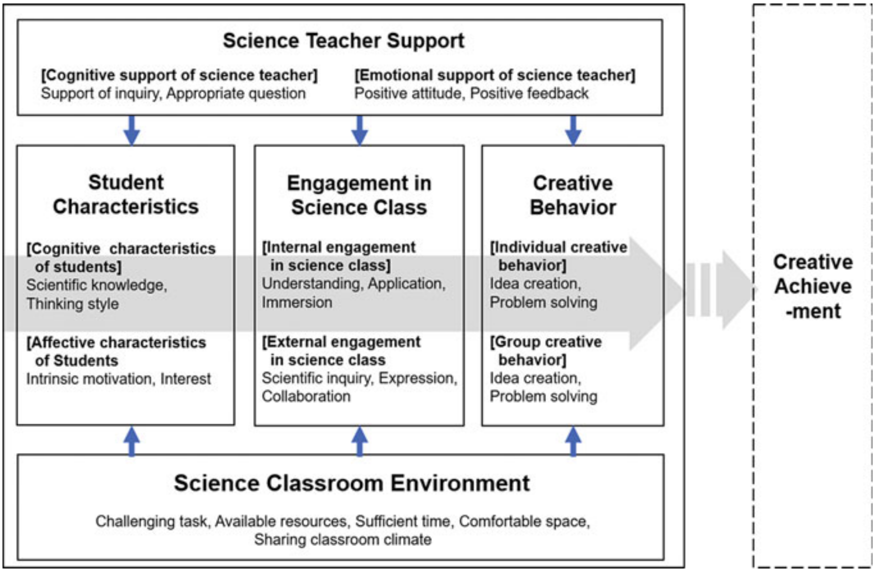

Fig. 4 A componential model of science classroom creativity (SCC) (Hong, 2016)

3.4 *Instruments for Investigating Science Classroom Culture*

Understanding the details of science classroom culture is not easy and cannot be done without appropriate tools. Several well-established and widely-used instruments for classroom environments have been developed, for example, Science Laboratory Environment Inventory, (Fraser et al., 1992); What is Happening In This Classroom (Fraser et al., 1996); and Cultural Learning Environment Questionnaire (Fisher & Waldrip, 1997). Throughout the ECCO-SM project and related studies, we have experienced difficulties caused by a lack of appropriate and useful instruments to investigate what is going on and how students and teachers interact and communicate in science classrooms.

To overcome these difficulties, several instruments needed to be developed by ourselves, each having a different focus: Video Analysis of Behavior and Participation (VABAP) to analyze what kinds of activities students do during science lessons; Science Classroom as Community of Practice (SCaCoP) to learn how much students consider their science classroom as a community of practice; Community of Inquiry in Science Classroom (CoISC) to register how much students perceive their science classroom as a community of inquiry; Engagement and Participation in Classroom-Science (EPIC-S) to investigate how students engage and participate in the science classroom; and Science Classroom Creativity Scale (SCCS) to check how much creative is a science class as a whole. A brief explanation for three is given below.

3.4.1 VABAP

When students are engaged in classroom learning, it occurs through verbal communication and nonverbal behaviors. Especially in science classrooms, different kinds of meaningful nonverbal behaviors (e.g., observation, measurement) happen during practical activities. The VABAP was developed to analyze students' behavioral engagement in science classrooms by using Microsoft Excel with a framework consisting of 14 categories which are grouped into four different participation patterns: participatory speech, non-participatory speech, participatory silence, and non-participatory silence. The VABAP was used to investigate and analyze elementary and middle school students' participation in Korean science lessons (Choi, 2015; Choi et al., 2015).

3.4.2 SCaCoP

Science learning in school happens in a somewhat organized way inside science classrooms, rather than in an isolated situation. In particular, in a collective society like Korea and East Asia, the classroom culture plays more important roles than in the West. With this in mind, the SCaCoP was developed to analyze science classrooms from the perspectives of community of practice (Wenger, 1998; Wenger & Snyder, 2000). It is comprised of 27 Likert scale items with one open-ended question. Through a pilot test with statistical analyses (Chun et al., 2015), the SCaCoP appears to have five structural factors: responsibility for learning, common interest, mutual relationships, open participation, and practice. The overall reliability (Cronbach α) was 0.938, while those of five factors ranged between 0.744 and 0.866. The SCaCop instrument was then used in studies to analyze science classroom culture in Korean elementary schools (Chun et al., 2015) and to investigate Science Core Schools in Korea in terms of communities of practice (Kim et al., 2017).

3.4.3 EPIC-S

The EPIC-S was a revised version of the Engagement and Participation in Classroom (EPIC) instrument that had been developed to investigate students' perceptions and preferences toward their engagement and participation in science lessons (Kim, 2015; Park et al., 2015). Revised in collaboration with Taiwanese and Australian colleagues and with special attention given to science lessons, the EPIC-S consists of 16 sub-categories with a total of 79 Likert scale items. The 16 sub-categories were organized around four main categories: students' personal backgrounds, expectations of participation, preferred participation patterns, and learning environments. The EPIC-S appeared to have Chronbach's α reliabilities ranging from 0.83 to 0.95 for its main categories. It was used to investigate students' participation patterns in science classrooms in East Asia regions (Ahn et al., 2016; Chien et al., 2016; Chien, Jen, Martin, Chu, & Chang, 2018).

4 A Need of Socio-Cultural Approaches to Science Classroom Culture

In East Asian culture, education is so fundamentally central. Thus, families and society, in general, make every effort to ensure its good learning conditions, although it often results in serious social conflicts. For this reason, Koreans often say that education is more political than politics itself. Accordingly, to understand the reality of school science education and classroom culture requires deep-rooted cultural approaches penetrating deeply into educational phenomena.

East Asia is widely known to be distinctive from the rest of the world, especially in terms of people's attitudes toward learning, teachers, and schools. The high value and respect given to education and its teachers are well represented in a popular Chinese idiom of 君師父一體. Zhang and Bai (2015) argue that "the most conspicuous phenomenon throughout Chinese history is that the state leaders were learned scholars and educators who advocated the value of education and manifested such value at their paramount position" (p. 68). This educator image of a leader is common in East Asian traditions.

For example, in Korea, the two most highly respected kings of Chosun (朝鮮) Dynasty, namely King Sejong (世宗) and King Jeongjo (正祖), were typical examples of the Confucian Scholar-King image (Bu, 2013). One of the main, if not the most responsible duties of a king (and other) was studying (공부: 工夫) and self-discipline (자기수련: 修己). He set the example for others of high positions to follow in the kingdom.

Being connected with this education and learning tradition, the phenomenon of classroom silence in Korea (and perhaps across East Asia) is suspected to have a long historical and cultural background. East Asian regions embrace cultural traditions that both emphasize silence and discourage outgoing utterances and assertions. For example, in Taoism, the teaching not-through saying was emphasized: 聖人處無爲之事, 行不言之教 (meaning that The Sage focuses on non-action in his works, practices not-saying in his teaching) and 知者不言, 言者不知 (meaning that one who knows does not speak, one who speaks does not know) (Cho, 2006).

In Korean history, the culture of Seonbi (선비) belonged to their society's high class. They strictly followed the teachings of neo-Confucianism; for example, the duty to cultivate oneself and rule others (修己治人). In Seonbi culture, there were two educational ways to become 君子 and 賢人 (Choi, 2006):

1. **存養 (存心養性):** to keep the mind quiet and concentrate on building character, so that man's innate nature is rightfully directed, and the kind heart preserved;
2. **窮理:** to continuously study, learn, and gain insight into the basic principles of the universe and nature.

And in the theory of learning (工夫論) by Yulgok (栗谷 李珥, pp. 1536–1584), there are two ways of learning to cultivate oneself (修己工夫), that is, "leaning of knowing" (知工夫) and "learning of doing" (行工夫). We brighten the goodness through the learning of knowing, while we strengthen our behavior with integrity through the learning of doing (Hwang, 2002).

As illustrated above, the traditions of Korean culture have emphasized (a) not-saying, (b) to keep the mind quite, and (c) learning by doing. These suggest the kind of learning with self-discipline and quiet practice. Thus, the silence in the classroom is not just the phenomena of schools or of students, but a long-standing tradition of Korean culture extremely difficult to change.

In East Asian culture, learning is not just an individual student's business. In Confucius culture, education is often regarded as a family business. While East Asian cultures are quite collectivist, Confucianism puts a lot of emphasis on the family relationships. In Confucianism, there are five basic human relationships (五倫), and among them, three belong to family relationships (i.e., of father–son, of husband–wife, and of elder–younger) (Huang & Gove, 2015). It is thus very common that children's education is considered the most important and central issue in their family. Parents believe that they have responsibilities to provide the children with the best environment for a better education. In Confucian culture, the parent's sense of responsibility over their children's educational environment has a long history following the story of 孟母三遷之教, of which literal meaning is "Mencius' mother's three moves for her child." Because of this heavy involvement of family, and sometimes even the nation, toward learning and education, the focus of learning behavior is not subject to self-enjoyment and a person's desire. Thus, Korean students perhaps study science not because it is interesting, but maybe because it is believed to be important for the future of the family or nation.

The special emphasis on the mutual relationship between teachers and students in East Asian culture is surely deep-rooted in its culture and tradition, even though it is often seen as hierarchical and unbalanced in terms of communication power. Some best examples of this tradition are most popular and loved expressions related to education in Korea (and probably across East Asia), such as "교학상읍(教學相長)", "줄탁동시(啐啄同時)," both of which symbolize the mutually complementary and interdependent relationship between teachers and students. Together with another famous traditional Chinese idiom, 군사부일체(君師父一體), these educational expressions somehow explain why the relationship between teachers and students is often seen much like those between parents and children. The strong inter-relationship between the teacher and students in East Asian regions can be understood as a typical example of a so-called "high context society" (Hall, 1976).

Through the studies related to the ECCO-SM project, we came to understand that Korean science classroom culture is not as much an anomaly as we thought. Students engage in science lessons through their silent participation. Teachers' support appears to be essential for forming appropriate science classroom norms and for encouraging science classroom creativity. In addition, the relationship between the teacher and students is quite close and similar to that of a family.

Nevertheless, students' passive participation and science teachers' focus on delivering knowledge didactically still remain major challenges to Korean science education. How can we meet these challenges to improve the practice of science education for the future? What should be the future direction for Korean science education to address its weakness while maintaining its relative strength? How can we increase students' enjoyment of, and participation in, science learning?

5 Korean Science Education Standards for the Next Generation

To meet these challenges, the previous nationwide effort over five years (2014–2019) produced a series of short projects that succeeded in developing basic concepts and details to serve as a reliable basis for the Korean Science Education Standards (KSES) for the future generation. The KSES projects were initiated by the Korea Foundation for the Advancement of Science and Creativity (KOFAC), based on the joint support from the Ministry of Education and the Ministry of Science and ICT. KOFAC's aim is to develop a blueprint or long-term roadmap for the preparation of Korean science education for the future. The KSES projects benchmarked and tried to go beyond the US's Next Generation Science Standards (NGSS Lead States, 2013), which was started by AAAS's Project 2061 during the mid-1980s.

In 2014, KOFAC started to support several small projects, each having a different focus and set of features that eventually led to the concept of KSES. The last two KOFAC projects produced a KSES conceptual framework and finalized several details such as its performance expectations, comprehensive descriptions, and indicators (Song et al., 2018, 2019a, 2019b).

The conceptual framework of the KSES is the Tree of Scientific Literacy (ToSL) model, which has three interwoven, interdependent, and mutually complementary dimensions: competence, knowledge, and participation and action as shown in Fig. 5. The scientific literacy described by ToSL is defined as "the attitude and ability as a democratic citizen to participate in and act on solving personal and social problems using science-related competences and knowledge" (Song et al., 2018, p. 73). It is considered the basis of the character of future citizens, which is defined as "a creative and cooperative person equipped with scientific literacy" (Song et al. 2018, p. 73).

In the ToSL model, the competence dimension is purposefully listed first, while the knowledge dimension is placed second. This sequence was reached based on the belief that the knowledge dimension of science should be given an equal priority among the three dimensions. Maybe the most noticeable feature of the ToSL model would be the inclusion of the third dimension, participation and action, which goes beyond the conventual boundaries of the school and school curriculum. This participation and action dimension is introduced with an ambition that this new dimension would be vital to remedy and improve the long-standing phenomena of little participation in science learning. Each dimension is divided into several categories which are further divided into several sub-categories. In total, KSES has 3 dimensions, 16 categories, and 65 sub-categories (Fig. 5).

In order to provide concrete guidelines for future developments in national science education, the KSES also developed more elaborated explanations, examples, and

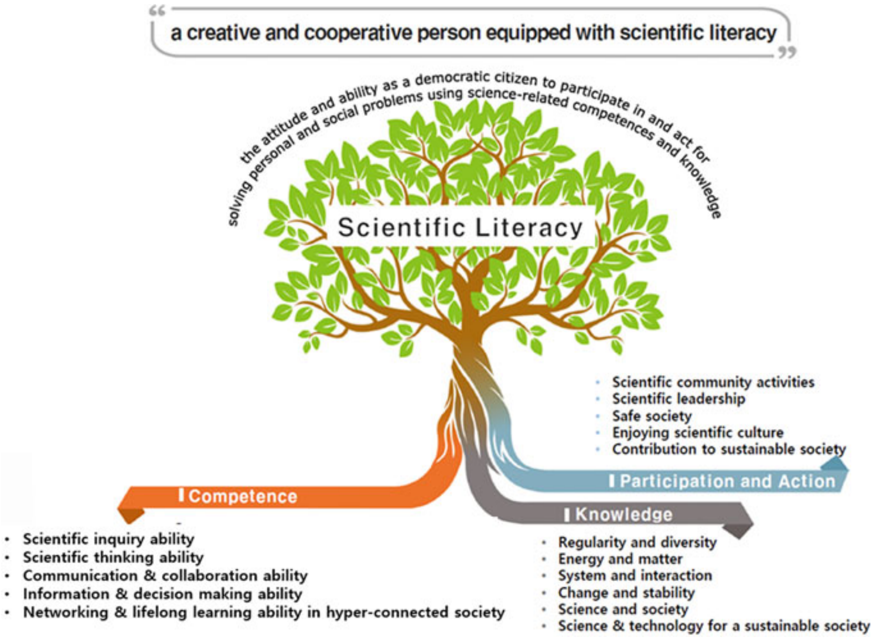

Fig. 5 ToSL model of scientific literacy of Korean Science Education Standards (KSES) (Song et al., 2019a, 2019b, translated)

suggestions. For the convenience of implementation, the KSES provides its details in terms of six stages, corresponding to the following grades: K-2, 3–4, 5–6, 7–8, 9–10, and 11–12.

In addition, a comprehensive framework set of KSES indicators is also suggested. This should help (a) future monitoring of the implementation of KSES and (b) future progress of school science education as indicated by a collection of quantitative and qualitative data from students, science teachers, and schools. These data will be used as the foundation for government policies for Korean science education. More details of KSES and its comparison to features of the US's NGSS can be found in Song and colleagues (Song, Kang, Kwak,…Kim, & Joung, 2019b) and in Kim and Song (2019), respectively.

6 Summary

In this chapter, by introducing some major results and outcomes of ECCO-SM project and related studies, I have tried to address the importance of the socio-cultural approaches to understand what is really happening inside the science classroom and why it is so. Even although the contents (and more) of school science education might be universal and similar across the world, the way they teach and learn science in school can and must be very different. It is because the activities of teaching and learning cannot be beyond the cultural boundaries and independent of the values and traditions of the society. If the East and the West are different and persistent in terms of educational interactions, the way we teach and learn science in schools must also be different accordingly.

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Addressing the Challenges and Scaffolding of Inquiry-Based Teaching on Secondary School Students' Efficacy in Conducting Scientific Inquiry

Aris C. Larroder

Abstract Anderson (J Sci Teach Educ 13(1):1–12, 2002) raised several questions about inquiry in terms of meaning, emphasis, approach, teaching, and learning among others. However, the question on barriers in initiation and implementation offers few answers in literature. Likewise, despite several attempts to explicate scientific inquiry, few studies delve on the process of scientific inquiry as a practice. It is observed that different schools have different approaches as a practice on how scientific inquiry is implemented. This chapter presents the practice of scientific inquiry at Philippine Science High School Western Visayas Campus. Likewise, the chapter highlights the entire curriculum for programs where scientific inquiry can be practiced. However, this chapter tackles only the implementation of its Science Internship and Science Research programs. It presents the barriers to its implementation and how these barriers were addressed. Examples of successful practices are presented as type study which led to students to publish their paper to peer-reviewed journals. The chapter concludes with insights and lessons on how scientific inquiry can be successfully practiced in classrooms all over the world. Lastly, an implication of school's practice on scientific inquiry, science education, inquiry learning and teaching is also presented.

1 Introduction

The science education literature generally supports inquiry-based instruction. In fact, most countries' science curriculum requires it. This causes numerous definitions of inquiry to exist in the literature. The term "scientific inquiry" is prevalent in the United States while "science investigation" is widely used in the United Kingdom, Australia, and New Zealand (Moeed, 2013). In this chapter, "inquiry" is favored as a more encompassing terminology.

For the meaning of inquiry, most researchers and educators rely on a functional definition of inquiry, in which emphasis is given to the role of the learner's control

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over the activity (Minner, Levy, & Century, 2010). This would sometimes lessen the teacher's direct control of the activity, thus only being the facilitator of learning. Leaving out the teacher prevents us from seeing the whole picture of inquiry. This chapter provides a more holistic point of view and enriches the role of inquiry facilitators.

Anderson (2002) pointed out that in addition to the meaning of inquiry, other issues are important: emphasis in, approaches to, the teaching of, and students learning inquiry. Inquiry's emphases are being questioned: for example, who provides the research question and determines other inquiry tasks, the teacher or student? Ryker and McConnell (2014) tabulated the various possibilities and levels of inquiry determined by who controls each characteristic (see Table 1). According to these researchers, provision or non-provision is a matter of teacher's choice, which is highly based on a teacher's positionality. Positionality may be considered to be attitudes and beliefs about inquiry in classrooms. Unless inquiry is required and clarified by the curriculum, a teacher is forced to implement inquiry-based teaching methods without explicit guidance concerning the intended approaches (Center for Science, Mathematics, and Engineering Education, 2000).

The approach to inquiry as used in this study is synonymous to process. Warner and Myers (2008) emphasized that teachers play a vital role in adapting the inquiry process to the knowledge and ability level of their students. According to the Center for Science, Mathematics, and Engineering Education (1995), inquiry approach on the part of the students involves students undergoing the following five basic steps: (1) question; (2) investigate; (3) use evidence to describe, explain, and predict; (4) connect evidence to knowledge; and (5) share findings.

Table 1 Characteristics and levels of inquiry determined by the teacher's control versus the student's control

Characteristic	Level 0: Confirmation	Level ½: Structured	Level 1: Guided	Level 2: Open	Level 3: Authentic
Problem/Question	Provided	Provided	Provided	Provided	Not provided
Theory/background	Provided	Provided	Provided	Provided	Not provided
Procedures/design	Provided	Provided	Provided	Not provided	Not provided
Results analysis	Provided	Provided	Not provided	Not provided	Not provided
Results communication	Provided	Not provided	Not provided	Not provided	Not provided
Conclusion	Provided	Not provided	Not Provided	Not provided	Not provided

Note Adapted from Ryker and McConnell (2014)

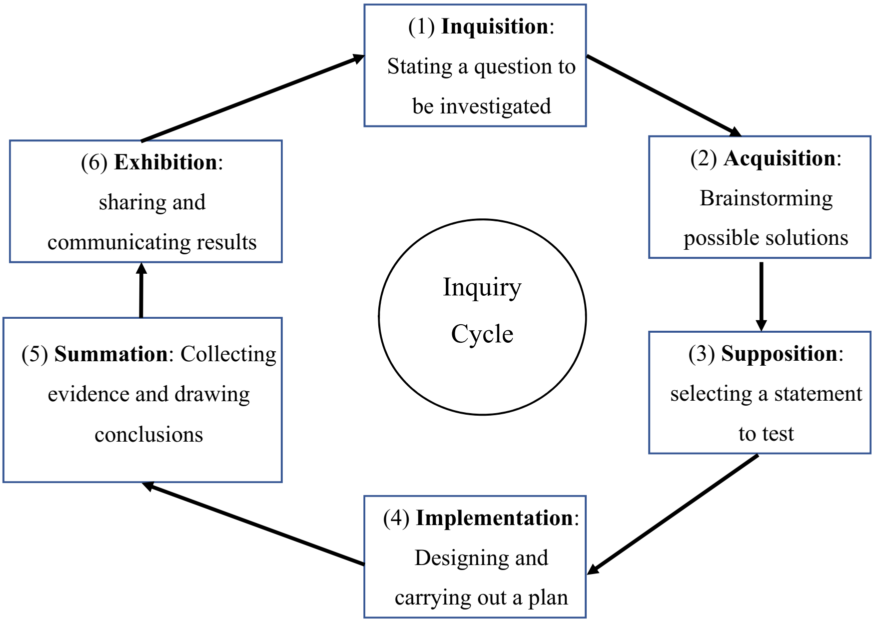

Fig. 1 The inquiry cycle

Llewellyn (2002), however, would consider inquiry approach as a cycle. The cycle includes: (1) Inquisition—stating a "what if" or "I wonder" question to be investigated; (2) Acquisition—brainstorming possible procedures; (3) Supposition—identifying an "I think" statement to test; (4) Implementation—designing and carrying out a plan; (5) Summation—collecting evidence and drawing conclusions; and (6) Exhibition—sharing and communication results (see Fig. 1).

One thing is clear, the approach in inquiry involves both the learner and the teacher as a facilitator of learning. As for the teacher inquiry approach, it may involve: (1) starting the inquiry process; (2) promoting student dialog; (3) transitioning between small groups and classroom discussions; (4) intervening to clear misconceptions or develop students' understanding of content material; (5) modeling scientific procedures and attitudes; and (6) utilizing student experiences to create new content knowledge (Warner & Myers, 2008). One thing is clear that the approach in inquiry involves both the students as learner and the teacher as facilitator of inquiry learning. Therefore, the teaching and/or learning of inquiry must be viewed from both the teacher's and the learner's perspective.

However, most researchers investigate the students' perspective only, while a few investigate the teacher's perspective. Likewise, research on teachers' inquiry is more extensive for pre-service than for in-service teachers (Graves & Rutherford, 2012). With the scarcity in the literature of research among in-service teachers, the question of barriers to initiation and implementation of inquiry science teaching offers few answers in the literature.

Lastly, the Center for Science, Mathematics, and Engineering Education (2000) published *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning*. It discusses two tenets on science inquiry. The first states that educators need evidence drawn from research to help them implement and justify inquiry-based approaches to teaching and learning science. The second tenet states that one of the best ways to understand school science as inquiry is to visit a classroom where scientific inquiry is practiced. Inquiry-based science education produces positive results, yet in classrooms that conduct inquiry, teachers are frustrated, and they encounter difficult problems in implementing inquiry teaching (Anderson, 2002).

This chapter chronicles the implementation of inquiry as a scientific practice in a school by presenting a case of inquiry-based science education.

2 Context of a School-Based Implementation of Inquiry

Locale of the Study

The research study took place at the Philippine Science High School Western Visayas Campus (PSHS WVC) in Iloilo City, Philippines. The campus is one of the 16 campuses across the Philippines that operates under one system. It envisions preparing its scholars to become globally competitive Filipino scientists equipped with twenty-first century skills and imbued with the core values of truth, excellence, and service to the nation. Its mission is to provide scholarships to secondary students with high aptitudes in science and mathematics.

PSHS WVC offers scholarships (i.e., free tuition fees, free loan of textbooks, monthly stipend, uniforms, transportation, and living allowances for low income groups, and dormitory accommodation) with special emphasis on subjects pertaining to the sciences and mathematics in order to prepare its students for science and technology careers. The course offerings are divided into three: (1) Foundation Years (Grades 7–8); (2) Advancement Years (Grades 9–10); and (3) Specialization Years (Grades 11–12). Aside from academic requirements, students have to complete several non-graded subjects as a requirement for graduation.

A “Science Immersion Program” comes in many forms and may be taken in any school break after Grade 9 or Grade 10. It requires a minimum of 80 h exposure to a professional science laboratory and working with a scientist. Science Electives, such as Engineering, Agriculture, Robotics, Microbiology, and Microcontroller, are offered but they are optional. If Elective classes are taken, however, students’ grade is included in a student’s general weighted average mark. Lastly, SCALE which stands for Service, Creativity, Action, and Leadership Enhancement, should be complied during Specialization Years. In this non-graded requirement, students have to comply with one activity for each letter of the subject’s acronym.

The school’s Specialization Years has the following features: (1) Outcomes-Based—decisions on curriculum are driven by a predetermined set of student exit learning outcomes; (2) Learner-Centered—an emphasis on students doing the learning, with teachers acting as facilitators; (3) Humanistic Design—teaching and learning are based on reason and scientific methods; and (4) Focus on Higher Order Learning—outcomes target the more complex thinking skills.

A "Research Program" is the core of the inquiry teaching and learning. The country, and thus the school, have just recently adopted the K-12 program that has been running for only two school years. In the new curriculum, science inquiry is implemented in the Research subject in the second year of Advancement Years up to Specialization Years. This is due to the fact that the Research Program is a three-year program starting from Grade 10 up to Grade 12. The program expects that during Research 1, learners can produce research proposals and preliminary paper. In Research 2, learners are expected to submit a research proposal, implement, and analyze research. During the final year in Research 3, learners are expected to write and publish their research work in scientific journals published by the school.

The Research Unit implements the research program of the school. It is composed primarily of one Unit Head, 15–17 research advisers, and six research teachers. The Unit Head works hand in hand with the teachers teaching the research subject and managing work units or groups through research advisers. The number of research advisers varies according to the number of work units formed during a particular school year. The research teachers and the research advisers are the core facilitators of learning who run the research program of the school. Both have teaching and/or advising load in the Research Subject. There are nine research teachers manning the entire research program with one research teacher handling a class composed of 30 students. A total of three teachers handle one research subject. Since there are three classes for each year level, the three teachers work as a subject unit considering the team-teaching mode of subject implementation. The research teacher can handle up to six work units which may be composed of only one or up to three student researchers for every work unit. This scheme is due to the provision that students can work alone, with a partner, or as a triad. The teachers provide the classroom instruction while advisers work with students as they conduct their research.

In contrast, teachers do the input conceptually while advisers are involved in the process or the conduct of the research. As the core of the research is highly dependent on the advisers, students' grade constitutes about 60–75% of adviser's rating. The research advisers are considered experts in their respective fields. Just like research teachers, a research adviser can only take up to six work units. A corresponding 0.5 unit is given to research teacher or adviser in handling a work unit in research. Research advisers are needed to (1) encourage accomplishment of more specialized projects; (2) neutralize the tendency of students to propose research studies based on available campus expertise; (3) widen opportunities for research linkages; and (4) increase the competitiveness of PSHS researches for presentation to public audiences through publication or other means.

The PSHS Curriculum (see Fig. 2) includes eight general capabilities. These capabilities include literacy, numeracy, information and communication technology, critical and creative thinking, personal and social capability, ethical understanding,

Foundation Years						Advancement Years						Specialization Years					
Grade 7			Grade 8			Grade 9			Grade 10			Grade 11			Grade 12		
Subjects	Mtg	Unit	Subjects	Mtg	Unit	Subjects	Mtg	Unit	Subjects	Mtg	Unit	Subjects	Mtg	Unit	Subjects	Mtg	Unit
Integrated Science 1	5	1.7	Integrated Science 2	6	2.0	Biology 1	3	1	Biology 2	3	1.0	Biology 3	5	1.7	Biology 4	5	1.7
						Chemistry 1	3	1	Chemistry 2	3	1.0	Chemistry 3			Chemistry 4		
						Physics 1	3	1	Physics 2	3	1.0	Physics 3			Physics 4		
Mathematics 1	5	1.7	Mathematics 2	5	1.7	Mathematics 3	3	1	Mathematics 4	4	1.3	Mathematics 5	3	1.0	Mathematics 6	3	1.0
English 1	4	1.3	English 2	4	1.3	English 3	3	1	English 4	3	1.0	English 5	3	1.0	English 6	3	1.0
Filipino 1	3	1.0	Filipino 2	3	1.0	Filipino 3	3	1	Filipino 4	3	1.0	Filipino 5	3	1.0	Filipino 6	3	1.0
Social Science 1	3	1.0	Social Science 2	3	1.0	Social Science 3	3	1	Social Science 4	3	1.0	Social Science 5	3	1.0	Social Science 6	3	1.0
Physical Education / Health / Music (PEHM) 1	3	1.0	Physical Education / Health / Music (PEHM) 2	3	1.0	Physical Education / Health / Music (PEHM) 3	3	1	Physical Education / Health / Music (PEHM) 4	3	1.0	-	-	-	-	-	-
Values Education 1	3	0.7	Values Education 2	2	0.7	-	-	-	Science, Technology, Engineering, & Mathematics (STEM) Research 1	3	1.0	Research 2	6	2.0	Research 3	6	2.0
Art, Design, & Technology 1	3	1.0	Art, Design, & Technology 2	3	1.0	Probability & Statistics	3	1	-	-	-	Any one of the Biology 3, Chemistry 3, Physics 3, Computer Science 5, Engineering, Technology 1, Agricultural Science	5	1.7	Any one of the Biology 4, Chemistry 4, Physics 4, Computer Science 6, Engineering, Technology 2, Agricultural Science	5	1.7
Computer Science 1	3	1.0	Computer Science 2	3	1.0	Computer Science 3	3	1	Computer Science 4	3	1.0	-	-	-	-	-	-
-	-	-	Earth Science	2	0.7	-	-	-	Elective	-	-	-	-	-	-	-	-
Total	31	10.4		34	11.4		30	10		31	10.3		28	9.4		28	9.4

Fig. 2 Philippine Science High School System. (2015). The PSHS six-year curriculum subject matrix

global perspective, and scientific literacy. In the school's Student Handbook, scientific literacy means involving "scholars in acquiring and applying scientific knowledge to critically evaluate claims, issues, and problems about the natural world, and draw evidence-based conclusions. Passion for science, and positive values and dispositions such as curiosity, risk-taking, open-mindedness, resilience, collaboration, and pursuit of the truth are cultivated'. The organizing elements of this capability are: (1) Examining natural phenomena; (2) Expressing positions that are scientifically and technologically informed; (3) Planning and conducting an investigation; (4) Processing and analyzing data and information; (5) Evaluating scientific arguments, processes, and results; and (6) Communicating using scientific language in a range of mediums.

3 Science Inquiry: School/Classroom Perspective

The school's interpretation of inquiry's meaning is inspired primarily by its role to equip students with an inquiring profile[1] (see Fig. 3). Consequently, one must conduct inquiry and purposeful research. Another inspiration is the school's vision to prepare students to become scientists in the future. We share meaning with the National Science Education Standards, which defines science inquiry as: (a) the diverse ways in which scientists study the natural world, and (b) the act of proposing explanations based on the evidence derived from their work. The meaning of scientific inquiry is best summarized by Lederman (1998) as the systematic approaches used by scientists in an effort to answer their questions of interest. The meaning of science inquiry is therefore defined by the scientist and determined by the nature of the scientific problem. The scientist finds an answer to a scientific question according to the extent of their creativity and engagement with the scientific problem.

However, Anderson (2002) would point out that this definition is independent of educational processes. He lamented the lack of operational definitions of what indeed inquiry is. The school's meaning of inquiry is to mimic the scientist and inculcate an inquirer's character in learners. Learners should think and act like a scientist. The school's emphasis on inquiry, however, is an independent work. Students are the primary researchers who are driven to become like a scientist. A scientist seeks answers to questions of self-interest. The inquiry's interest is not determined by teachers. The inquiry's interest is not determined by teachers but the students' interest as the primary scientist or investigator. The teachers simply give inputs during formal classes, and advisers follow up it during research consultation. However, there is a gray area concerning to what extent students can be allowed to conduct research independently. Issues on legality, safety, ability, and other delimiting factors would prove challenging to both research advisers and advisees.

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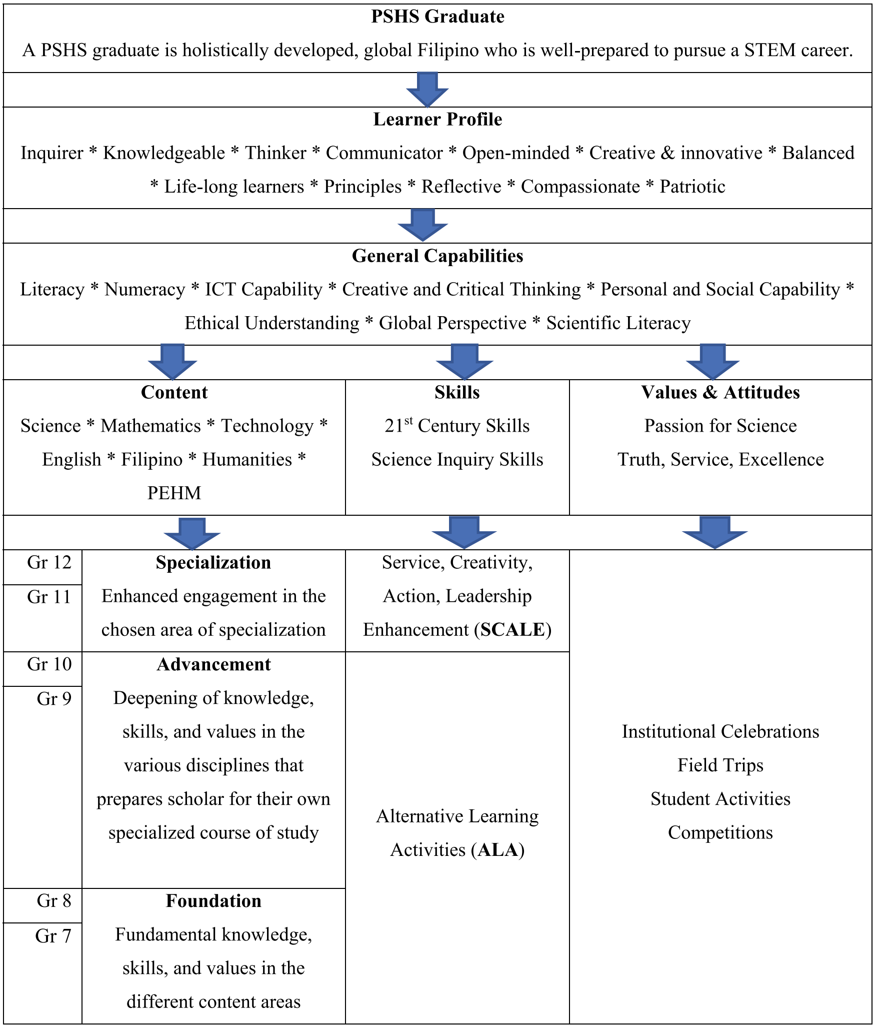
[1] A PSHS WVC scholar should be nurtured as a holistic individual and strive to become inquirers. As inquirers, they should enhance their natural desire and enthusiasm to ask questions, conduct inquiry and purposeful research, and cultivate their love for learning.



PSHS Graduate

A PSHS graduate is holistically developed, global Filipino who is well-prepared to pursue a STEM career.

Learner Profile

Inquirer * Knowledgeable * Thinker * Communicator * Open-minded * Creative & innovative * Balanced * Life-long learners * Principles * Reflective * Compassionate * Patriotic

General Capabilities

Literacy * Numeracy * ICT Capability * Creative and Critical Thinking * Personal and Social Capability * Ethical Understanding * Global Perspective * Scientific Literacy

	Content	**Skills**	**Values & Attitudes**
	Science * Mathematics * Technology * English * Filipino * Humanities * PEHM	21st Century Skills Science Inquiry Skills	Passion for Science Truth, Service, Excellence
Gr 12 Gr 11	**Specialization** Enhanced engagement in the chosen area of specialization	Service, Creativity, Action, Leadership Enhancement (**SCALE**)	Institutional Celebrations Field Trips Student Activities Competitions
Gr 10 Gr 9	**Advancement** Deepening of knowledge, skills, and values in the various disciplines that prepares scholar for their own specialized course of study	Alternative Learning Activities (**ALA**)	
Gr 8 Gr 7	**Foundation** Fundamental knowledge, skills, and values in the different content areas		

Fig. 3 An expected PSHS graduate, profile, and capabilities

The Research Unit composed of research teachers and advisers agrees that students should be given opportunity to manage all research-related work unless delimiting factors are justifiable. The Unit has to approve if a research task should be terminated or not. Kirschner, Sweller, and Clark (2006), however, claim that students do not suffer from such guidance and supervision. While their claim may be true, a clear scheme of implementation and explicit listing of responsibilities can counteract the issue.

The approach to inquiry at the school is a student-driven inquiry. Whenever possible, the student researchers do everything as if the adviser serves as the head of the science laboratory head. The research advisees, forming work units or research groups, act as research scientists under the adviser supervision. An adviser simply manages and monitors the students or the work units assigned to students. The research teachers, on the other hand, teach students about the concepts and skills in doing research.

The teaching of inquiry is a product of methods of teaching science and math. The Curriculum and Instruction Manual stipulates that lessons in these two subjects should be computer-based, integrated, application-based, internship-like, mentored, and inquiry-based. An inquiry-based instruction includes holding investigations and research. It has sometimes gone to the extent of requiring students to submit full-blown research outputs in Filipino (a language subject) and Social Science. On top of the research project in research subject, scholars are also expected to submit a full-blown research document integrated across the school's curricula; for example, in the school's Filipino language subject, and Social Science classes. In addition to the research project within the school subject of research, scholars are also expected to submit miniresearch in their chosen core subject. Research teachers, on a weekly basis, see to it that the cycle of seminar-workshop-consultation is followed by everyone.

The learning of inquiry in formal settings also undergoes the cycle of seminar-workshop-consultation. The seminar-type instruction is implemented through team teaching. Research teachers agree who will conduct a seminar on a particular research topic. Instead of a quiz, learners' understanding is assessed via a workshop on a typical research case. Teachers evaluate the outputs (i.e., a synthesis of a journal article, concept map, or standard procedure) of the workshop and require students to apply what they have learned in their respective research projects. The research adviser and the advisees would then discuss the research progress during a weekly consultation which can last for a minimum of 20 min for every work unit.

Inquiry is also learned in other subjects as well. In the core subject areas of Physics, Chemistry, and Biology, students are required to submit a modified inquiry output. A teacher may modify the inquiry by providing the problem or procedure in the conduct of an inquiry. The output is simply report-based and devoid of preliminary and terminal pages in writing research outputs. As for the other STEM subjects, inquiry is learned by doing investigations, experiments, or simple science activities.

Prior to enrollment in the research program, students are exposed to learning inquiry by engaging in a science internship. A science internship exposes students to an authentic research-based laboratory under the guidance of a scientist or an expert for a minimum of 80 h. Students complete all the research tasks agreed upon by the school and the host laboratory. During internship, students are exposed to the daily routine of a scientist as they observe or even help with some tasks assigned to them. Research tasks may be designed by the lab or simply embarking on whatever are the tasks at hand during the period of internship.

Other opportunities to learn inquiry come through science workshops and through visits to nearby laboratories, and attendance at conferences and science fairs.

3.1 *The Case of Barrios*

Barrios is one of the two outstanding stories in a span of two years of the research program. His research project was published as "The use of convex lens as primary concentrator for multi-junction solar cells," in *Emergent Scientist*, an international journal. Certainly, there were co-authors such as the adviser, supervisors, and head of the collaborating laboratory.

Barrios' journey began when his adviser introduced the possibility of having a onemonth internship in a Japanese laboratory. He had to conduct his designed research (i.e., different aspects of solar cells) under several supervisors. Among the five of them, Barrios excelled in terms of skills and abilities acquired during the internship. His experience motivated him to investigate multi-junction solar cells.

The support of the science laboratory in providing materials, research articles, advice, and on-line consultation paved the way for the research to be materialized. It exposed him to recent findings and the problem of increasing the efficiency of solar cells. His inquiry experience culminated with his co-authorship of the research publication as expected of all scientists. He also presented his work in an international conference held in Tokyo, Japan.

4 Challenges and Scaffolds on Realities of Conducting Science Inquiry

Challenges are presented as barriers by Anderson (2002). Scaffolds are school-based initiatives to address the challenges when implementing a research program. Both are investigated here.

4.1 *Teachers' Indifference Towards Teaching and/or Advising Research*

School science teachers shy away from research teaching and/or advising for several reasons. The ultimate reason is their lack of formal training to become research teachers and advisers. Preciado Babb, Saar, Brandon, and Friesen (2015) observed that science teachers are simply reluctant to shift from their role in classroom. Teachers find the process of authentic inquiry messy due to its unstructured nature.

Unlike other subject area's research programs, science students have to work with an adviser with whom they share an interest. At our school, teachers have to adjust to students' research interests. Therefore, the Research Unit initiated team-teaching and mentoring. This scaffolding enables us to match the qualifications of research teachers with the research topic they are most likely qualified to teach. Likewise, students are also matched with their research advisers by encouraging them to apply for their research adviser whose knowledge, interest, and skills match theirs.

Ogawa (2002) did a study on how novice teachers gained expertise and the study revealed that a close daily-based deep, apprenticeship-typed or in some sense, family-type communication with peer science teachers in non-formal setting.

Preciado Babb et al. (2015) decided on teacher professional development project in order to engage high school students in authentic research. The researchers found that effective teacher training should resemble the authentic work of engineers and experts in the field. One example of teacher training that provides research experience is reported by Zhu et al. (2018). Teachers develop a capacity in engineering design and manufacturing research, which they taught their students.

If a research teacher fails to mentor effectively due to indifference, student researchers may develop a poor scientist identity (Robnett, Nelson, Zurbriggen, Crosby, & Chemers 2018). A teacher's indifference could take the form of a preconceived notion about the discipline, inexperience, a negative attitude toward the subject matter of interest to the students, plus other factors that influence how students identify with or pursue a topic of interest.

4.2 *Students Are Neophytes in Research*

Students simply lack the content and skills for conducting science research. Nikolova and Stefanova (2014) suggest that the major challenge of a neophyte is learning on how to work efficiently with new information. Their content knowledge is limited and their acquired expertise is too meager for them to comprehend research articles. As a result, they are required to undergo an internship in an authentic science laboratory. The experience acts as scaffolding.

Vicarious experience related to science research is acquired by passing a quick course or getting certified for a specific skill. For instance, students engaged in work units on aquatic-related research must show certification that they are licensed to swim or dive. Those in work units who have no experience on microbiological skills are already advised to take up Elective courses of their planned research projects. It is through an Elective course where students learn advance concepts and acquire laboratory skills. However, if content and skills are futile, students are sent to scientists in nearby research laboratories for consultation and mentoring. In Malaysia, Abdullah, Majid, Bais, Bahri, and Asillam (2018) also fostered research aptitude among high school students despite their being neophytes. The researchers rationalized that high school students have a competitive nature and introducing research is appropriate. Results of their study indicated that high school students are capable of conducting research with minimal guidance as long as step-by-step guidelines are provided. While this rationalizes the conduct of high school researchers, Kardash (2000) revealed that some research experiences and skills are enhanced better at certain school-age levels.

4.3 The Program Has Limited Research Infrastructure

Limitations to a program could be the availability of research mentors for the Unit, access to equipment, and a sufficient budget. The campus is located in the central Philippines where most mentors and equipment are scarce. Most scientists who could serve as mentors and offer equipment are concentrated in the capital in the northern part of the country. Students have to contend with whatever is available and with limited research infrastructure.

Scaffolds were initiated, such as partnership with nearby government agencies with qualified personnel who could serve as mentors. Parents were tapped to help out in the conduct of research. The Research Unit requires parents to participate at least in the research proposal defense and during the conduct of research tasks that pose hazards.

Since we attempt to define our science inquiry as the systematic approach of a scientist, we are faced with living up to the standards and expectations of scientists in the scientific community. Even when we get local scientists on board for the program, however, getting them involved posed several challenges (Andrews et al., 2005). Scientists consider their participation in a high school research program as being auxiliary to their more pressing responsibilities as scientists. There is usually a lack of time to do both. Scientists may be encouraged to engage more in whatever capacity if the school could address diverse issues such as classroom management, logistical or organizational problems, the outreach skills of scientists, and the value of outreach participation to augmenting a scientist's career path.

When Kirkup et al. (2015) did an inquiry with a national science agency, they added to this list of challenges: the duration of an investigation, explicit assistance in the use of supporting technology, and appropriate guidance.

4.4 Publication of Completed Research

At the school, research activity culminates with the preparation of a journal-ready manuscript that is reviewed by experts for journal publication. The school has already published a journal for high school research which is named as *Publiscience.* It is an open-access journal, accessible at http://publiscience.org, showcasing the work of high school students with the hope of sharing their outputs and inspiring other institutions to do the same. For instance, The School for Science and Math at Vanderbilt University has an innovative research-based program for high school students. The University is proud of the numerous publications in scientific journals that represent a culmination of their research programs (Eeds et al, 2014).

4.5 Conducting Inquiry Is Competition-Driven and Principle-Bound

It is a prevailing notion at our school that research is conducted to compete in research fairs and participate in research conferences. While fairs and conferences are ways to promote inquiry, student researchers are driven by its competitive nature. Research seems to be a product to be compared with other research projects.

The Research Unit addresses this challenge by formulating three guiding principles to live by. The first principle is to hold proper training as more important than the output. Proper training entails subscribing to appropriate standards when doing research. The student-driven approach in implementation and personal conduct assures that all students experience the research process from the problem formulation to the publication of a paper in a research journal. This research output must have gone through the appropriate processes, and student researchers must provide proof of their conduct.

The second guiding principle is that research must be for all students. Research is for everyone to experience and no one should be left behind. Even though they work as a pair or triad, student researchers must undergo the same research process and learn a minimum of competencies. This is achieved by letting students perform individually before collaborating their output as a work unit.

The third principle gives emphasis to the formation of character and life skills. When the first two principles fail to uphold the decision on research concerns, the Unit has to consider the implication on character and life skills. Students are informed of this research philosophy during their first meeting in research class. Parents are also informed during the parent–teacher conference. Research teachers and research advisers are held accountable to live by this three-principle research philosophy.

In a study conducted by Hu, Chang, and Lin (2003), they found that students favor the curriculum components of science in the following order: manipulative skills, scientific concepts, the application of science, social issues, problem-solving skills, and the history of science. An authentic research allows students to manipulate on their own and to see the scientific concepts in action and application. The research project addresses social issues and problem-solving skills. The history of science may only be seen in the review of related literature on how previous attempts were made to address the research problem.

As for participating in the science fair is concerned, a student may consider a study on the so-called “reverse science fair” that links secondary students with university researchers. Mernoff et al. (2017) found that the reverse science fair allowed high school students to increase: (a) their understanding of various applications of the methods found in scientific inquiry and (b) their interest in doing scientific research. The university researcher gained valuable experience by interacting with high school student researchers.

It is imperative that a research program be driven with learners as its core consideration. In fact, a student-oriented program led by them may reap benefits more than other drivers of inquiry. This was demonstrated by a youth-led participatory research that posed problems of concern to them (Ozer & Wright, 2012).

5 Conclusion

A contextualized approach is necessary for addressing and scaffolding inquiry-based teaching for secondary school students' efficacy at conducting scientific inquiry. As scientific inquiry's meaning is researcher- and problem-driven, it calls for an approach in these contexts. For instance, a contextualized approach may be researcher-centered to address the needs of the neophyte student researcher, because their challenge in doing research is their lack of experience. On the other hand, a problem-driven context could be appropriate standard protocols in conducting inquiry. As the campus is regional in scope and nature, with its unique delimiting factors in conducting inquiry, the problem-driven approach has proven to work with all its stakeholders. Teachers of inquiry must work with the students to achieve the goal of inquiry, while keeping in mind the school's vision, mission, and curricular framework. It is paramount that all stakeholders, such as parents, partner agencies, mentors, and school personnel, subscribe to this research philosophy. Lastly, learning inquiry should be the primary means to inculcate the holistic development of an individual as far as science inquiry skills and values are concerned, while the acquisition of content knowledge should be the secondary means.

The scaffolds, although not entirely devoid of limitations, have helped the campus-based implementation reap its success to immerse students in the major aspects of the research process. A few of the school's achievements are the conduct of school-based and community-based research congress, the participation in international science conferences, and the publication in a school-based journal, both in print and on-line. The program also boasts several research events such as research workshops, sharing of research skills, research pitching, and the desire to promote science inquiry among learners from other public elementary and secondary schools in the region.

A research area to investigate next would be the student's confidence in their research abilities and their understanding of what it means to be a scientist. A trustworthy evaluation tool should be implemented to assess the high school inquiry program with respect to students' gained abilities, knowledge, agency, and self-identities (Boyce, et al., 2019). Data-driven results may help policy makers come up with ways on how inquiry should be implemented at the practitioner level in meaningful and rewarding ways (da Palma Camargo et al., 2012). Fitzgerald et al. (2014) highest assessment criterion related to a student's research project is the student's capacity to conduct meaningful original research.

6 Implications for Science Education

The conduct of classroom scientific inquiry proves to be complex and transcendental. Making sense of the what, how, and why of inquiry causes it to be complex. It must be anchored in a research philosophy to which all stakeholders must subscribe. A well-grounded philosophy should be the guiding principle so that advisers, teachers, and student researchers can work well together. Just like any project-based learning, this scaffolding ensures that during their authentic inquiry, student researchers receive constant guidance and support (Hmelo-Silver, Duncan, and Chinn, 2007).

The classroom transcends beyond the physical structures used for research instruction. The instruction itself may take the form of research consultation, a dialog with scientists or experts, specialized trainings/lessons, and other research experiences.

Yet, the interaction of all stakeholders bounded by their own positionalities and beliefs creates complexity. Further complexity is generated by accommodating local views on what constitutes inquiry-based learning and what motivates it (Barab & Leuhmann, 2003).

Another issue concerns the research questions and problems formulated by students. Do students really raise meaningful questions to push the frontier of knowledge? Or do these research questions act as an educational exercise? Bielik and Yarden (2016) argue for the development of students' ability to ask research questions in an inquiry-oriented high school program which should be student-centered, dialogic, and interactive. It is also important to note that the entire experience should develop students' positive science dispositions. This requires that inquiry be technology-driven, builds a research team's cohesion, and disseminates their findings to the community. It must also entail researching with scientists, training under teachers, and acknowledging teachers' knowledge (Ebenezer, Kaya, & Kassab, 2018). McNally (2012) suggested that science inquiry must mobilize and collaborate toward a more engaged learner of science.

While the core of the research program is the learner, I strongly suggest that it must be well complemented with equal emphasis on research mentoring. In any authentic inquiry, learners may be the main investigator but the process should have research mentors who are well equipped to guide student researchers. The mentoring has, after all, a significant role in promoting a strong scientist identity as to the degree to which students perceive their science-related pursuits as integral to their self-identity (Robnett et al., 2018).

This chapter also stresses that a more authentic inquiry should provide an institutionalized interaction between scientists and students, not only during internships and professional science laboratories experiences. It cannot be underestimated how strongly the personal engagement of students with scientists influences students' development of a scientist self-identity.

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Science and Nature: Science Teachers' Views at the International Collaborative Project Between Japan and South Africa

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Abstract Ogawa (1998, 2000) has been discussing cultural differences in Japanese science education which is called Rika. One of the characteristics of Rika is an aspect of nature in science education. This research tried to reveal Japanese science teachers' views on science and nature in science education using reports, interview data and drawings. Teachers in this research participated in an international collaborative project run by Japanese and South African universities. The project included intense discussion and interaction which helped teachers to realise their own views on science and nature. As a result, Japanese science teachers considered nature as a more important concept than science in science education. On the other hand, the South African teachers explained Nature as objects, for example, river, forest and sun. Their focus in science education was scientific thinking so that Nature was one of the concepts they teach in science education. The result showed Japanese science teachers' views reflected Rika concepts, but they were unaware of the difference from South African teachers. This implied that Japanese teachers were looking at nature and science not as the object to analyse but the subject for educational purposes.

1 Introduction

1.1 Episodes

A group of teachers said, "Human beings have intuitive power to learn from nature. …[I]t would be brilliant for pupils to find out the vision of what sustainable society is like"; (translated by author, International Christian University, 2009, p. 6) another group of teachers said, "We shared the same concerns about biodiversity … The project will definitely benefit our schools as much is needed in fulfilling the aims of our environmental education agenda" (International Christian University, 2009,

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p. 8). These were comments from Japanese teachers and South African teachers, respectively, who participated in an international collaborative project.

The five-year project aimed to create an educational module for Education for Sustainable Development (ESD) (International Christian University, 2009). Teachers from Japan and South Africa: visited each other, communicated through Skype and e-mails, discussed teaching methods and materials, and taught their pupils with an international team-teaching format. When I participated in this project as a member of the secretariat in charge of translation and interpretation, I could not ignore the discomfort when teachers discussed science education. I could not stop thinking that the translation between *science* and the Japanese word *kagaku* simply did not work. Linguistic images, reactions from teachers, approaches, and groundings related to these terms are all misaligned. That discomfort can be observed in the teachers' comments. Although science is thought by many to be universal and to consist of value-free methods used to analyse nature, inevitable differences concerning the meaning of science were observed between the two cultures, leading to a need to elaborate on Japanese science education and its cultural features.

1.2 What Matters?

Japanese teachers seem to focus on feelings toward nature. They think about environmental issues. On the other hand, South African teachers talked about scientific skills and actions that were problem-oriented, outcome-based, methodological, and pro-con ideas. The project provided a sympathetic atmosphere for individuals to share their thoughts on science education. Why were there such differences? What is Japanese science education? These are substantial questions that are difficult to answer. Notably, few studies in this field are available at the international level.

In this study, I reviewed the literature on Japanese science education mainly conducted by Ogawa (1986, 1989, 1995, 1998, 2000, 2001, 2011). His studies on Japanese science education from cultural perspectives showed that it includes aspects of the environmental study (Ogawa 1998). This conclusion was based on the unique perspectives that Japanese culture has on nature (Ogawa 1989). This perspective differs from that of Western science education, which takes seemingly objective points of view on nature. Ogawa (1998) and Kawasaki (2005) claimed that Japan does not have the grounding to observe nature objectively but draws on religious and metaphysical perspectives called traditional cosmology. They have also claimed that the term *science* is limited to modern Western science and influenced by Christianity.

Kawasaki (2005), referencing Yanabu's (1995) analysis of the Japanese history of translation, summarised that Japanese science education had been influenced by a traditional, indigenous approach toward nature. In Japanese, *shizen* (nature) means not only the natural resources of the Earth but also "as it is" or "extreme beauty outside of human capturing." *Shizen* is what humans cannot understand (Tsuji, 1989, p. 163), in that it is not an object, but a circulating relationship. By contrast, Western culture is influenced by Christianity and has a sense of "God" as having the supreme authority on Earth. These differences in approach to science are reflected in the unique use of *Rika* to refer to the subject of science in Japan that includes "a love of nature" (Isozaki, 2014, p. 1164).

Based on these understandings, research on Japanese views of science and science education reflecting Japanese cultural viewpoints have been conducted (Ogunniyi, Jegede, Ogawa, Yandila, & Oladele, 1995; Aikenhead & Otsuji, 2000, Sumida, Inagaki, & Nakayama, 2001). However, only a limited amount of research has investigated teachers' views on science education from cultural perspectives (Yamaguchi, Inagaki, & Nogami, 2009; Kato & Matsumoto, 2011; Ohtaka, 2000). Research on how teachers encountered and analysed cultural differences in their views on science education is even more limited. Ogawa (1989) mentioned that it seemed that Japanese people involved in science education do not feel any controversy between their traditional views of nature and teaching modern Western science. Notably, for teacher development, it is essential for the teacher to engage in self-reflection on such perspectives, on teaching, on considering cultural differences, and on how to resolve or react to those differences.

1.3 Cultural Studies on Science Education

Ogunniyi et al. (1995) addressed research questions shared among researchers involved in cultural studies on science education (CSSE). One of the questions is how do science teachers reconcile their broad worldviews with the narrow, mechanistic worldviews presented in science curricula. Aikenhead's border crossing theory (1996) and its following work (Aikenhead & Jegede, 1999) states that teachers or students can hold two conflicting worldviews. Ogawa (1989) found that Japanese teachers do not feel that it is problematic to encounter different worldviews in science curricula.

These arguments are based on a definition of science as a collaborative summary of the analysis of nature by multiple scientists. These studies aimed to solve gaps among non-Western science learners. However, there have been other outcomes. Kawasaki (2005) explained that these studies had the possibility to clarify cultural features in science education and re-capture modern Western science education worldwide. One way this can occur is through teachers' professional development. Currently, teachers examine their country's culture and examples from abroad to enrich their teaching. When they encounter different science cultures based on CSSE research outcomes, it contributes to their reflection on their beliefs and views on science education. For this to occur, it is important for teachers to realise and reflect on their cultural grounding as well as to have the opportunity to communicate their practices in depth.

This international collaborative project on ESD between Japan and South Africa began to provide space for this form of communication and the realization of cultural differences; however, from the author's viewpoint, discussions remained limited.

According to a review of the literature, no study has focused on how teachers perceive the cultural features of Japanese science education and science education in other cultures. Therefore, this study attempts to reveal Japanese science teachers' personal views (i.e., their honest opinions) on science, and how they explore and react to different views from another cultural perspective. The project provided a rare opportunity for this research because teachers from two very different countries intensively collaborated for five years to create an educational module for ESD. Although their rich experiences cannot be fully captured in this research, I attempt to explore the teachers' views by explaining and comparing drawings that the teachers created in response to the question, "What is the relationship between nature and science?"

2 Revealing Japanese Teachers' Views on Science

2.1 Methods

The participants of this study were three primary school teachers and three junior high school teachers from Japan, and four primary school teachers and two junior high school teachers from South Africa. They all participated in the five-year project organised by Japanese and South African universities to create an educational module for ESD. Two primary schools and junior high schools from each country participated in the project.

Japanese primary and junior high schools are community-based schools, the teachers interacted by visiting each other's schools on several occasions, such as for lesson observations and at the beginning of the new school year to help students move from their primary to their junior high school. The data were collected during the last year of the project, after all collaborative lessons were completed and before the final summarising symposium was held.

At the primary school level, teachers from the two countries discussed the theme "Water and Soil," during face-to-face visits and with Skype conversations. They created lesson plans together and, in the end, two classrooms in Japan and South Africa were connected through Skype to conduct a lesson together.

At the junior high school level, teachers selected "Weather and Climate" as the theme based on discussion together with faculty staff from universities as well as teachers in both schools. The protocol used was the same as for the primary school level, except junior high students focused on the universal validity of scientific methods and included global issues in their discussions. The project was unique in that teachers were given various opportunities to explore, think, and discuss the other country's education system. They visited each other's schools once per year and had discussions regularly through e-mail and Skype.

I was one of the secretaries of the project and my duties were to support their communication by searching for references and providing translation and interpretation. The 12 participants, their educational role, and their involvement in the project are listed in Table 1. Pseudonyms were assigned to each respondent for anonymity.

Table 1 Participants in this study

Country	School	Name	Sex	Interview	Visit (times)	Collaborative lesson (lessons)
Japan	Primary	Abe	F	Yes	None	None
	Primary	Endo	F	Yes	1	None
	Primary	Chisaka	M	No	1	3
	Junior high	Domoto	M	Yes	1	1
	Junior high	Fukai	M	Yes	None	1
	Junior high	Baba	M	No	3	2
South Africa	N Primary	Gabriel	M		None	1
	N Primary	Hannah	F		2	1
	J Primary	Megan	F		2	1
	J Primary	Olivia	F		1	1
	Junior high	Patrick	M		1	1
	Junior high	Robert	M		1	1

Abe and Fukai did not visit South Africa in person; however, they participated in Skype meetings regularly and actively involved in creating educational modules. Abe and Endo did not participate in collaborative lessons as main teachers who instruct in front of students. However, they invited South African teachers to their classes when they visited Japan and taught classes together without using ESD modules. I included those teachers because they had sufficient opportunity to communicate with South African teachers and students. They also had opportunities to reflect upon their views.

2.2 *Drawings*

To reveal Japanese teachers' views on science and nature, I asked each teacher the same question, "What is your idea of the relationship between science and nature?" Because teachers had few occasions to reflect on their views of science and nature, contrasting their ideas with those of others would help them realize their honest opinions. I met each Japanese teacher face-to-face to explain the purpose and procedure of this research. After the explanation, I mailed the Japanese teachers a paper written in Japanese with the question and ample space to draw a picture of their ideas. For the South African teachers, I emailed the materials as an attachment in English. I asked the teachers to return the paper to me within one week. I assumed that this duration would be sufficient for teachers to reflect on their views.

I decided to ask the teachers to draw a picture that represented their ideas because drawings transcend language. Thus, Japanese teachers were able to understand the ideas presented by the South African teachers. Similar drawing methods were used by Chambers (1983) to reveal images of scientists and by Sumida and colleagues (2001) to analyse Japanese children. The drawing method makes comparisons of ideas among cultures easier.

As Ogawa (1998) pointed out, Japanese science education includes concepts of nature; thus, the inclusion of both science and nature was required in the question to the teachers. Usually, when questions are asked concerning science, answers are about scientists and scientific tools and methods, which do not reflect an understanding of nature. From a psychological perspective, Yamada and Kato (2006) and Yamada (2008, 2010) showed in their chrono-topos model the possibility of unveiling cultural richness in people's viewpoints. She explained that time had been understood in a linear model from left to right; however, she presented a circular model of time in Asian culture by using drawing methods. Yamada's idea shows that some concepts may be captured in relation to other concepts.

In this case of Japanese teachers' images (or views) toward science education, I assessed the relationship between nature and science. The concept of nature is broad and Japanese studies have shown researchers' preconceptions. I have attempted to capture teachers' voices as much as possible throughout this analysis to remove my own preconceptions. When analysing nature from the angle of subtopics, the analysis can lose the holistic viewpoint of nature in Japanese culture. Drawings make it possible to capture the "as it is, extreme being" view of nature that Japanese teachers may have.

The main limitations of this study are the small size of the participants and my selection of teachers who have frequent interaction with teachers from another country. Nevertheless, the study provides insights into the difficulty and value of capturing the nuances of teachers' views.

2.3 Interviews

After the teachers were asked to draw the picture, I conducted a semi-structured interview for consenting Japanese teachers (Abe, Endo, Domoto, and Fukai). During the interview, I asked:

1. Please look at your picture again and explain what you drew.
2. After looking at other Japanese teachers' pictures, what did you notice?
3. After looking at South African teachers' pictures, what did you notice?
4. Based on the two groups of pictures from Japan and South Africa, what did you notice?

By asking those questions, I explored teachers' views on nature and science in depth and analysed their reactions and responses to a different culture. The data and discussions are found in the following subsections with an examination of the pictures drawn by the teachers.

Table 2 Categorisation of Japanese teachers' drawings

	Abe	Baba	Chisaka	Domoto	Endo	Fukai
Shape	Arrow	Star	Circle	Question Mark	Human, Arrow	Graph
Enclosure	Science, Nature	–	Science, Nature	Universe, Science	Science	Science, Natural Science
Addition and metaphor	–	Star, Arrow	–	Universe	Economics, Art, Religion, Human Beings	Phenomenon, Non-natural Science
Positioning and relationship	Inside	Up/Down, Dotted	Outside	Outside	Inside, Cycle	–

2.3.1 What Did the Japanese and South African Teachers Draw?

First, drawings were analysed based on four characteristics:

1. Shape: included how science and nature were represented in different figures, such as circles, squares, stars, or arrows.
2. Enclosure: stated if science and nature were in the drawing.
3. Metaphor and addition: characterised the drawing as using metaphors, replacing *science* or *nature* with words, or adding concepts other than science and nature.
4. Positioning and relationships: detailed how they positioned or related to science and nature.

The categorisation of each teacher's drawing is shown in Table 2 (Japanese) and Table 3 (South African). The actual drawings created by each teacher are presented in Figs. 1, 2, 3, 4, 5 and 6 (Japanese) and Figs. 7, 8, 9, 10 and 11 (South African).

2.3.2 How Did They Draw Nature?

All the Japanese teachers drew nature either bigger or higher than science. Baba (T2 F2[1]) and Endo (T2 F5) did not enclose nature but wrote science further down on the paper. Domoto, Chisaka, Abe, and Fukai (T2) enclosed nature and showed its predominance either by drawing the elements of science smaller (Domoto [F4], and Chisaka [F3]), by drawing science within nature (Abe [F1]), or by placing nature in a higher position in a graph (Fukai [F6]).

During their interviews, nature was explained as "everything that pre-exists" (Chisaka, Endo, Fukai). Chisaka (F3) enclosed nature as a metaphor for the planet.

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[1] T2 and F2 refers to Table 2 and Fig. 2.

Table 3 Categorisation of South African teachers' drawings

	Gabriel	Hannah	Megan and Olivia	Patrick	Robert
Shape	(Real objects)	(Real objects)	–	–	–
Enclosure	–	–	–	–	–
Addition and Metaphor	Sun, House, Tree, Water, Fire, Human	Sun, Water, Plant, Human, Notebook, Earth, Formula	Arrow	Fire, Smoke, Charcoal, Human, Mud, Tree, House, Acid Rain, Cloud, Golden Rice, Rice Field, Medicine	Cloud, Thermal Power Plant, Acid Rain, Forest
Positioning and Relationship	Circulation	Parallel	Circulation	Evaluation	Evaluation

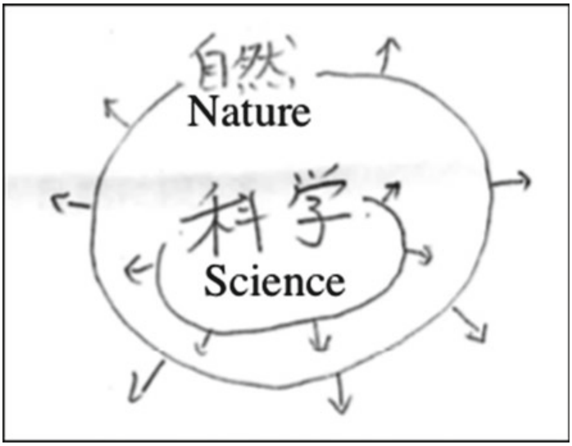


Fig. 1 Drawing by Abe

Some teachers replaced *nature* with other words, such as *universe* in Domoto's drawing (F4). The Cambridge Dictionary defines *nature* as "all the animals, plants, rocks, etc., in the world and all the features, forces and processes that occur or exist independently of people, such as the weather, the sea, mountains, the production of young animals or plants and growth;" therefore, it includes only things on Earth. Domoto (F4) used *universe* instead of *nature* in order to show the bigness of the concept and include things outside the Earth. Chisaka did not use the word *universe*, but he used universe as a metaphor during his interview. Baba (F2) used stars in his drawing as a metaphor for the universe. The replacement of nature with universe, therefore, necessitates further discussion.

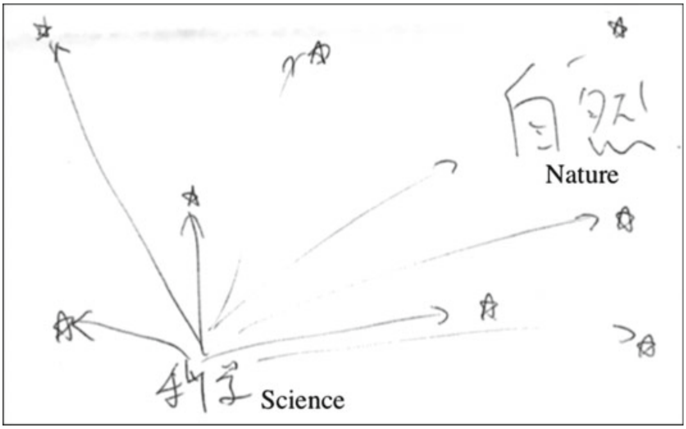


Fig. 2 Drawing by Baba

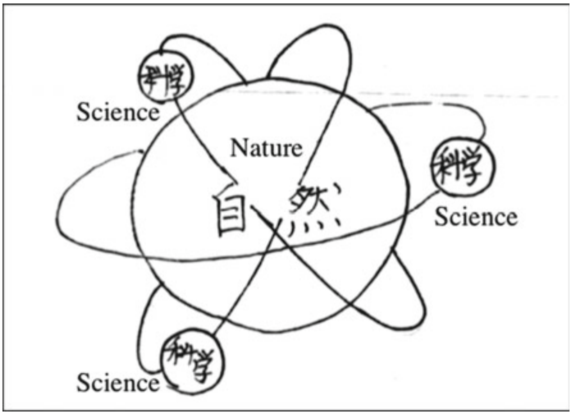


Fig. 3 Drawing by Chisaka

The Japanese schools in this study are located near The National Astronomical Observatory of Japan. In their roles as teachers, they have many opportunities to collaborate with the scientists at the observatory. As a result, the teachers thought of planets and astronomy first when thinking of nature and science. For the South Africans, planets are only one aspect of nature.

Fukai (F6) used a unique and more academic approach to categorise nature and science. He included the word *phenomena*, demonstrating that he thought of living creatures or objects, as well as concepts. During his interview, he explained:

> In primitive religion, there was worship of various natural phenomena, from which the wisdom of living human beings accumulated. This is the origin/root/source/beginning of science. Mathematics developed first, then agriculture, astronomy and meteorology. Afterward, with the progression of civilization, other natural sciences, sociology and human

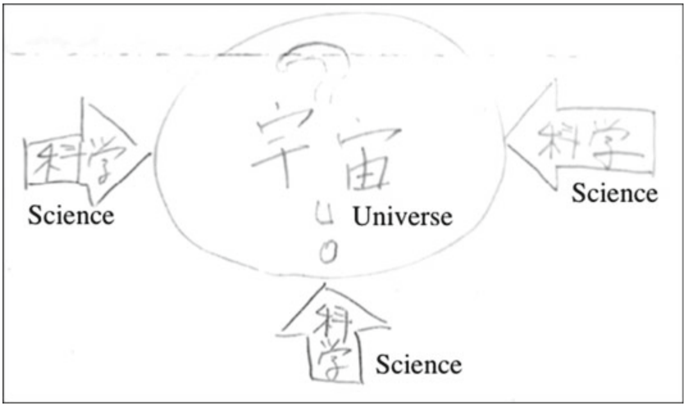


Fig. 4 Drawing by Domoto

Fig. 5 Drawing by Endo

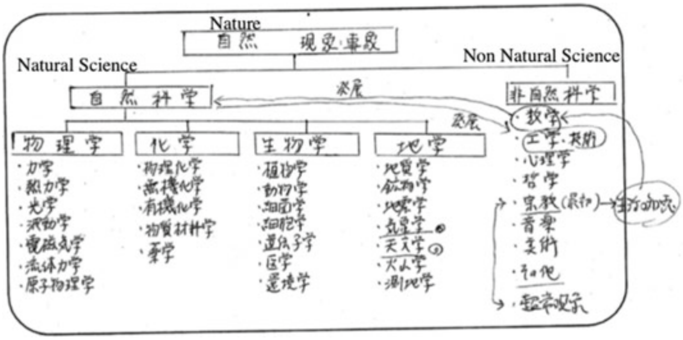


Fig. 6 Drawing by Fukai

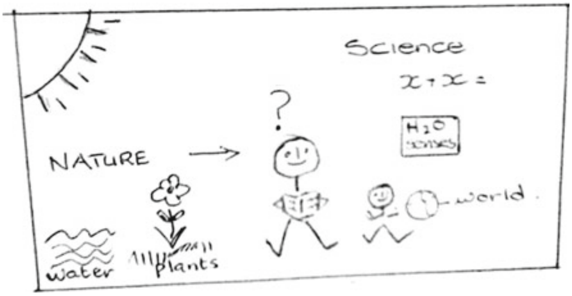


Fig. 7 Drawing by Gabriel

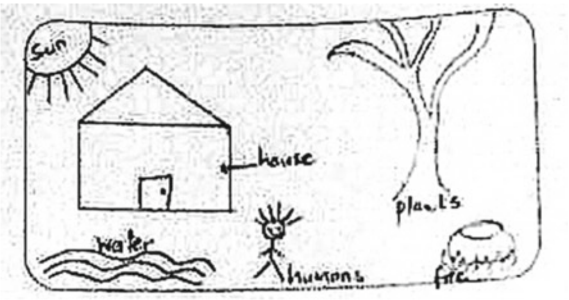


Fig. 8 Drawing by Hannah

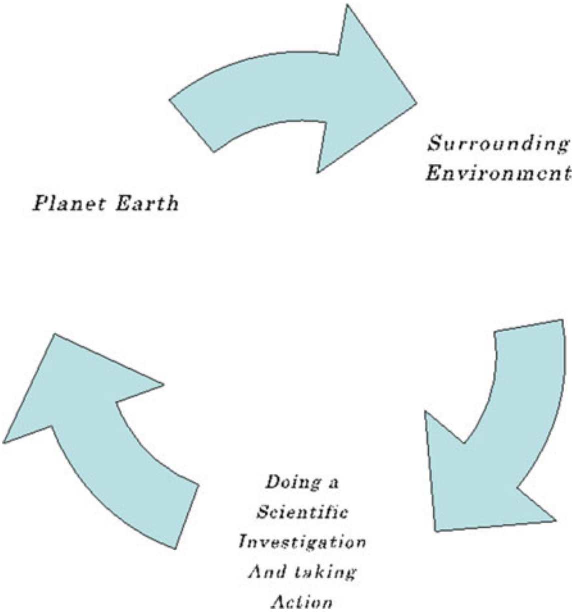
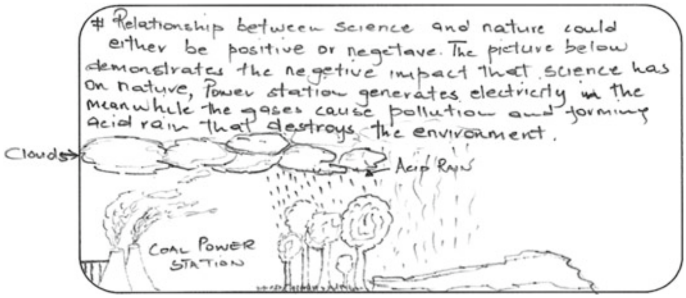


Fig. 9 Drawing by Megan and Olivia

The relationship can be positive or negetive. A positive relationship improves nature but a negative relationship destroys nature.

Fig. 10 Drawing by Patrick



Relationship between science and nature could either be positive or negetave. The picture below demonstrates the negetive impact that science has on nature, Power station generates electricrly in the meanwhile the gases cause pollution and forming acid rain that destroys the environment.

Fig. 11 Drawing by Robert

> sciences developed. It is my opinion that nature existed in the beginning. (translated into English by the author)

Similarly, Endo explained, “Nature was pre-existent. Everything from the Big Bang, including any type of phenomena.”

Although Abe, Chisaka, Domoto and Fukai enclosed nature, Domoto (F4) used a question mark and Abe (F1) used an arrow to demonstrate expanding fluidity. Chisaka, Endo and Fukai wrote that “nature is everything pre-existent.” Chisaka and Fukai indicated an awe of nature in their interview explanations. Chisaka stated, “If science ignores the rules of nature or attempts to get bigger, collisions occur and they will become extinct. Science does not exceed the power of nature.”

Conversely, South African teachers did not apply a metaphysical approach, but drew materials and objects (F7–11). Gabriel (F7), Patrick (F10) and Robert (F11) did not use the words *nature* or *science* in their drawings, but used real objects such as sun, plants, or water to demonstrate their views on nature. This difference may have been caused by literal translation differences between Japanese and English. Another difference between the Japanese and South African teachers was that the latter used the concept of environment to depict nature. The ESD project demonstrated that nature is related to the natural environment that we must protect, and this may have influenced South Africa teachers' impressions. Megan and Olivia (F9) collaborated to draw one picture and explained nature according to two scales: planet Earth on the universal level and the environment on Earth. This idea may be from the ESD concept of thinking globally and acting locally. In their figure, science was depicted as action.

Capturing the concept of nature differed in the two cultures. Representations of nature were abstract and metaphysical for Japanese teachers but were real objects and living creatures for South African teachers. Thus, Japanese teachers' view of nature is broader and includes feelings of awe, while South African teachers' view of nature was closer to their lives. It could also be concluded that South Africa is undergoing development. However, taking into account that they are science teachers, the Japanese view of nature as removed from their lives or teaching may reflect the results of the Programme for International Student Assessment (2006), in which Japanese students tended to think that science was not related to them: scientific topics were too far removed from the students for them to think actively about the subject.

2.3.3 How Did They Draw Science?

Abe explained in writing that nature contains laws and always holds within it mysterious, uncovered concepts. "I have not thought about the relationship between nature and science. Science is formulas. Within the nature, there are various formulas. Nature itself is also changing. Science is the formula that humans have found. Nature eternally holds unexpected parts for humans." This quote sounds as if the laws of nature are pre-existent. Human involvement is confined to the action of finding, not an action of discussion or interaction with others, as occurs in science. Baba said in her interview that science does not overcome nature: "Nature is there from the beginning. Everything existing in the universe. Science is about exploring it from macro level to micro level." This explanation indicates the action of science by exploration. Both of their pictures reflect the bigness of nature compared with science.

Only one teacher, Fukai (F6), replaced *science* with *natural science*. In Japanese, *science* often directly means "natural science." From the explanations of the Japanese teachers, "laws" or science is a satellite to nature. This connection was shown concretely by Abe (F1) and Chisaka (F3).

Baba, Domoto, Endo and Fukai, however, used verbs, when they talked about science *exploring* or *revealing questions*. This depicts the action and movement of science. Domoto's explanation was that science is "revealing various questions (mysteries) of our living in the universe." In their interviews, Endo and Fukai depicted science as a human activity.

The Japanese teachers added other factors to the meaning of science, demonstrating that nature embraces science as well as other factors such as arts, religion and economics (F5). South African teachers explained real cases, occasions and events compared with the abstract, conceptual levels of cognition of the Japanese teachers.

2.3.4 How Did the Teachers Draw the Relationship Between Science and Nature?

Domoto (F4), Baba (F2) and Abe (F1) drew an arrow from science to nature. Endo (F5) also drew an arrow to depict directionality from science to nature. However, he included other arrows from nature to science to demonstrate that nature also influences science. Abe (F1) drew a circle to enclose nature but indicated that the circle was expanding. Domoto (F4) also enclosed nature, but in this picture, nature is drawn as a planet. Chisaka (F3) similarly and centrally placed nature with science surrounding it, as if encircled. Fukai (F6) and Endo (F5) added other related areas of study. In all cases, the fluidity of nature is indicated.

For South African teachers (F7–11), science and nature did not have the hierarchical relationship depicted in the drawings by Japanese teachers. The South Africans focused on circulation, including human activities. They also used out-siders' viewpoints to assess its relationship as either positive or negative. This is different from the Japanese teachers' drawings, because they did not show any judgment or evaluation on the relationship itself.

2.3.5 Presence of Human Beings

The presence of human beings was represented differently in each culture's drawings: Humans were not strongly represented in the Japanese drawings but were represented in the South African drawings. Gabriel (F7) and Hannah (F8) drew a human in the middle of their pictures. Their explanations when interviewed also spoke strongly to the involvement of humans. Of the Japanese, only Endo included this sentiment during his interview: "Science is a part of culture that humans constructed. So, within a small section of nature, humans exist and understand nature by using science as a way of looking and thinking." In the South African pictures (F7–11), the relationship among humans, nature and science is evaluated as positive or negative. This evaluation was based on the idea that humans either destroy or improve nature. Patrick evaluated the relationship as neither positive nor negative.

These sentiments are relevant in evaluating the literature. Onwu and Mosimege (2004) showed that South African Indigenous culture considers the environment and humans inseparable. In this study, it is also shown that South African teachers demonstrated the integration among science, their daily lives, and with the environment.

2.4 Interviews with Japanese Teachers

2.4.1 How Did They Explain Their Drawings?

Domoto already had ideas about nature and science; thus, he thought about how to represent his ideas rather than what to draw. He had formed his ideas based on his emotional struggle in moving from teaching in a high school to a junior high school. His difficulty teaching junior high school students was due to his strong background only in chemistry, which caused him to teach biology, physics, and earth science at a superficial level. When he had an opportunity to listen to a talk by a scientist at the national observatory, the scientist explained that science was about solving and unveiling questions concerning the universe. This idea fit into his understanding, and he felt more settled in his role as a science teacher at junior high school.

Fukai and Abe said that they had not thought about the relationship, concept, or definitions of science and nature; thus, the task was difficult (Abe) and took time (Fukai). They drew their images coming from their words. Endo also found the task difficult; thus, after he summarised his ideas, he used the internet to collect information on similar ideas. This process shows that unless an opportunity for reflecting on their own views such as Domoto had, the expression of ideas on an abstract topic is difficult.

Although Abe included science, she explained that it was not her intention. She explained that much in nature remains undiscovered and that nature is vast, like the universe. She said that science is nearly equal to the laws of science and is only the parts of nature that humans have discovered.

As mentioned above, Endo thought that nature was pre-existent, despite her not conveying this in her drawing. She found information online that said science is a method and agreed.

Fukai said that he started his picture by dividing science into four categories based on the science topics in the school's curriculum. He included all topics with science in the name, including the humanities (*jinbun-kagaku*, humanities-science, in Japanese), social sciences and natural sciences, and he categorised *rika* (school science) as a natural science. He stated that everything was under nature. When I asked him what would be "other than nature?" He responded, "Well, non-nature; it would be something artificial. I wrote engineering and technology under non-natural science, but that is a bit confusing… non-nature would be artificial objects, but using natural science would let technology be included …" He was confused about the distinction between nature and non-nature. He provided another example in his discussion of music. "Well for music, it should have a long history, like religion, to gather people and is a part of art. If it is art, then it is not a part of nature, but if you think of it as a way of communication, then it may be included in nature, because other animals, such as birds or small animals, use sound to communicate."

2.4.2 About Their Relationships: Use of Arrows or Vectors

Abe discussed the areas of nature that humans understand as science. In her view, those areas are expanding as new laws of science are discovered by humans; therefore, she used an arrow to depict science “following or running toward” nature (F1). Simultaneously, nature is expanding continuously and eternally, and she depicted this with an arrow pointing toward no particular direction. Endo explained that her arrow represented feedback:

> We did ESD, so I thought of action or movement. For example, while nuclear plants may be questionable in a scientific value system, they are encouraged when there is economic favourability. That kind of attitude leads to the destruction of nature. But that condition would provide feedback to us, and we think about it and go to the next action.

Her explanation demonstrates a cycle of feedback from science and nature. Fukai explained that the arrows he drew around nature, science, and humans were the course of history. Domoto’s arrow was about answering questions; an idea he gained from the observatory scientist. These ideas show the human component in their ideas, even though they did not draw humans.

2.4.3 How Did the Japanese Teachers React to the Japanese Drawings?

All the teachers expressed strong views of nature, and their viewpoints did not change upon comparison with other teachers’ pictures. What is the core of their views?

For the Japanese teachers, the connection between science and nature is metaphysical, but for the South African teachers, nature is on the ground level where humans are directly involved. Additionally, although all of the teachers were involved in the ESD project and taught science, the Japanese teachers said that they did not feel close to the school subject when they think about science and nature. They did not talk about science as the school subject they teach, but used the image they got from the word. Moreover, they said that they had never considered this kind of topic before, yet their ideas were closely held and did not change.

This finding indicates that drawing pictures and talking about why they drew them the way they did, only served to emphasize their ideas. Abe’s thought that “Everything is included in nature” was shared among Japanese teachers. Both Abe and Domoto were relieved when they looked at other teachers’ pictures because they represented some shared views.

Endo observed and summarised that there were three points shared among Japanese teachers: (a) “science is ways or methods,” (b) “nature is the beginning,” and (c) “science never exceeds the power of nature.”

In summary, the Japanese teachers’ thoughts on nature and science were:

1. Nature is the beginning and is everything,
2. Science is a part of nature, and it is a tool or method, and
3. Science is the extent to which individuals understand nature, and people can never exceed nature.

On the other hand, there some disagreements when the Japanese teachers compared their own pictures to the drawings of their colleagues. Abe (F1) considered his views similar to those of Endo (F5), Domoto (F4), and Fukai (F6). Endo, however, related to Abe and Fukai but not to Domoto. Domoto thought his and Endo's views were similar. Fukai evaluated Endo's views as being similar to his own, yet Domoto's views as being different.

These comparisons show what teachers think is more important. Abe emphasized the breadth and eternal disorganised expansion of nature. She also believed in the power of nature, disagreeing with Chisaka's indication that nature would be destroyed. Looking at Endo's drawing, she said that she had not thought of the influence of science on nature. Fukai, also clarifying his ideas by looking at other pictures, said that science exists in the larger framework of nature. Therefore, the ideas that Chisaka and Domoto conveyed did not correspond with his thoughts.

Domoto explained, "It is confusing to think why there is science, why there is *rika*, and why there is a universe. But it is also interesting that we think supernatural things can be revealed and translated into our words. Thus, science is like the *language* of science."

2.4.4 How Did the Japanese Teachers React to the South African Drawings?

When the Japanese teachers compared their drawings with those of the South African teachers, the Japanese teachers observed the following:

1. The objects drawn to define nature and science differed.
2. A parallel relationship existed between nature and science.
3. The South African teachers drew human beings but the Japanese teachers did not.
4. The South African teachers assessed the relationship between nature and science as positive or negative.

Why did these differences occur? Domoto proposed that environmental differences, including economic differences, were the reason. Fukai concluded that cultural differences between Western and Eastern thought resulted in these differences, However, he was unsure if South African could be considered as being Western because of the colonization of South Africa. Endo discussed language differences.

In any case, the Japanese teachers' views on the relationship between nature and science were rather strong and fixed. During the project, however, they attempted to observe more similarities than differences. When analysing the South African teachers' pictures, the Japanese teachers used educational aspects, such as pupils' conditions or teaching environment, to stay close to and understand the South Africa teachers' ideas.

Domoto and Fukai said that the pictures of Japanese and South African teachers were completely different. From their perspective, the Japanese teachers' drawings were abstract, metaphysical, and depicted universal features; whereas the South

African teachers' drawings depicted their perspectives in relation to the Earth. Fukai continued that the Japanese drawings were more abstract in their representation of science, whereas the South African teachers included specific and real objects and educational perspectives. Endo said that Japanese teachers think of science as a tool or method, "but [that] maybe in the South African language, the word for science includes action. Their understanding is broader. Japanese teachers think of it in terms of the divine, laws, formulas, and so on."

Fukai said that Japanese teachers' pictures showed "big nature and small science." In contrast, the South African teachers' representations of nature and science were on the same level. Abe remarked on the involvement of human beings: "They [the South Africans] think about very real human action (behavior). What humans do and have done." Domoto also noted the centrality of human involvement: "They have not just thought of what is nature and what is science, but how humans connect to science and nature."

Abe was surprised to realize that science could have a negative result when she noticed that Patrick and Rachel had identified positives and negatives in the relationship between nature and science. Abe also said that at the end of Japanese textbook sections on *rika,* they are showing science and nature going along well.

Domoto remarked that both sets of teachers included discovering laws in nature, but that the South Africans thought more about how to apply those laws. Abe further elaborated on how nature influences human thought. All of the teachers understood how nature works.

On the one hand, the Japanese science teachers considered nature as being a more important concept in science education than science itself. On the other hand, South African teachers explained nature in terms of objects, for example, a river, a forest, or the Sun. South African teachers' focus in science education was scientific thinking; thus, nature is one of the many concepts they teach in science education.

2.5 Why Should It Matter?

This research investigated certain differences between Japanese and South African science teachers. In doing so, a variety of perspectives on the fundamental relationship between science and nature emerged from the data. These all led to wondering: Does it matter to teachers?

The results demonstrate that Japanese science teachers' views reflect *rika* concepts strongly influenced by a concept of nature. This finding implies that Japanese teachers consider nature and science to be subjects for educational purposes, not as objects of analysis to be used outside of school.

The tendency of Japanese teachers to define nature and to hold conflicting viewpoints is confirmed in the literature. Previous studies have summarised the features of Japanese science culture and this study clarifies the differences between Japanese and South African thought. In spite of their differences, Japanese teachers focused more on the similarities than the differences between their views and those of their colleagues. For example, Domoto first mentioned a difference but followed by identifying the same core thought.

Why did this occur? One conclusion is that the collaboration between the teachers resulted in a desire to understand their colleagues rather than disagree with them. An evaluation of this statement requires the same stimuli. For example, Endo said that based on her homestay experience, "The nuance of language may be different in Japan and South Africa."

When teachers observe cultural differences in science education, they observe these differences in the context of their culture and education. There is value and meaning in doing so. The collaborative project demonstrated that major concerns did not result from these differences because dealing with systematic differences in schooling and value systems were the priorities of the project.

The Japanese historian (Maruyama 1961) discussed the Japanese cultural tendency to collect different thoughts and ideas without integrating them. Maruyama called this phenomenon "octopus pots" (p. 129). He used the phrase to describe that there is not any single grounding to be shared among in modern Japanese culture, compared to Western society. Japanese modernization took place after Western society had modern science and specializations in 19th century academia. This made Japan's placement of different cultures into different pots, gathered in one place instead of learning the core and splitting into various specializations. Although significant differences were observed in the two groups of drawings, the teachers interpreted the core premise of nature to be the same and related to humans.

Teachers mentioned the differences but then went one giant leap forward by attempting to understand them. Kawasaki (1999) argued that observation, *kansatsu*, in Japanese science classes was not to observe but to gaze at objects in a spirit of contemplation. This argument may be supported in this study because the teachers practiced *kansatsu* in an attempt to understand.

These results hold broad implications for improving science education methods for ESD and a sustainable world in any country (Ogunniyi 1988; Ogunniyi and Ogawa 2008). The Japanese teachers had a tendency to note differences between themselves and the South African teachers, but then they went on to look for similarities at a deeper level, as a result of contemplation. This tendency can be transferred to the relationship between science teachers and their students in any country.

Students will certainly have varying ideas of nature and science. Teachers could learn what these are, in contrast to the teacher's own ideas. However, capturing students' ideas is difficult compared to this study's participants' experience articulating their own ideas. Students' ideas are not organised or put into words for communication. The teacher's next step is to contemplate how the students' differing cultural contexts (i.e., the students' worldview, self-identities, or theories) may explain students' different ideas of nature and of science. In other words, a teacher can acknowledge cultural or self-identity differences experienced by their students, and then modify how they teach ESD according to the results of the teacher's contemplations. Furthermore, it is important for science education to take into consideration how conceptions of science and nature are captured in diverse local communities.

The drawing method, combined with semi-structured interviews and discussions, can be used to communicate and reflect different worldviews concerning the relationship between nature and science.

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Amateur Scientists: Unique Characteristics and Possible Factors Supporting Japanese Amateur Scientists' Continuous Scientific Practices

Yuuri Kimura

Abstract Among the science education research so far, a kind of dichotomy, science experts and lay public, is popularly presupposed, and few attentions have been paid to those in between, who continue to engage themselves in scientific practices after finishing their schooling. However, in recent years, studies on these people who are committing to and/or engaging in scientific practices as non-scientists have been visible (Corin et al. in Int J Sci Educ Part B, 7(2):161–180, 2017; Edwards in Stud Educ Adults 46(2):132–144, 2014; Kimura in J Sci Educ Jpn 41(4):398–415, 2017; Nielsen in Reinventing discovery: the new era of networked science. Princeton University Press, Princeton, NJ, 2011; Stebbins in Pac Sociol Rev 20(4):582–606, 1982). Accordingly, it is necessary to localize such people as the third position toward science between scientists (experts) and citizens (non-experts). Therefore, we attempted to identify various stances within the third position through the literature review and the examination of the term amateur, and could found amateur scientist, science devotee, science novice, and science dabbler among them. They could be allocated as science amateur practitioners between scientists (experts) and citizens (non-experts). The amateur scientist in this study is referred to as non-professional scientist, who have expertise of a certain area of science (for example, entomology), equally or higher than that of the professional scientists of the area of science. In this particular research, non-professional means the people, who do not make a living by that activity. It is well-known among Japanese science educators that pupils lose their interest in science as getting older, and also the level of Japanese adult's interest in science in general remains low. Therefore, it has been paid attention in Japanese science education research how students can maintain interest in science and how people can continue learning science after finishing their schooling. In Japan, scientific practice is supported not only by school science classes, but also by extracurricular activities such as club activities and/or Super Science High-School Project (SSH). In such a scene, what kind of scaffolding will be able to make students continue their learning science? In order to answer the question, studies on why amateur scientists can continue their scientific practices might be helpful and promising. As a trial, Kimura (J Sci Educ Jpn 41(4):398–415, 2017) generated a

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hypothetical model of the reasons (internal motivation and socio-cultural contexts) why Japanese amateur scientists could continue to devote themselves into their own favorite scientific practices, by using the modified grounded-theory approach (M-GTA) which is one of the qualitative research methods. The model has shown that purpose of their activities is just 'doing what I want to do until satisfied'. Their activities consisted of the following four components; (1) achieving their own aims, (2) developing special and unique relationship with the subjects, (3) committing the certain subjects that are very special to them, and (4) feelings of 'hard to let go'. And a process was uncovered that amateur scientists could continue their scientific practice by being supported by Fostering curiosity and Squeezing resources.

1 Introduction

Until recently, research in science education has popularly presupposed a dichotomy between science experts and citizens. For example, the purpose of science education is viewed from two distinct perspectives: human resource development in the domain of science, or the development of scientific literacy (Ogawa, 2001). This shared presumption among scholars has unconsciously hidden, or has paid scant attention to, those who fall in between the two fields and who continue to engage in scientific practices after completing their schooling.

However, studies on such individuals committed to and/or engaged in scientific practices as non-scientists have become visible in recent years (e.g., Corin, Jones, Andre, Childers & Stevens, 2017; Edwards, 2014; Everett & Geoghegan, 2016; Kimura, 2017; Nielsen, 2011; Stebbins, 1982). These individuals may be described as those who hold a "*third* position" toward science: somewhere between scientists (experts) and citizens (non-experts).

How can people who occupy this third position participate in and continue to learn scientific practices? This question interests Japanese science education researchers because Japanese science educators are well aware that pupils lose their interest in science as they become older. What suggestions can this research make to ameliorate this problem?

Furthermore, a Japanese adult's interest in science remains low in general (Okamoto, Niwa, Shimizu & Sugiman, 2001). Therefore, attention is now given to research on the manner in which students can continue their interest in science and to the ways in which people can continue learning science after accomplishing their schooling. What kind of scaffolding would enable students to continue their learning of science with interest? What kind of scaffolding would be effective for Japanese adults to develop an interest in science? This study tries to shed light on: (a) evidence-based answers to all the questions above, and (b) specific ways to study why people in the third position continue their scientific practices.

In other words, this chapter focuses on individuals who are usually addressed as amateur scientists and who possess a high degree of curiosity about science. The goal here is to elucidate how they can continue their scientific practices.

The chapter unfolds in the following sequence: identifying the complexity of who belongs to the third position in order to explore the amateur scientists within them, generating a hypothetical model with which to explore research related to amateur scientists, showing an analysis of a questionnaire survey's results to verifying the hypothetical model, and commenting on implications for science educators.

2 Who Are the Amateur Scientists in the *Third* Position?

I wanted to locate people who continue to engage in scientific practices in the third position. They may be described in many ways, including various definitions found in the literature pertaining to their nature and interests within the third position. A clarification of what "the third position" means in the study will lead to an appropriate sampling of these amateur scientists for this research.

2.1 The Third Position

What kind of people occupy the third position? To begin with, those *not* included in the third position for this study are science journalists, science communicators, science teachers, people in science public relations, and so on. They have attracted the attention of discrete domains such as science communication, science education, and teacher instruction in the role of *connecting* experts and non-experts. Those in the third position of interest to this study actually commit to and/or engage in scientific practices.

In recent years, research on people included in the third position has emerged from the perspectives of citizen science and open science. Numerous studies demonstrate the roles and measure the contributions of such citizens to the scientific research conducted by scientists (e.g., Bonney, et al., 2009; Fradera, et al., 2015; Nielsen, 2011; Roy et al., 2012). Nevertheless, despite this recent spurt, studies on individuals in this third position remain sparse in regard to what their features are and why they participate in science practice (e.g., Corin et al., 2017; Edwards, 2014; Everett & Geoghegan, 2016). Moreover, it is not clear why and how they *continue* scientific practices.

Before the establishment of professional scientists in the nineteenth century, those who did what today is called "science" have been studied by Alberti (2001) and Lankford (1981) for instance. But since the professionalization of science, inadequate attention has been paid to the existence of amateur scientists in contemporary society. It is certainly considered difficult for amateurs to be established in the domains of modern science (Sato & Takeuchi, 1996).

However, amateur scientists such as amateur entomologists or amateur astronomers certainly exist. Although these domains may not be considered as mainstream modern science, there are also those in the domain of modern science, such as bio-hackers (Wohlsen, 2011). Though scientific knowledge tends to be considered being produced only by scientists, It's interesting that amateur scientists also be able to produce it.

In the research reported in this chapter, I categorize citizens engaging in scientific practices as belonging to the third position. Amateur scientists certainly belong to this group. I will examine two points in more detail in order to define amateur scientists more clearly: (a) the classification of citizens engaging in scientific practices in relation to scientists or citizens; and (b) the categorization of various *gradations* in the group designated as citizens engaging in scientific practices, such as devotee, novice, or dabbler.

2.2 The Classification of Citizens Engaging in Scientific Practices in Relation to Scientists or Citizens

Some terminology needs to be clarified. First, both the expressions "citizens engaging in scientific practices" and the term "scientist" refer to people engaged in scientific practice. However, they differ with respect to their occupations—a living that people make through activities. In other words, the amateur is distinguished from the professional on the basis of whether the activity they are practicing is their occupation.

Secondly, the terminology "citizens engaging in scientific practices" in the classification structure posited in this investigation and the word "citizens" in the conventional viewpoint of scientific education research share the basic attribute that the scientific practice is not their occupation (e.g., Stebbins, 1977). Conversely, they are different with regard to whether or not they are engaged in scientific practice.

Accordingly, the presently coined definition, "citizens engaging in scientific practices," denotes people who practice of their own volition, and not as an occupation. Numerous people other than amateur scientists are also included in this third position.

Therefore, an overview of the categorization of the people occupying the third position is necessary to finally define an amateur scientist. To this end, I discuss the types of commitment of "citizens engaging in scientific practices" in the next section.

2.3 Classifying Types of Commitment in Citizens Engaging in Scientific Practices

To outline each type of concept that comprises the third position, I examined extant scholarly literature regarding citizens engaging in scientific practices from the view point of how they relate to science and what kind of positions they possess.

Studies on the Concept of an Amateur

I focused on the extant research on the concept of an amateur, including the term "amateur scientist." A series of studies have defined an amateur via a relationship between the professional and the public (Stebbins, 1977, 1980, 1981, 1982). Stebbins provides an overview of amateurs in various domains including science, and proposes a professional-amateur-public system (P-A-P system). He elucidates the definition of an amateur by comparing it with, and distinguishing it from, certain concepts similar to "amateur" that exist within and outside this P-A-P system: "hobbyist," "dabbler," and "novice." These conceptions of "professional" and "amateur" as proposed by Stebbins are applied to the field of science in his work, "Amateur and Professional Astronomers: A Study of Their Interrelationships" (Stebbins, 1982). An amateur is represented by the term "avocational astronomers," which is opposed to "professional astronomers" in his article.

According to the P-A-P system proposed by Stebbins, an *amateur* has a corresponding professional; in other words, there is a formal occupation in the area of activity. In addition, amateurs, like professionals, have specialized knowledge and skills in a particular field, but are distinguished from professionals by the amount of time they spend on the activity and their income from the activity.

Studies on Concepts other than "Amateur" in the Classification of Citizens Engaging in Scientific Practices

I delved into extant literature on concepts other than the "amateur" ascribed to citizens engaging in scientific practices. They include various descriptors such as scientific volunteers, contributors to citizen science projects, hobbyists, dabbler, and novice. Studies have highlighted the features of subjects of study and have tried to compare the terms conceptually (e.g., Edwards, 2014; Stebbins, 1980).

Stebbins (1980) shows three categories that are similar to but different from amateurs, both inside and outside of his P-A-P system. *Hobbyists* are practitioners who possess a clear and continuous goal like amateurs, but they do not have a corresponding professional. When active involvement in activities and specialized knowledge and skills are insufficient (not unlike the notion of public), a person is designated a *dabbler* and distinguished from an amateur. Moreover, people who have not yet grown in their proficiency and who have insufficient knowledge and skills cannot be termed amateurs or professionals, but their steady and active engagement in the activities in a relevant field assign them the nomenclature of "*novice*." They are distinguished from amateurs, but they have the potential to become amateurs (and sometimes even to become professionals).

In a study by Edwards (2014), an attempt was made to clarify the features of contributors of citizen science through a comparison of the three different terms conceptually; scientific volunteers, contributors to citizen science projects, and amateur. Edwards (2014) first summarized studies on volunteers; for example, a study that focus on three principle characteristics; it is unpaid, undertaken by free will, and is a benefit to others (Paine, Hill & Rochester, 2010); and studies regarding motivations or attitudes toward learning (e.g., Low, Butt, Ellis, & Davis Smith, 2007;

Raddick et al., 2013). Based on these studies, he claimed that many citizen science contributors are unpaid (by the projects), do it of their own free will and for the benefit of others, like a volunteer; and there is some consistency between citizen science contributors and volunteers' motivations and attitudes toward learning. Next, regarding amateurs, Edwards (2014) overviewed some studies that exemplify the fact that amateurs possess equivalent or additional knowledge or skills to experts and that they contribute to the discipline (e.g., Dodge & Kitchen, 2013; Goodchild, 2007) and another study that called skilled amateurs active in the scientific field to "semi-amateurs" (Lankford, 1981). Nevertheless, he also admits that the term amateur may be used in a negative or restrictive sense that is contrary to the above, signifying insufficient knowledge or skills, or the lack of income. By summarizing the abovementioned studies, Edwards (2014) recognized that the term amateur is a multifaceted concept. According to him, amateurs contributing to such projects for the love of it, bringing experiential learning to that activity, and wishing to learn through participation is consistent with the part of my survey data pertaining to the contributors of citizen science projects who contribute to scientists' research through ecological surveys and astronomical observation data collection.

Four Concepts of Citizens Engaging in Scientific Practices

The above examination has provided the basis in this research for axes from which to classify types of commitment witnessed in citizens engaging in scientific practices: corresponding professional, specialized knowledge and skills, degree of contribution for the discipline, their purpose and goal on the activities, length of activity time, percentage of time spent on the activities, percentage of income from the activity, decision maker of their activities. I considered these axes. Then I organized the citizens engaged in scientific practice into four concepts.

Stebbins (1977) refers to amateur, hobbyist, dabbler, and novice as people who practice a discipline of their own will, not as occupation. He calls practitioners who have a clear and continuous purpose as well as specialized knowledge and skills in a particular field an amateur or a hobbyist. If there is an occupation corresponding to the field of activity, the person is defined as an amateur, and if not, an individual is defined as a hobbyist.

However, in our times, whether or not a profession is established is fluid; for example, even if no professional athletes exist in a field, new professional athletes may be born or a professional sports system may be newly established (e.g., the case of J League: a professional football league established recently in Japan). In the same manner, there is also the possibility that an existing professional position will disappear. Thus, it is not appropriate to use classification criteria depending on the current existence of an occupation. Therefore, I redefine practitioners with clear and continuous purpose and with specialized knowledge and skills in a field as *amateurs in the narrow sense*, regardless of whether or not a corresponding occupation actually exists at the current time.

My concept of amateur in the field of science denotes people who correspond to terms such as semi-amateur, as described in the previous research initiatives. Therefore, I name these individuals "*amateur scientists*" and define them as: "Practitioners who continuously and actively engage in scientific practices in the long term, not as an occupation, but with sufficient knowledge and skills."

Stebbins (1977) defines a "dabbler" as a person who is less aggressive and who commands insufficient technical knowledge and skills in a discipline. However, there are certainly people who cannot be explained as "dabbler". It is shown in the context of open science and citizen science that there are people who are different from "dabbler", actively and continuously engaged in activities in a particular domain (e.g., Nielsen, 2011). They participate partially as collaborators in certain phases of the research activities of scientists and enjoy the experience and the participation. They do not aim to improve their specialized knowledge or skills. However, even if it was not intended, their knowledge and skills are sufficiently professional and advanced compared to the general public (e.g., Dodge & Kitchen, 2013; Goodchild, 2007), even though their knowledge or skills are insufficient or biased when compared to professionals. Therefore, their knowledge and skills or roles may be constrained when compared to professionals, but they may be said to be legitimate practitioners of a discipline. Although "dabblers" certainly exist, this concept alone is not enough in this study. Hence, I believe that it is appropriate to label those who are not "dabblers" shown in this paragraph as citizens engaging in scientific practices and to designate them as *devotees*.

A *novice* is someone who steadily and actively engages in the activities of a field, but who has not yet acquired requisite proficiency. Although the knowledge and skills of a novice are insufficient when compared to an amateur or professional, a novice may become an amateur or a professional in the future. In common with a *devotee*, a novice actively engages in the activities of a discipline, but with inadequate knowledge and skills. The difference between novice and devotee is one of whether or not there is continuous participation. A novice has just started and thus there is no steady engagement. Therefore, I have divided these two concepts according to the period of engagement in a discipline.

Although dabblers and novices are not specifically shown in previous discussions in the field of science, a novice may correspond to a university student for example, who majors in math, science, and engineering or a student who belongs to the science club in the school (e.g., elementary, junior high, and high school). Also, while it may seem at first glance that the uncertain ways of involvement of dabblers are unrelated to the works of science, such participants in a discipline are also regarded as important and legitimate practitioners who support the works of science.

The Definition of an Amateur

Based on the above reviews, I was able to find four types of citizens engaging in scientific practices: the amateur, the devotee, the dabbler, and the novice. As a result, I am able to define the term amateur scientist as "a practitioner who actively and continuously engages in scientific practices in the long term; not as an occupation, but with sufficient knowledge and skills."

3 Why Can Amateur Scientists Continue to Devote Themselves to Scientific Practices?

3.1 Generating a Hypothetical Model

As is shown in my definition above, amateur scientists continue to participate in scientific practices. Three issues stand out: What makes them participate in scientific practices? Why do they keep performing these practices? and What supports them to be able to continue their scientific pursuits?

To discover answers to these questions, Kimura (2017) generated a hypothetical model of the reasons (related to internal motivations and socio-cultural contexts) why Japanese amateur scientists can continue to devote themselves to their favorite scientific practices. The model is repeated here as Fig. 1. Kimura utilized a modified grounded theory approach (M-GTA) (Kinoshita, 2003), to accomplish her model. The analysis procedure of M-GTA first generates a concept or the minimum unit of analysis from interview results. Next, it generates a category comprised of a group of concepts. Finally, summarizing the correlation between the concepts and the categories, it creates a result diagram representing the entire process, indicated by arrows. In this chapter, I refer to result diagrams as structures, and concepts and categories as elements, in addition, the concept is represented by [] and the category by < >. Here is an example of each, taken from the outline of the hypothetical model developed in Kimura (2017) that is presented in this section: [13. Product representing satisfaction] and <2. Satisfaction>.

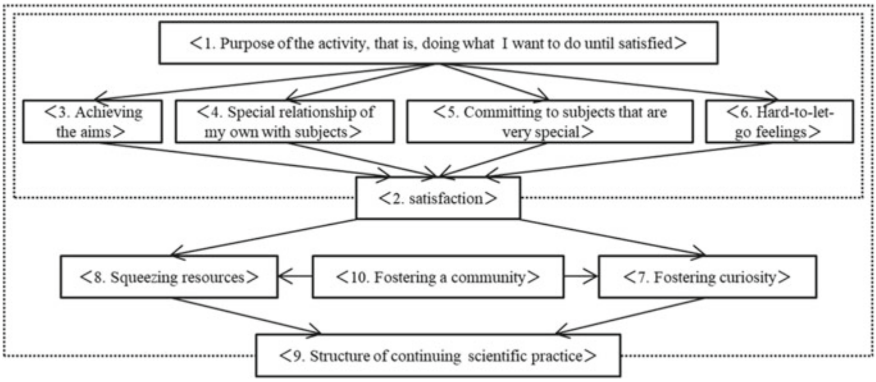

Fig. 1 Hypothetical model: elements and structure that allow Japanese amateur scientists to continue their scientific practices [Original is in Japanese: Kimura (2017) Fig. 1]

An Outline of the Scientific Practices of Amateur Scientists

Since amateur scientists are active in Japan in the fields of entomology, astronomy, and ecology research, Kimura interviewed[1] amateurs in the domains of entomology and astronomy. The generated hypothetical model that resulted represented the internal and external factors that support the scientific practices of amateurs, and how those factors relate to each other.

As shown in Fig. 1, the purpose of the activities undertaken by amateur scientists is to obtain satisfaction by fulfilling their curiosity. Thus, amateur scientists pursue scientific experiences to satiate their curiosity about science. At the same time, however, they undertake activities that satisfy their own special feelings: <4. Special relationship with subjects>, <5. Committing to subjects that are very special>, and <6. Hard-to-let-go feelings>. Hence, the activities that satisfy their curiosity are not narrowly defined; rather, they convey the broader sense that amateurs acquire satisfaction by actualizing their subjective desires. Therefore, it is understandable that there are some aimless activities that also form a part of their activities. These activities are not undertaken toward <3. Achieving the aims>, but to obtain another type of satisfaction such as the realization of their own special interests. Moreover, Kimura discovered that activities that seem to be unrelated to their curiosity or seem to be meaningless are actually pertinent to the development of their curiosity.

It was further revealed that several social factors influence the scientific practices of amateur scientists. First, the pressures of social factors such as work or home reduce their activities. For instance, it was found that the time for an amateur's scientific practices was constrained by work related to employment; the money and the time for scientific practices were also restricted by the needs of their family (especially their children). Thus, it may be elucidated that some factors negatively affect the scientific practices of amateurs. Conversely, participating in communities such as clubs or circles enhances their activities.

Therefore, although social factors may influence the reduction of activities undertaken by amateur scientists and although they may inhibit the continuation of their scientific practices, social factors may also comprise aspects that help the overcoming of the constraints. Hence, the activities of amateur scientists fluctuate according to their particular social factors. Amateur scientists are able to adjust these variations in their activities and continue to devote themselves to their scientific practices by using social factors exemplified by their communities such as science clubs consciously and/or unconsciously. In the next section, I will explain the five major parts of this model in more detail.

Five Major and Characteristic Parts of the Model

Characteristic part 1: Scientific practices of amateur scientists are continued by <7. Fostering curiosity> and <8. Squeezing resources>

Amateur scientists act to achieve the purpose of doing what they desire until they achieve satisfaction. Thus, they recognize various things and/or phenomena as their

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[1] In the interview survey, I referred to Suzuki (2005).

products: things that show their satisfaction, their skills, their experiences, and so on through their activities. These products may be published widely or kept within a guarded range or may be privately owned without being published. Amateur scientists can continue their scientific practices because they are constantly able to foster their curiosity and to squeeze more resources; through the activities to make/possess/publish their products or the activities to fulfill their purpose of "doing until they are satisfied," or of interacting with others.

Characteristic part 2: The purpose of the activities of amateur scientists is simply to do what they want to do until they are satisfied

Although amateur scientists are constrained by time and money under the external pressures of their work or families, they continue scientific practices that require their time, money, and effort. Some activities have definite aims, such as Case 1 and Case 2 illustrated below; and some do not as in Case 3. Why do amateur scientists set or unset such aims? Why do they continue the activities without aims? They do so because the governing purpose of their scientific practices is to do what they want until the point of satisfaction is achieved, as shown in <1> in the hypothetical model.

Case 1: Activities to achieve scientific aims:

I am interested in meteors. My research is to be able to forecast the movement of meteors.

Case 2: Activities to achieve non-scientific aims

I hope that everyone, not just me, will be able to collect this data

I had never seen that butterfly, so I wanted to capture it for myself.

I want to catch all the species of butterflies in Japan on my own.

Case 3: Aimless activities

I don't use it for anything, but I try to observe, take a photo, or take a video.

Characteristic part 3: The activities of amateur scientists consist of four elements (Fig. 2)

Amateur scientists conduct their scientific practices to fulfill their purpose of doing what they want to do until they are satisfied as shown in <1> in the hypothetical model. What kind of activities do amateur scientists undertake to fulfill this purpose? They are satisfied by the realization of their own special interests, through the processes or products of their activities. Those activities comprise the four elements outlined below and found in Fig. 2.

1. <3. Achieving the aims>

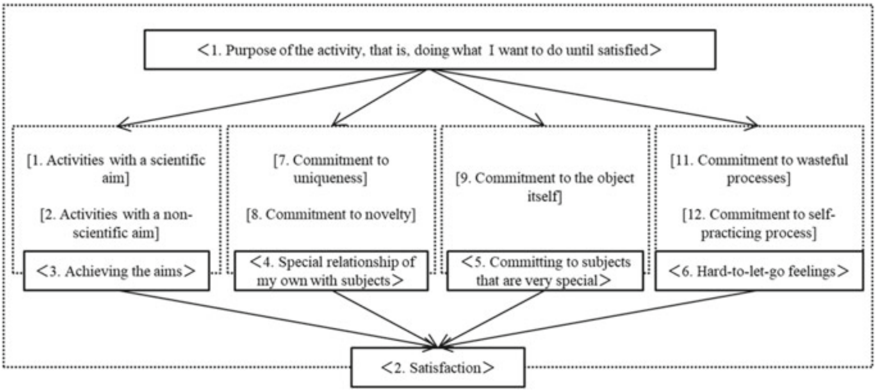

Fig. 2 Elements and structure of <2. Satisfaction> [Original is in Japanese: Kimura (2017) Fig. 3]

Amateur scientists emphasize the achievement of their own aims. They are satisfied by the accomplishment of the goals they have established, which include both scientific and non-scientific objectives.

2. <4. Special relationship with subjects>

Amateur scientists are content in developing a special and unique relationship with the distinct subjects of their scientific practices. In other words, it can be said that they are satisfied with the quality of "extraordinariness" of their subjects. Those special relationships include two types: (a) uniqueness (amateur scientists value a unique relationship with their subject that is different from all others); and (b) novelty (they value their establishment of a relationship with a subject that is new and that no one else has yet been able to create).

3. <5. Committing to subjects that are very special>

Amateur scientists value certain subjects regardless of the benefit they offer. They do not need anything in return, since they regard the subject itself as a special entity that they value unconditionally for itself. Therefore, they can be satisfied merely by committing to that special entity through their activities.

4. <6. Hard-to-let-go feelings>

Amateur scientists value doing the activities or the practice by themselves, using their own inefficient methods. The hard-to-let-go feelings; that is, their desire to keep in touch with the subject more, are satisfied by feeling contentment with regard to the time and effort they expend in their direct engagement with a special subject and/or in being able to visualize and realize an extraordinary relationship.

Characteristic part 4: Three types of processes foster the curiosity of an amateur scientist (Fig. 3)

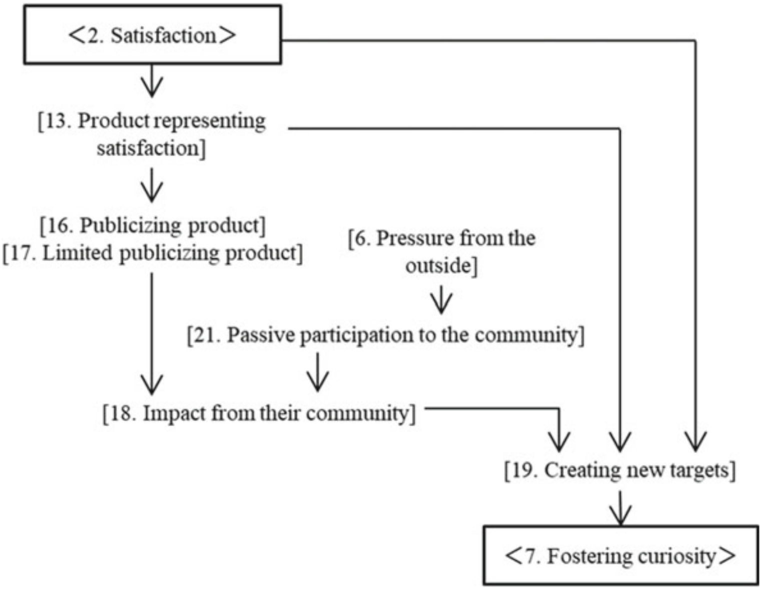

Fig. 3 Elements and Structure of <7. Fostering curiosity> [Original is in Japanese: Kimura (2017) Fig. 4]

Curiosity is an important motive that determines the direction of the scientific practices of amateur scientists. In what way is curiosity fostered in their activities? The hypothetical model illustrates three types of processes that foster curiosity: (a) by products, (b) by activities, and (c) by stimulation from the community. Further, these three processes enable amateur scientists to foster curiosity even if their activities are constrained, and even if they cannot "do what they want to do until they are satisfied" (Figs. 1 and 2). In other words, these multiple processes particularly lower the risk of the system to interrupt the fostering of curiosity.

(a) Process by which curiosity is fostered by the product [13. Product representing satisfaction]

As mentioned above, amateur scientists recognize varied things and/or phenomena attained through their activities as deliverables. In this process, the product is a source of curiosity. For example, as new findings are obtained, more new ideas are born, and a feeling (curiosity) of wanting to know or wanting to do grows within the amateur scientist. This pattern fosters curiosity in very personal and subjective ways.

(b) Process by which curiosity is fostered by activities that are satisfying <2. Satisfaction>

In this process, curiosity is fostered in amateur scientists by being triggered by events and information obtained during the process of conducting an activity. For example, information that has been obtained accidentally during activities may lead to questions or other ideas, or having examined wide-ranging records in the process of activities may lead to the classification of data.

(c) Process in which curiosity is fostered in amateur scientists by their community [18. Impact from their community]

Amateur scientists participate in communities that share the same interests. In this process, curiosity is fostered as a result of their participation in such a community and the stimulation they receive from others. Such stimulation has several types, and it triggers curiosity: hearing other people's presentations, working together on scientific practice, and receiving responses and questions to the presentations they deliver. These socio-cultural contexts function to encourage curiosity in amateur scientists. Further, this mechanism retains and promotes curiosity even when a person's scientific practices may be stagnant due to external pressures from other socio-cultural contexts, factors, and work. Amateur scientists are able to keep their curiosity uninterrupted by consciously generating this process according to their particular situations.

Characteristic part 5: Two types of processes lead amateur scientists to further wring their resources for scientific pursuits <8. Squeezing their resources> (Fig. 4)

Although curiosity is an important motive in the scientific practices of amateur scientists, it is not enough to continue their scientific practices, which are embedded deeply in their daily lives. Social factors such as work or family may exert a negative influence in many cases. Therefore, it is not hard to conceive of situations in which amateur

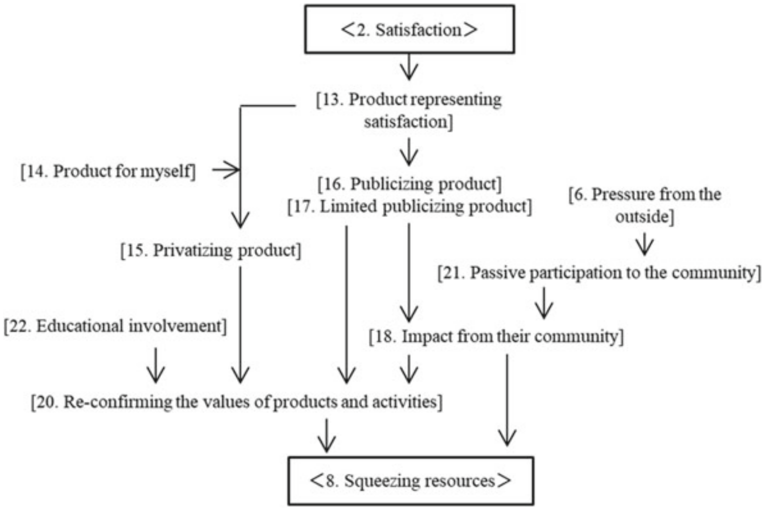

Fig. 4 Elements and structure of <8. Squeezing resources> [Original is in Japanese: Kimura (2017) Fig. 5]

scientists cannot continue with their activities despite their curiosity because they cannot spare resources such as time or money.

However, amateur scientists do continue their scientific practices in the longer term even though they are embedded in such daily lives: they keep squeezing their resources into the activities. Two types of processes may be used to wrest the most out of scant resources and to influence the determination of the scale of the activities of amateur scientists:

(a) Processes in which resources are squeezed via the influence of their communities [18. Impact from their community]

Amateur scientists devote and consume their time, money, and space by being inspired by their specialized communities. Moreover, they are inspired by others to overcome constraints such as being busy and can make room for their constrained resources. This process may be effective in squeezing resources and promoting activities through minimal costs.

(b) Process in which resources are squeezed by a reaffirmation of the value amateur scientists place on their scientific pursuits and products [20. Re-confirming the values of products and activities]

Amateur scientists consume more resources by reaffirming the value of their activities and products. For example, an amateur scientist may manage to spend time to write a thesis because this person reaffirmed values of his/her activity by the praise and positive opinion received from others. Similarly, once products are published, amateur scientists may reaffirm the value of their activities from the stimulation they receive from their community. In other cases, the value may be reaffirmed through the process of combining new knowledge (i.e., the product) with his knowledge, or through the publishing of research results, or through the appeal of a particular subject's intrinsic attraction for a beginner. Those cases show that the value emanates not merely from an evaluation from others in a community; it also originates from unpublished products or from educational relationships with a novice that leads amateur scientists to the reaffirmation of the worth of their activities.

3.2 Empirical Evidence Concerning the Hypothetical Model

I conducted questionnaire surveys on amateur entomologists and amateur astronomers with regard to the main structure of the hypothetical model (Fig. 5). As a result, I found elements common to most amateur scientists, and I discovered attributes that were different between amateur entomologists and amateur astronomers.

In the sections that follow, I will introduce the major findings of the results of these surveys; that is, the results obtained from the surveyed entomologists vis-à-vis

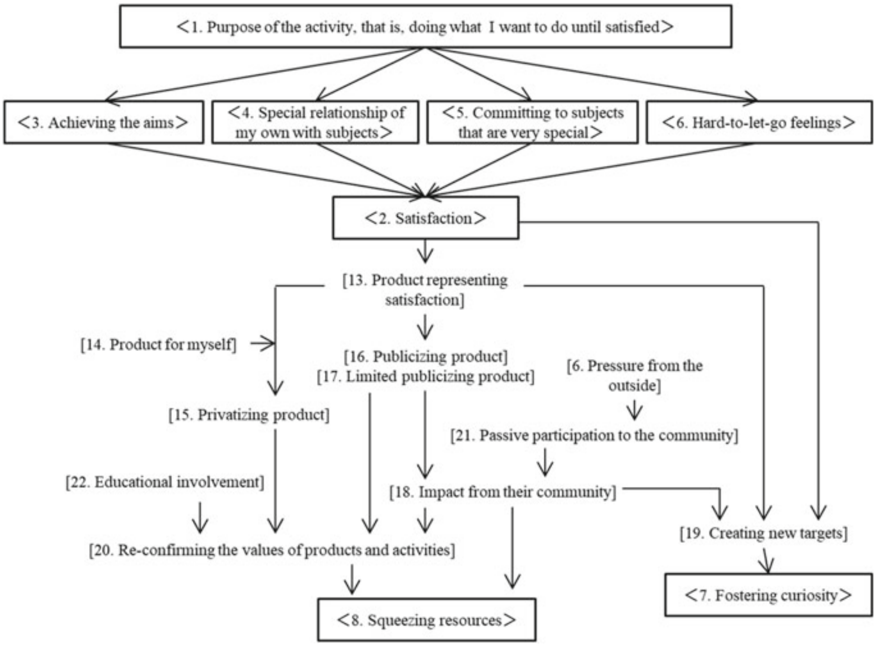

Fig. 5 Main structure of the hypothetical model modified for the empirical survey [Original is in Japanese: Kimura and Ogawa (2018) Fig. 1]

Kimura and Ogawa's (2018) findings; those attained from the surveyed astronomers and their comparison with Kimura's conclusions (2019); and add more details to the results of the survey.

3.2.1 Survey Respondents' Demographics

According to the survey results (Table 1), amateur scientists are more likely to be men. This finding is congruent with the outcomes obtained by other researchers on amateur scientists (Raddick et al., 2013). In terms of age composition, the results reveal that the highest layer of Japanese amateur scientists is occupied by people in their 50s and 60s.[2]

A majority of amateur entomologists began their activities at an early age, a fact that may be related to their familiarity with certain insects in their childhood. On the other hand, many amateur astronomers also started their activities in junior high or high school. In Japan, astronomy clubs (club activities at schools) are popular, and such club activities become one of the triggers for the growth of interest. The Astronomical Society of Japan provides junior sessions for junior high school and

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[2] There may be a bias due to the survey site, so further surveys will be better to improve the validity of the demographics.

Table 1 Demographic data of the questionnaire respondent

		Amateur entomologists	Amateur astronomers
Number of surveys collected		70 sheets	28 sheets
Survey sites		The 73rd Insect fair Tokyo, Japan September 23, 2017	Astronomical society of Japan Annual spring meeting Chiba, Japan, March 2018
Male/Female ratio		Male = 90.0%	Male = 85.7%
		Female = 10.0%	Female = 14.3%
Age group	10–20s	14.3%	14.3%
	30–40s	24.3%	21.4%
	50–60s	55.7%	57.1%
	70s or over	5.7%	7.1%
Start of activity	Primary school students or under	55.7%	32.1%
	Junior high school students or high school students	12.9%	28.6%
	University students	7.1%	17.9%
	Adults and above	24.3%	17.9%

high school students, and helps these students to play an active role as amateur astronomers.

As mentioned above, many amateur scientists began their activities in early childhood, but surprisingly, a large number started their scientific practices after graduating from university (24.3% for amateur entomologists, 17.9% for amateur astronomers).[3]

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[3] As is shown in the beginning, Japanese science educators are well aware that pupils lose their interest in science as they become older. However, the result of this research shows a different reality that there are some people who joined science practices after growing up. This suggests that though the general interest in science decreases as growing older, the same hypothesis does not hold true for those involved in scientific practices. This is a very surprising finding. In particular, it is noteworthy that in case of the field of entomology, amateur scientists joined after adulthood are the next majority to those participated in primary-school age. Traditionally, people who practice science have been assumed to be gradually selected. However, exploring the motivation of those who participate in science practice after growing up would potentially recreate come-back opportunities for those who once gave up science in school education.

Table 2 Results of Q6: What is the most important reason for yourself being in the activity?

Reason	Amateur entomologists (%)	Amateur astronomers (%)
To be useful	2.9	3.6
For interest	74.3	60.7
Get recognition from around people	1.4	0.0
Doing together with friends	12.9	0.0
It can be used for work and life	1.4	17.9
Earn	0.0	0.0
Contributing to academics	12.9	17.9
To have fun with the activity	70.0	53.6
Other	0.0	7.1
No answer	7.1	10.7

3.2.2 Major Findings of the Questionnaire Survey

The questionnaire had a total 22 of questions; 19 main questions and three demographic questions. Of these, 17 questions had a closed-ended format and five were formatted as open questions.[4]

(a) Motivation

The value placed by amateur scientists in their activities was expressed in their answers to Q6: "What is the most important reason for yourself being in the activity?" (Table 2). The results "for interest" and "to have fun with activity" were overwhelmingly large. Amateur scientists were performing their activities through an intrinsic motivation.

(b) [13. Product representing satisfaction]

The details pertaining to the product of the activities of amateur scientists [13. Product representing satisfaction] were shown in the answers to Q8: "What is (was) the product for yourself in the activity?" (Table 3). According to the results, all amateur entomologists and all amateur astronomers achieved products. The general type of the product of their activities [13. Product representing satisfaction] was expressed as "experience in the activity" and "knowledge." Thus, amateur scientists recognized varied phenomena as products, because there were responses in all the given options.

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[4] Children who cannot read the questionnaire and express themselves clearly in writing were not included in this survey.

Table 3 Results obtained for Q8: What is (was) the product for yourself in the activity?

Product	Amateur entomologists (%)	Amateur astronomers (%)
Results of observation and survey	44.3	50.0
Experience in the activity	65.7	67.9
Knowledge	55.7	46.4
Photo	35.7	32.1
Specimen	80.0	7.1
Presentation at a conference or circle	27.1	39.3
New knowledge of science	27.1	21.4
Books, columns, and so on	7.1	0.0
academic paper	17.1	10.7
Other	2.9	3.6
Nothing	0.0	0.0
No answer	0.0	0.0

Notably, the product representing satisfaction for many amateur entomologists was “specimen.”

(c) [6. Pressure from the outside]

The details of external demands [6. Pressure from the outside] were in evidence from the answers recorded to Q11: Are (were) there any constraints in practicing the activity? See Table 4 for the results.

Table 4 Results obtained for Q11: Are (were) there any constraints in practicing the activity?

Constraints	Amateur entomologists (%)	Amateur astronomers (%)
Time	84.3	92.9
Money	75.7	71.4
Family	34.3	21.4
Job	52.9	35.7
Human relations	10.0	7.1
Equipment such as tools and machines	17.1	50.0
Other	17.1	7.1
Nothing	2.9	0.0
No answer	1.4	0.0

According to Table 4, 95.7% of the amateur entomologists and all surveyed amateur astronomers felt external pressure. The general type of pressure was "time" and "money." Amateur astronomers responded in particularly high numbers with the statement, "equipment such as tools and machines," illustrating the particular characteristic of amateur astronomers that they required several types of specialized equipment for their activities.

(d) [18. Impact from their community]

The details of the influence exerted by the specialized community to which amateur scientists belonged [18. Impact from their community] are shown in the answers to Q14-4: "What kind of impact did (do) you experience by joining the community? (Table 5). According to the results of the questionnaire, 97.1% of the amateur entomologists and 97.1% of the amateur astronomers felt the impact of their community. The general type of influence that was reported [18. Impact from their community] included "made friends," "confirming the values of products and activities," and "found new targets." In addition, when the hypothetical model was created, I could not confirm the negative impact of the community. However, this was slightly confirmed in the results of this survey, as shown through the statements, "I lost the attraction and value for my activity" and "problems occurred in human relations."

(e) [19. Creating new targets]

The details of new goals and objectives being developed [19. Creating new targets] were shown in the answers to Q9: "Have you found (did you found) new targets in the activity?" and in the open-ended responses to Q10-1: "For example, what new

Table 5 Results obtained from Q14-4: What kind of impact did (do) you experience by joining the community?

Impact	Amateur entomologists (%)	Amateur astronomers (%)
Found new targets	48.6	60.7
Confirming the values of products and activities	55.7	64.3
Felt like spending more time and money on the scientific activities	17.1	25.0
Made friends	67.1	67.9
Lost the values of products and activities	2.9	0.0
Problems occurred in human relations	7.1	14.3
Other	0.0	7.1
Nothing	1.4	3.6
No answer	1.4	10.7
Joining no community	18.6	10.7

targets have you found?" According to the results to Q9, all the surveyed amateur entomologists and 91.4% of the amateur astronomers created new targets. When I look at their responses to Q10-1, I can understand their new targets concretely. For example, in the case of amateur entomologists; "I become eager to capture other insects, too," "I become eager to try to breed insects that are difficult to breed, too," and "I want to discover new species and new production areas" were some indications of fresh objectives. In the case of amateur astronomers, "I was mainly looking at the moon and planets, but now I would like to see some darker objects such as the Great Nebula of Orion," "I would like to find the correlation between small objects in the solar system (meteor and meteor trails) and solar activity," and "acquisition of new techniques for astronomical photography" were cited as new areas of interest.

3.2.3 Elements Common to the Amateur Scientists of Both Fields

All the elements that construct an outline of the scientific practices of amateur scientists were applicable to many of the amateur scientists of both fields; that is: <1. Purpose of the activity, that is, doing what I want to do until satisfied>, <2. Satisfaction>, <7. Fostering curiosity>, and <8. Squeezing resources>. Therefore, the structure indicated by the hypothetical model (see Fig. 1) is likely to be a general structure in the scientific practices of Japanese amateur scientists.

The analysis of the results of the questionnaire survey reveals the other general structures applicable to the scientific practices of Japanese amateur scientists:

- The process of fostering curiosity takes two general routes: the creation of new targets from experiences encountered in the course of activities undertaken; and the creation of new targets through the influence of a specialized community.
- More resources are consumed through the impact exerted by the specialized community.
- Amateur scientists continue their scientific practices under the influence of social factors such as external demands [6. Pressure from the outside] and the effect of their specialized community [18. Impact from their community].

Moreover, it has been suggested that "keeping relationship with their community" and "keeping multiple routes in various situations of their activities" may be important factors for uninterrupted scientific practices of amateur scientists (Kimura, 2019).

3.2.4 The Unique Characteristics of Each Field

Amateur entomologists were significantly less numerous than amateur astronomers in the following two elements: publicizing products [16], and educational involvement [22]. Therefore, amateur entomologists generally tend to treat their products personally and they are less involved with others. In other words, amateur entomologists place greater emphasis on individual activities in their scientific practices.

In addition, amateur astronomers are significantly higher than amateur entomologists with regard to the element of being actively engaged in their communities [21. Passive participation to the community]. Thus, amateur astronomers are thought to generally emphasis on the relationship with others and/or their community in their scientific practices.

4 Implications to Science Education

4.1 Implications About Scaffoldings to Students

What suggestions can this research make concerning the issue of preventing students from losing their interest in science as they become older? First, this study exhibited that fostering curiosity and participating in scientific practices are mutually supportive actions. Therefore, participation in scientific practices may lead to the development of interest. The present investigation suggests that interest in science can be maintained by a continuation of scientific practices.

In addition, this study clarified the existence of at least three processes that foster curiosity: (a) by products, (b) by activities, and (c) by stimulation from the community. Among them, it was suggested that two processes may be effective to maintain scientific interest: a process from participating in scientific practices (b), and a process from the stimulus of engaging in their specialized community (c).

Various ideas may be considered for specific scaffolding, for example: (a) the introduction and promotion of scientific practices in the school, such as regular classes or club activities; and (b) the recommendation and creation of systems that can motivate students to get to know people involved in scientific practices inside and outside of the school.

4.2 Implications About Scaffoldings for Citizens

For amateur scientists, participating in scientific practices represents an activity that is undertaken to gain satisfaction through the fulfillment of personal special interests. Therefore, it may be effective to design activities that can achieve scientific aims and can simultaneously create some special interests to support such scientific practices by citizens.

Besides, the continuous scientific practices of amateur scientists are supported by fostering their curiosity and by enhancing their resources for their activity. Curiosity and resources are both essential elements for scientific practices. Especially, squeezing resources for their activities is an important element, as the activities of amateur scientists are influenced by social factors, which sometimes affect them negatively. Therefore, the offer of support for these two factors would be an important part of any scaffolding to encourage scientific practices by citizens.

A social factor that is intimately allied to these two elements (fostering their curiosity and squeezing resources) and promotes the scientific practices of amateur scientists is the impact from their specialized community, and Kimura (2017) shows varied ways of the interactions of amateur scientists with such communities. For example, "active involvement" such as publishing their product and asking for opinions on it, "passive involvement" such as listening to others' stories about scientific practices, and "educational involvement" for the purpose of spreading. It may be possible to consider specific support methods with reference to these cases.

4.3 Implications About a New Science Communication Model

In recent years, science communicators have been positioned as specialists who mediate between the experts (scientists) and the non-experts (citizens). On the other hand, the focus on amateur scientists in this research makes it possible to consider a model connecting the three positions of experts (scientists), non-experts (citizens), and people in the third position. As a result, the space for interlocution by science communicators may be increased or fragmented, new roles for them may emerge in each space, and new possibilities may be created from these newly created spaces and functions.

For example, we can also contemplate forms of communication that include the practice of science: the communication established between people involved in scientific activities and people who are not. Because understanding can be context-specific, people in the third position (e.g., the amateur, dabbler, devotee, and novice scientist) may have advantages over professional scientists in the domain of communicating scientific practices with the general public.

Moreover, I can mention that there is another way to directly reach for science, that is, the scope of who is directly related to science is expanding. So far, traditional scholarship has assumed that this is a form of communication that only professional scientists can perform. However, by focusing on amateur scientists, this study has given evidence that this type of communication form has been opened to the modern general public (e.g., peoples in the third position). It is a form of communication in which the general public can also participate in scientific practice and be directly involved in science, not indirectly (through scientists or the products produced by scientists). The dissemination of this form of communication may enable scientific practices to spread extensively through society and may enable varied actors to participate in scientific practices. Thus, members of society may widely share the experiences of scientific activities. In other words, the culture of "doing" science may be fostered.

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Lessons of a Veteran Teacher's Ordinary Instruction in Elementary School Science: Implications to Using an Analysis of Fujio Hiramatsu's Practice

Hisashi Otsuji

Abstract In this chapter, I present all the protocols of a lesson video conducted by a veteran elementary science teacher, Mr. Fujio Hiramatsu, and interpret it as if the readers were taking my teaching methodology class at university. The lesson was an "electromagnet" for a sixth-grade elementary school student, conducted at the attached Elementary School of the University of Tsukuba. Hiramatsu had found that children miss understood the essential concept of the electromagnet, and then conducted the lesson starting with one enameled wire. Through a multi-disciplinary approach, such as historical examination and the interview, I not only confirm some basic skills of teachers' but also point out some advanced techniques. You will see how sensitive the teacher's thoughts are, that class is a work of art, and that research themes are hidden in daily practice.

The aspects of things that are most important for us are hidden because of their simplicity and familiarity. (Wittgenstein, 1953, 2009, p. 56).

1 Introduction

A teacher's work in the classroom is described as an art, whose primary aim is changing students. To be a successful science teacher, for instance, the most significant change that is expected of pre-service students is their shift (transformation) from the learning side of instruction to the teaching side. In order to cause such a shift to occur, it is necessary for these prospective teachers to contemplate objective classroom phenomena in front of them, and lessons experienced in their past as students that have been given less attention.

In 1995, I was hired by the College of Education, Ibaraki University, and ever since, I have been involved in science teacher education. Soon after I arrived, a senior academic next door to my office kindly gave me a VHS video (Japan Educational Book Center, 1995) for which I developed the transcription introduced in this chapter. I was in my 20 s, and the senior academic, Masakata Ogawa, was in his early 40 s.

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Photo 1 The VHS Video

I have been using the video ever since because I thought it portrays many notable tactics and intentions of a veteran science teacher. By showing an excellent image of a Japanese science class, the video is worthwhile for university education students to watch, analyze, and discuss (Photo 1).

This chapter does not report new knowledge through analysis of science teaching/learning, nor does it propose new research/educational methodologies. Instead, the chapter identifies and discusses various educational and cultural codes embedded daily in science classes, for the purpose of reconfirming their importance.

Moreover, this chapter does not follow the academy's formal and typical format of arguing, such as: purpose, method, result, and argument. Instead, the chapter unfolds according to the flow of an actual teacher education class. I would like you to enjoy the short journey.

2 Mr. Hiramatsu's Practice

The video shows a sixth-grade class being introduced to electromagnets. Elementary school students start learning about magnets and electricity separately in the third grade, and the essence of these units is integrated into this sixth-grade unit. The instructor is Fujio Hiramatsu, who used to be a host of an elementary science teaching program on educational TV. He was also the vice principal of the elementary school associated with the University of Tsukuba at the time of producing the video.

I show this video to all my science methods classes in the pre-service programs where I have been employed. Before showing this video, I give the following introductory talk to my students:

> Let's listen to some veteran teacher's words and students' responses. Pay attention to what you think is remarkable, and mention anything you had a question about. Let's watch the video while highlighting points on the scripts I have transcribed. The video is so impressive

> that it even makes me cry at the end every time I watch it (smile). After watching it, let's have a discussion in order to brush up our sense to observe real classes in depth.

While arousing students' interest, I implicitly give them instructions on how to watch the video, and I inform them of its value. I would like you, the reader of this chapter, to follow the full text of the video's transcription, and to notice something valuable for all teachers, as my students did. In the transcription, "S" represents students, "T" represents Mr. Hiramatsu, "[ ]" signifies a subtitle within the transcription only, and "()" indicates comments of the author or a supplementary explanation. A broken line (-----) shows the beginning and end of a segment of the transcription.

Narration 1: Miniature bulbs light up when an electric current passes through them, and electric heaters become warm when an electric current passes through them. This is due to electric energy turning into light or heat energy. But does an electric current turn only into light and heat? It can turn into other things, too. For example, if you place a compass near an enameled wire through which an electric current passes, the needle of the compass will move. This is because a mysterious power is emitted from the enameled wire. What is this mysterious power that is emitted from an enameled wire connected to a battery? Let's take a look at it now.

T1: *We used dry cell batteries to turn on a miniature light bulb (while writing on the board). What have we learned so far? What did an electric current turn into when it passes through something? Yes, S1?*

S1: Light.

T2: *Right. It turns into light.*

T3: *Then it becomes warm, so it also turns into heat, doesn't it? It changes into light or heat*

[**Apart from Light and Heat**]

T4: *We have been using electricity, but are we using things that turn electricity into light only, or are there things other than light that we can find when we use electricity? Can electricity also create a magnet? Is there anything else electricity can turn into?*

T5: *This is a device that turns electricity into light. Of course, this has turned electricity into light and heat, because it is warm. There are also heaters that are used only for heat. What does this turn electricity into?*

S2: *H-e-a-t.*

T6: *It turns electricity into heat.*

S3: *I think…*

T7: *So it's not a miniature bulb but something else that you use to pass electricity through?*

S4: *If we pass an electric current through a motor, for example, its shaft will turn around, and if we attach something onto it, it creates power and…*

T8: *You mean electricity can turn into power? Raise your hands if you would agree.*

S5: *(Most students raise hands)*

T9: *Today, I have an enameled wire. The wire would produce power if we passed electricity through it. That's what I think. Raise your hand if you think that an enameled wire would produce power if we pass electricity through it*
Maybe we can't tell by looking at the wire alone. We might not be able to tell by looking at the wire alone, but we might see a surprising amount of power coming out if we use a device. Could we see it if we used a microscope?

T10: *What is this?*

S6: *A compass.*

T11: *Shall we pass electricity through this? What do you think would happen if we did?*

S7: *The needle would m-o-v-e.*

T12: *Raise your hand if you think it would move.*

S7a: *(almost all raise their hands)*

T12a: *Why would it move?*

S7b: *(most of them put their hands down)*

T12b: *It would not move by passing electricity through, would it?*

S8: *K said that when electricity is passed through, it will become a magnet, and if you use it, the needle will point north and south as the earth is like a magnet with the north and south poles and the compass will point in those directions. So, if you put something like a magnet on the top, the compass needle will also move.*

S9: *As my previous answer (it has been deleted by VHS editor), when electricity is passed through something, it will create a magnet-like object around it, and the needle of a compass will move because of it.*

T13: *But I wonder if it will move. There isn't an enameled wire directly attached to the compass?*

S10: *If you put a magnet close to a compass, the needle would spin around like crazy. This is the same kind of thing. It becomes an electromagnet and moves because it has magnetic lines of force.*

T14: *Let's apply an electric current to the enameled wire. Let's see what happens, now.*

S11: *OK.*

T15: *Let's do it again. I'll keep the electricity on. Watch carefully.*

T16: *It stops at a certain angle* (Photo 2).

T17: *Let me remove it now. When I disconnect it, it will return to the original position.*

T18: *Now, I'll give you about three minutes to write down in your notebook why you think the compass needle moves when electricity is applied. Write down the reason why the compass needle moves* (Photo 3).

T19: *The question is: Why does it move?*

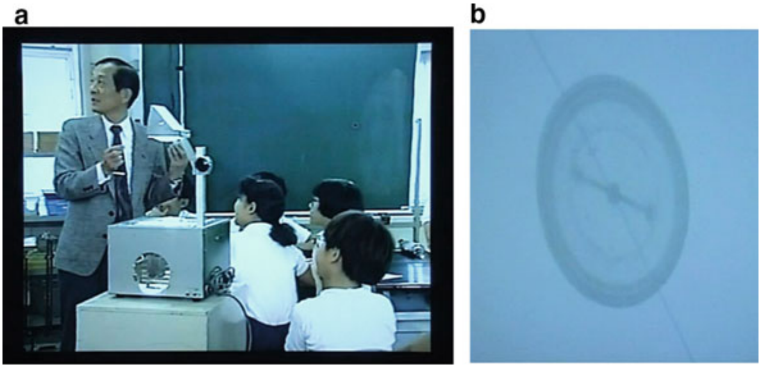


Photo 2 **a** Hiramatsu's Introduction, **b** What they saw

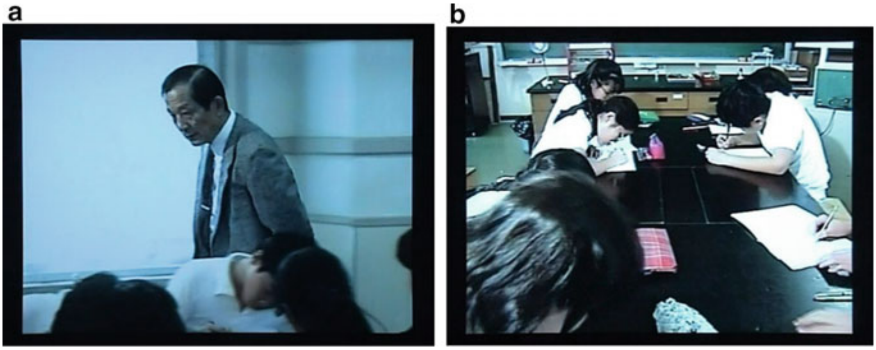


Photo 3 **a** Teacher passes by students' desks, **b** While students write their own thoughts

S12: *The compass beneath is a magnet and if a flow of electricity becomes a magnet, the compass needle was moved by the force of repulsion from electric magnet above it.*

T20: *A flow of electric current? What? You're saying electrical current might turn into a magnet?*

T21: *A magnet has a shape like this. It has a shape, and something strange comes out of it like this. And we call the invisible, strange power "magnetic force." A magnetic force might appear when electricity is applied. You think this magnetic force might affect the compass needle, do you?*

S13: *When electricity is passed through an enameled wire, it becomes a magnetic force. So I think the enameled wire turns the electric current into a magnetic force.*

T22: *The enameled wire turned into a magnetic force. You mean it is not the electric current that turned into a magnetic force?*

S14: *The electric current still turned into a magnetic force. The compass needle probably wouldn't move if we used ordinary iron instead of an enameled wire.*

T23: *I see. If we use an iron wire, the compass needle might not move.*

S15: *I've taken apart a motor. The wire is wound around in the motor, and when electricity passes through it, it repels and spins around. The spinning is the force of repulsion or attraction.*

T24: *Oh, you think the force that spins the shaft inside the motor might be the same as the force that moved this compass needle.*

T25: *This is why the compass needle spins. One is the "theory of a magnetic force." A magnetic force might be created. What do you think, S16?*

S16: *When an electric current passes through an enameled wire, it becomes an electromagnet, and since a magnet always has an N pole and an S pole, the needle of a compass also moves as its N pole and S pole also attract or repel.*

T26: *So you think an enameled wire becomes a magnet*

(An enameled wire seems to become a magnet when an electric current passes through it)

[**How Can We Prove That It Is the Magnetic Force?**]

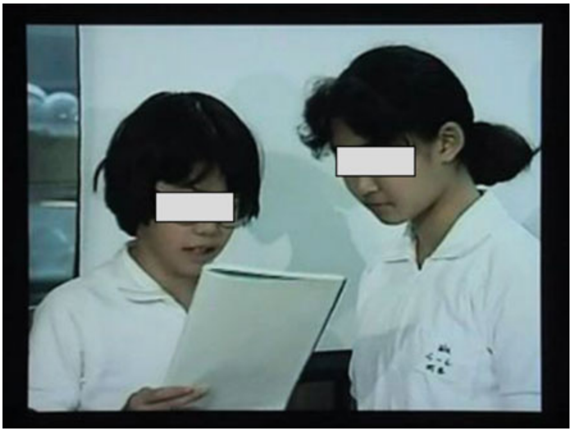
S17: *Why don't we spread out iron filings on a sheet of paper and then lie the cable on it? When the cable is electrified, we may see a line of iron filings. If we see the line, the same as the magnet, then we can say that is a magnetic force* (Photo 4).

S18: *When we put two magnets together, they repel or attract each other. Then it would be clear whether the cable and magnet repel or attract.*

S19: *If a metal clip is attracted to the electrified cable, then there is a magnetic force* (Photo 5).

Photo 4 Presenting their thoughts (For legal reasons, students' faces cannot be identifiable.)

Photo 5 Presenting their thoughts



T27: *Oh. When we put something like a clip on the cable and if it attracts the cable, then we can say it became a magnet. I see.*

S20: *Put a sheet of paper on the cable, spread out iron filings on it. If the iron filings move, there is a magnetic force* (Photo 6).

T28: *Spread iron filings on… the cable goes under the paper. Why does it go under?*

S21(S20): *Because. The cable… like a magnet lies under. If they move on…*

T29: *The cable goes… why do you put the cable under the paper?*

S22(S20): *Because if iron filings are attracted by the magnetic force and they are moved… It must be put under the paper. Otherwise, the iron filings stick on the cable.*

S23(S17): *It does not matter that iron filings stick on the cable. We can lay the cable directly on the paper* (Photo 7).

T30: *We are happy to see the iron filings stick on the cable.*

Photo 6 Figure drawn by student S20

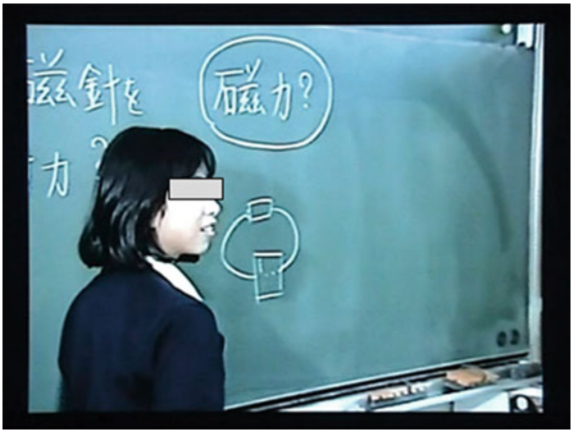


Photo 7 A little challenge by student S23

T31: *Is there another reason? Why did you try to put the cable under the paper?*

S24: *Normally, magnetic force is supposed to penetrate objects. She (S23) may want to do that* (Photo 8).

T32: *Who understands the meaning of what he (S24) said? Could you (S25) re-explain?*

S25: *The nature of magnetic force is to go through objects such as paper and to attract other objects such as iron filings. That's it.*

T33: *What is the magnetic force? It reaches through objects such as paper. That is why, we had better put the cable under the paper like that, if any iron filings are moved by the force through the paper, we can say:* "*Yes. This is the characteristic of magnetic force.*" *Oh, yes. That is why you (S20) put the cable underneath. There was a reason why you (S20) put the cable under the paper* (Photo 9).

Photo 8 (S24) defending (S23)'s remark

Photo 9 Hiramatsu (T33) organizes a student discussion

S26: *We can use a clip. Stretch it and rub it on the cable. If other clips are attracted by it, that is a magnetic force.*

T34: *When we rub a needle on a magnet, it attracts iron filings. You suggest to rub a needle on the cable. If the needle becomes magnetic… Oh, I See. We can say that the wondrous power out of the electrified cable is the magnetic force as expected*

Narration 2: Passing electric current through an enameled wire creates a mysterious force that moves the compass needle. What is this mysterious force? Considering the previous experiences, it is very similar to the characteristic of magnets that are created by permanent magnets. If it is a magnetic force, it should have properties as follows:

- It can go through things.
- When it is brought close to a permanent magnet, it will be attracted to or repel against the magnet.
- When a needle is brought close to an enameled wire, the needle will become a magnet.

If those characteristics are observed, we can call it a magnetic force.

This ends the first half of the video. I usually pause here, giving prospective teachers time to overview the flow of the lesson and to mark places on the transcript they found to be typical or interesting. How many parts did you mark? What have you identified in terms of teachers' basic skills, typical patterns of a science lesson, or interesting discussions? Did you find this video worthwhile for a teacher education course?

As Mr. Hiramatsu walked among the students (Photo 3), I also walk among my students. We call it Kikan-Shido 机間指導 (individual tutoring among students seated at their desks) or Kikan-Junshi机間巡視 (patrolling among the desks).

Teacher training textbooks usually mention that the purpose of Kikan-Shido is one-on-one tutoring. However, there is another important objective: to get information about which students have what questions or ideas, with which to plan out the order of nominating specific students in the following flow of the lesson. So, teacher is a director of the drama of class.

Here are common examples to be observed in university students' answers:

- Students are quite smart. They discussed beautifully, with Mr. Hiramatsu's ingenious leading.
- Typically, from S20 to T33, Mr. Hiramatsu nominates a specific student, asking in-depth questions.
- At the beginning, Mr. Hiramatsu adopted the method of showing concrete objects.

I always expect to see new discoveries by prospective teachers while I walk among them. Though there are more points I can indicate in addition to the items above, I will mention them in the later discussion. Let us see what happens in the second half, where you will encounter a super teacher Meister.

T35: *Ok, let's properly check each of the ways we've thought bit by bit so far.*

T36: *Let's try a plate, shall we? Will it go through a plate? If the mysterious force coming out of an enameled wire is a magnetic force, it will go through even a metal plate*

[**Examination of The Evidence That It Is A Magnetic Force**]

T37: *For example, today I have brought a plate here. It's not paper. It might be easy if we use paper, but do you know what kind of plate this is?*

S27: *Silver?*

T38: *Ha ha. We can't use silver. It's brass. A metal called brass.*

T39: *Let's do it with an ordinary magnet, first. Let's use a magnet to see whether a magnetic force can go through this plate.*

T40: *Here it is. Ready? There you go. The iron filings don't fall, either. It is sand that is falling now. It's not attracted because it's sand. Sand falls off neatly, leaving iron sand behind. This is how it can go through. So, if what is coming from the enameled wire is a magnetic force, this iron sand also should have some effect*

But we can't expect it to be like this because the force is very weak. We can say that it has a magnetic force if we electrified enameled wire and it moved even a grain or two of sand iron even a little. Let's try it with a metal plate. Like that, as S20 proposed, let's do it like that.

If iron sand didn't work, there was another tool that would move with less power. What is it? Hmm?

S28: (…)

T41: *We can use a compass. It moves because it senses even a very weak magnetic force. Do you get it? I'll give you iron sand and a compass, so please bring the dry cell batteries and the enameled wire to check it properly.*

T42: *The way you're spreading the sand is not nice. You are scattering it casually. I've made a film case for you so make sure to spread it out neatly like this. Run it like this for a while and tap the plate lightly. It won't come out if you don't tap.*

S29: *Wow, amazing!*

T43: *Look, you can see the lines. It's become similar to the magnetic field lines of a magnet.*

S30: *The enameled wire moves in the same direction when we move the magnet.*

T44: *How about you, TS(T31)?*

S31: *When I move the magnet closer to the enameled wire, it moved away from the magnet or stuck to it.*

T45: *When we keep the magnet close to the enameled wire and turn electric current on and off, the enameled wire swings. The swing must be caused by the repulsion or attraction between this magnetic force and that magnetic force. We should now be able to say that the mysterious force that moved the compass needle is a magnetic force that has been generated. Is everyone happy with that? Raise your hand if you agree.*

S32: *(most students raised their hands)*

How to Collect the Magnetic Power from a Cable

T46: *We have disclosed that magnetic power comes out of every part of the cable (This scene was omitted in the original VHS video). Then if I made a spaghetti with the cable, like this* (Photo 10).

S33: *Oh! What are you doing?*

T47: *We can make a good collection of magnetic power here, can't we?*

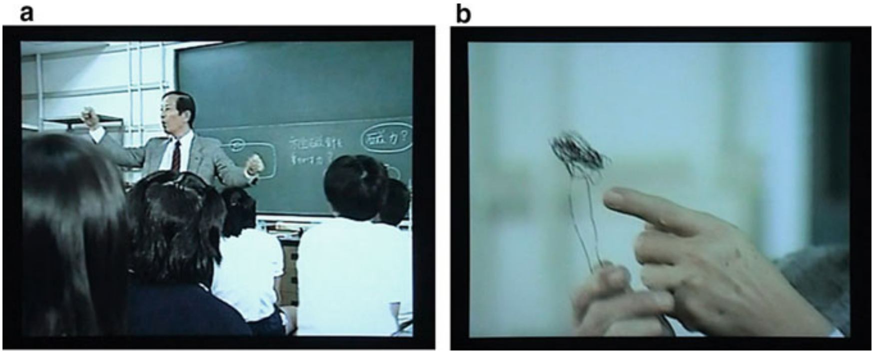


Photo 10 **a** Hiramatsu challenges students, **b** Hiramatsu (T24) showing spaghetti shaped wire

S34: *Well, no. In our experiment, when we put green cable on the plus, they attracted each other. And on the red they repelled. So we thought there is a rule in it. Ah, we will get into trouble with a muddled cable* (Photos 11).

T48: *OK. Then how about this? This shape I made is very much more organized. Electricity goes up and down very regularly. Don't you like this? Isn't it nice for collecting magnetic power?* (Photo 12)

S35 *Electricity flows in a regular rule. Going up and going down are opposites. It cannot make a compass move* (Photo 13).

(Mr. Hiramatsu proposes three pathways of the enameled wire (Photo 14) in order to offer concrete examples to help students think of a good explanation)

T48b: *How many understand what he said? Could you explain it again to all, please?*

Photo 11 (S34)'s response to Hiramatsu's challenge

Photo 12 Another challenge by Hiramatsu (T48)

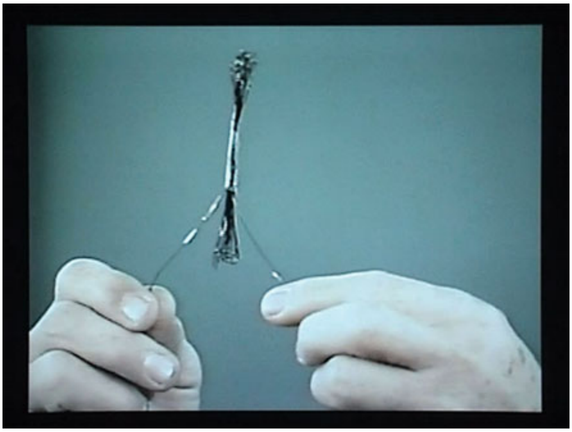


Photo 13 (S35)'s response to Hiramatsu's second challenge

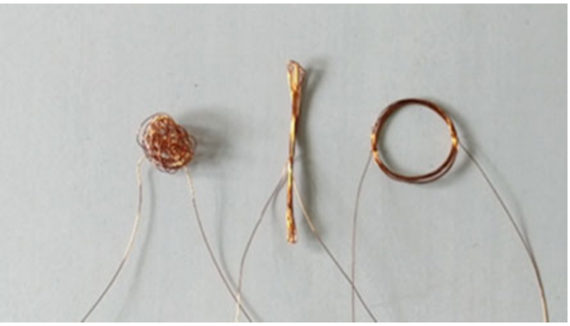


Photo 14 Three pathways for electricity to take

S36(S35, S15): *Magnet power comes… It goes around in a certain direction. By winding the cable in the same way in a circle, the power is strengthened twice, three times and so on.*

T49: *Oh, so we had better wind them in the same direction*

Checking the Lines of Magnetic Force

T50: *I am using a film case covered by gauze to spread the iron filings* (Photo 15a). *Beautiful isn't it?*

T51: *First, why don't we check with a normal magnet. All right!* (Photo 15b).

T52: *Yes. Though, those lines are invisible, magnetic power goes out of the magnet all around it*
Now let's check the spaghetti cable. If there is magnetic power collected, we can see the lines of the iron filings.

T53: *With one battery. OK? Watch!*

T54: *Off. On. Nothing happened. Tap it. Nothing* (Photo 16).

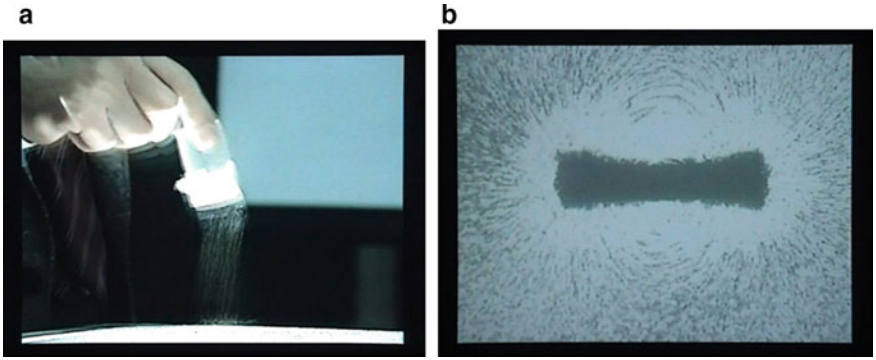


Photo 15 **a** Sprinkling iron filings over an overhead sheet, **b** Result with an iron magnet

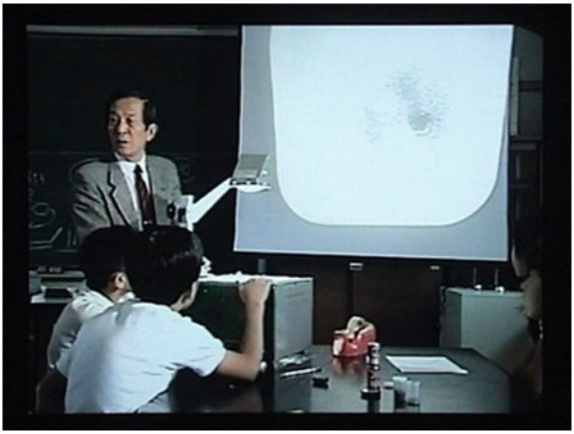


Photo 16 Testing the spaghetti shaped enameled wire

T55: *Can we see anything in this next step (showing the bundled cable the teacher made)? No we don't. Stop. How about this (showing the wound-up cable or coil)? Did you see something move? Did you notice that the iron filings moved? (Student S36 watched closely at the moment when his prediction was proved to be correct)* (Photo 17)

T56: *I double the battery next. Now two batteries.*

S37 *What are you trying to do? You are putting plus with plus.*

T57: *Oh, thank you for your good advice, Sato*
Can you check whether the magnetic power comes out? The bundled cable is not satisfied yet. Better to wind them to collect the power.

(Mr. Hiramatsu passes around the wound-up cable for students to observe carefully)

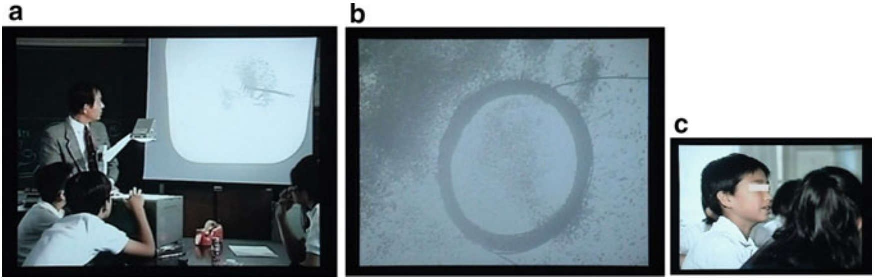


Photo 17 **a** Watching the bundled shaped wire, **b** Seeing the iron filings move, **c** Observing intently

T58: *I pass you the round cables then. What happens if you put a magnet inside it? We have done the experiment with one cable but now we have… Put the magnet close to the winded hanging cable. Do the iron filings move? How about the compass? We might see its attraction this time. You can test whatever you like, I give you ten minutes.*

S37b: *Yes!* (Photo 18)

S38: *Oh, that's beautiful!*

S39: *Stop it.*

S40: *Why?*

S41: *The magnetic field lines were stronger when we bundled the wires together rather than using a single one of them.*

S42: *When the teacher did it with this magnet for the first time, the iron sand went like this both inside and outside. But when a coil was used, only one line of iron sand was formed even though the wires are bundled.*

S43: *Only a little bit of iron sand stuck to the wire when we used it as a single wire, but when it was rounded, a lot of iron sand stuck to it and it moved properly.*

Photo 18 An experiment to check the lines of magnetic force

S44: *So, if we use this, the iron sand will stick. If we do it the other way…*
T59: *Anyone who has noticed it, stand up and show it to everyone. Even if we do the same experiment, some can make a good discovery and others can't… G, that's amazing. This group is excellent. If the electrical current goes that way, the iron sand moves away. If you reverse…*
S45: *Electricity has stopped flowing*

What Happens if an Iron Nail is Placed in Enameled Round Wires where a Magnetic Force is Accumulated?

T60: *What will happen if we put a nail in here and let an electric current pass through the coil?*
S46: *It will move away even when it repels.*
S47: *A magnetic force is accumulated at the center of the round coil, so if the iron is put in the center where there's a strong magnet, the iron will become a magnet.*
S48: *When we put it inside the ring, it will become a magnet, if it goes past the line of a magnetic force without touching the coil, like we saw in the OHP*

[Experimental Demonstration]

T61: *It would be meaningless if this nail was a magnet. OK, so let's make sure first that it's an ordinary nail.*
S49: *Hahahaha.*
T62: *But this is all right. We have to check first how week the nail's magnetism is. OK, then? Let's put it in the coil.*
T62a: *I've put it in properly. I'm not doing anything. Even if it doesn't touch the wire, iron sand sticks so well.*
T63: *Now turn off the electricity.*
S50: *Oh! (Iron sands dropped off from the nail.)*
T64: *So, when we gather a lot of magnetic force with a coil and put the iron in the coil, what will the magnetic force turn the iron into?*
S51: *A magnet.*
T65: *What do we call this? Everyone. This is the most important principle that we are studying. What is it? What principle is it? A permanent magnet?*
S52: *An electromagnet!*
T66: *Oh, this is* the *electromagnet. When electricity is turned on, a magnetic force is generated and iron is magnetized by the magnetic force. It's called "magnetization." Iron is magnetized and becomes a magnet.* This *is the electromagnet.*
T67: *If this is the case, it is no good if the nail is hanging out. It's boring of the waste space here between. If we make it, wind the wire closer to the iron, the magnetic force will be more concentrated. We can make a stronger magnet. Let's make an electromagnet next lesson. That's all for today*

Narration 3: There are several scenes of problem-solving in this transcription. The most important one that when an electric current passes through an enameled wire, an invisible mysterious force comes out of it. During the process of problem-solving, the teacher did not tell the children that the mysterious power is "a magnetic force," but let the children use all their knowledge and experience that they've acquired so far to make predictions and to identify the mysterious force through experiments based on those predictions. Lastly, let the children discover by themselves that the true nature of this force seems to be the same as the magnetic force generated from a permanent magnet. By cherishing this process of guided discovery, we can let the children acquire problem-solving skills, which are the most valuable thing in science classes.

For my prospective teachers, I give them another five minutes for to look over the second half of the video transcription. Some admire the wonderful practices, but some get stuck without being able to follow the lesson. The most important scene in the second half was the teacher's challenge and students' response. Before proceeding to the commentary below, I recommend that you, the reader, make a list of what you have discovered from your engagement with the transcription.

3 Based on the Transcription

Significant points about Mr. Hiramatsu's practice are described here, beginning with what my university students often highlight on their transcription; followed by my own thoughts.

1. *In general, students thought well and replied very well. They are so bright. For example, the replies of S34 and S35 show how bright they are. There was a child who had even disassembled the motor (S15).*

Although they are elementary school students, the sixth-grade class that has been trained for years can become very mature. There seems to be an implicit common awareness among students that they are supposed to find rules in the science lesson. This is a shared awareness among the members of the class because it is mentioned by everyone, not just among specific students.

2. *Mr. Hiramatsu asked a girl and made students discuss persistently (S20-T33).*

Here, Mr. Hiramatsu leads students expertly to notice one aspect of the nature of the magnetic force that penetrates through things. Mr. Hiramatsu, believing in students, has waited patiently for students' own words, such as "[the power] penetrate[s] objects (S24)" or "[the power] goes through objects (S25)," without giving the adequate representation immediately.

The Elementary School is aligned with the University of Tsukuba. It is the oldest elementary school in Japan, and currently, it is one of the best schools. For this reason, some teachers claim, “This kind of teaching/learning can only be implemented at this school. There is nothing I could learn from their practice.”

Introducing such a comment to my students, I additionally say to them how important it is for our profession to develop classes that achieve the high quality of the children’s responses found in the video, no matter who the children are in our classrooms. It took all related teachers at the school to ensure the children’s competency during their 6 years at the school. You young teachers also need to embrace their ideal image of science education.

I continue by saying, “If you have not felt anything special in the video, it means that you had received science education from a very talented teacher.” This is exactly what the quote of Wittgenstein points out at the beginning of this chapter. Many of my students smile back.

Next, I get them to focus on the phenomena that are taken for granted.

Considering the section of the video tape from T46 to T49, I must introduce the concept of “devil’s advocate” or ゆさぶり (yusaburi), which literally means “shaking” in Japanese. Mr. Hiramatsu enhanced students’ thinking with well-organized tools and questions. He had estimated his students’ ability beforehand and prepared three different types of enameled wire of spaghetti, bundle, and coil. The handmade tools are not meant to disrupt students’ perceptions, but to deepen their thoughts (devil’s advocate). They were organized logically and helped students to discover the nature of the coil whose shape needs to be rounded. I ask my students to imagine what Mr. Hiramatsu contemplated the night before the class, while preparing the three types of wires. “Yuzuru may reply. No, Naomi may get the point.” Then, what did he say when a student got the right idea? Mr. Hiramatsu might want to praise the student, stroking the child’s hair, “Excellent idea! Good job!” Without praising any student, however, what did he say? “How many understand what he said? Could you explain it again to all, please? (T48b).” Mr. Hiramatsu did not jump on the student’s talk, rather he tried to share the student’s idea to all of the class. In the proverb among teachers in Japan, it is said, “Teacher’s job is not teaching but waiting.” I learned this during my student teacher training about 30 years ago. Also, his practice reminds us of the famous proverb of Ellen Key, the Swedish educator who wrote *The Century of the Child*. She stated that “the great secret of education lies hidden in the maxim, ‘do not educate’” (Key, 1909, pp. 109). Most of my university students recognize the way of being a teacher, learning from the practice of Mr. Hiramatsu.

3. *The talented teacher does not teach but tries to leave the most delicious part to the students.*

Once, I mentioned as follows in an article (Otsuji, 2006):

> The teacher does not teach. They drive the lesson by findings, as if the students have discovered them by themselves. Leave the most delicious part to the students. (Omitted) What is important for teachers is waiting, and keeping the classroom atmosphere where students feel free to say anything related. Teachers don’t think about what to teach, but what not to teach. (p. 25)

What if a teacher jumps to a student’s correct answer immediately? The lesson seems to make progress as planned. However, there are students who have not yet reached that stage. They are deprived of their thinking time and left behind. If a teacher determines that an answer is correct, students take a break from continuing thinking, stopping the inquiring process. It means that the pleasure of inquiring will be taken away by the teacher.

4. *To enhance the students' thinking, the teacher uses a few levels of the devil's advocate.*

He sometimes gave students a wrong answer on purpose to enhance their thinking, such as "Microscope?" (T9), when he asked them to think about the way to see the mysterious force which was emitted from the enameled wire. Or "A permanent magnet?" (T65). This is to get the word "electromagnet" out of students, labeling the concept. Those are the lower level. Devil's advocate, "yusaburi," is not just a quick word to deepen their thinking. Preparing for three types of the enameled wire can be ranked as the highest yusaburi. Believing in children, expecting deeper understanding and debate among children, he had carefully prepared the educational materials, taking for a long time in advance.

5. *Careful preparation.*

For school teachers, it was obvious that Mr. Hiramatsu chose the right diameter of the enamel wire, adjusted its length, and considered the number of winding of the coil, in his preparation. If made a different choice, the batteries would generate heat, and the experiment will not be able to withstand two batteries. The bundle and the coil shown in Photo 14 were made with 0.4 mm diameter and 1.5-meter length enameled wire.

6. *Some words are easily understandable by children*, such as "even a grain or two (T40)" or "I'll give you 3 (10) min (T18, T58)."

We do not use such words in daily conversation among adults, do we? Those are the general codes of behavior in the science classroom. University students nowadays visit the attached school often. When they visit elementary schools and observe classes, such sense and lens will be useful.

7. *Even though those students seem to be smart at first (e.g., they mentioned electromagnetism at the beginning of the introduction stage), it is clear that they did not yet understand the nature of the electromagnets at that stage (S10, S16).*

When Mr. Hiramatsu realized they had immature knowledge, he did not take up their remarks. He even ignored them (S10, S16) because the remarks' content would be learned later on.

8. *However, he sometimes talks in a scientifically correct way.*

In T16, he described the motion of the compass, "It stops at a certain angle." No Grade 6 child would express the phenomena in this way. And after the long discussion

I mentioned before (S20-S25), he (T33) summarized the ideas in the scientifically right way.

Since this VHS teacher training video is commercially available, many people can share, learn from, and discuss it. This is why I submitted the whole transcript in Japanese as a research report (Otsuji, 2007).

Did you notice anything different from what I mentioned above? I have been using this video for many years, not only in Ibaraki University but also in other universities where I worked as a part-time instructor. I have watched this video so frequently that I have almost memorized most of it. Nevertheless, there was a new discovery recently.

9. *It is said that children should conduct an experiment after recognizing its necessity, particularly in problem-solving activities.*

It is not very meaningful unless a teacher pushes children to that level. Certainly, the experiments by Mr. Hiramatsu were conducted along with the child's inquiry. However, some of the experiments were started, not from children's ideas, but from adults' ideas. Did you notice them? I can point out at least three instances:

a. In the experiment, to see if the mysterious force could penetrate the brass plate, he took out an ordinary magnet and checked if the magnetic force could penetrate the plate. (T39)
b. When they tried to watch the magnetic field lines on the OHP (Overhead Projector), he started with the ordinary magnet instead of the enameled wire that was the focus of the discussion. (T51)
c. When inserting an iron nail into the coil, before the current was applied, he checked the weakness of the magnetic force of the nail. (T61)

There is a pattern here. After letting students recognize the prerequisite idea or assumption, or after giving an evaluation viewpoint, he started conducting experiments. These do not emerge from children's ideas. About 10 years of using this video, I finally noticed his way of teaching. I started to point it out to my prospective teachers. "If you get into the habit of starting an experiment like this, your students will be really good at experimenting. When you attend your educational practice in schools, carry out experiments. In addition to giving safety guidelines, introduce the experiment to your students by giving them assumptions or evaluation perspectives like Mr. Hiramatsu did. Your supervisors will certainly praise you." Again, my students smiled back.

I also found two more facts in the video this time. When I assembled the models of Photo 14, I noticed that Mr. Hiramatsu had consumed relatively longer enameled wire to make them. A length of 1.5 meters is not enough. Then I asked him how long was the enameled wire he used. He replied he used at least three meters for each coil he gave his students. There were 40 students in the class and a coil was given to two students. It means he prepared 20 coils using 60 meters of enameled wire totally. A teacher is also responsible for props.

Another finding is the iron sand used in the video. Normally, river and sea sand iron are not used to show the magnetic field lines. Eager young teachers take a magnet to rivers and coasts, but they do not show the magnetic field lines well. In the natural world, iron sand is worn and rounded, and if you put them in a magnetic field, they only turn around and do not be connected in lines. Veteran teachers, who know the property, purchase non-pulverized pointy iron powder from a vendor. Mr. Hiramatsu knows this and should have used iron powder when he sprinkled the iron particles from the film case through gauze. However, when the brass plate was introduced to the child, he said, "It is sand that is falling now. (T40)." Did he choose iron sand and iron powder for cases? If so, what was his intention? His intention may have been to make the children aware of something.

It has been said that Japanese science education is succeeding at a high level. I believe this video is a good example of why it maintains the quality it has. Teachers watch the children's growth from various aspects. Sometimes, they do not take up students' ideas. Sometimes, they even ignore students' ideas. And sometimes, they play the devil's advocate by conducting classes in a self-sacrificing way. To do so indicates that the teacher believes in the children proficiency to respond correctly. Enthusiastic students respond faithfully to the teacher's subtle agenda. It reminds me of a Chinese proverb 啐啄同時 (Sottaku Douji), "simultaneous pecking in and pecking out (of a bird and its chick);" in other words, "the perfect balance of action and reaction." This is indeed an artful drama occurring in the classroom.

4 Beyond the Transcription

When I realized that what I had learned in my practicum as a student-teacher was included in this video, I contacted Mr. Hiramatsu to get permission to publish the transcription I had developed. At that time, I thought it was worthwhile to publish the transcription. I remember the first phone call turned out to be 40 min long. Since then, our collaboration has continued. Coincidentally, Mr. Hiramatsu and I graduated from the same institution, the College of Education, Chiba University. After teaching at Chiba University demonstration school, he moved to the school associated with University of Tsukuba.

I became interested in our common intellectual roots. The elementary school associated with Chiba University was the school where a person named Tezuka Kishiei 手塚岸衛 played an active part in the Taisho liberal education era (1920 s–1930 s) when child-centered education flourished for a time. The child-centered genealogy can be traced back to Hideo Takamine 高嶺秀夫 in the 1870 s. He learned the Pestalozzian method of teaching in Oswego, USA, where the method thrived at that time, and he introduced it throughout Japan. He is known as the father of a normal school (Ogawa, 1998). His teacher in the United States, Edward Austin Sheldon, summarized the main points as follows (Sheldon, 1862, pp. 14–15):

1. *Activity is a law of childhood. Accustom the child to do—educate the hand.*
2. *Cultivate the faculties in their natural order—first from the mind, then furnish it.*

3. *Begin with the senses, and never tell a child what he can discover for himself.*
4. *Reduce every subject to its elements—one difficulty at a time is enough for a child.*
5. *Proceed step by step. Be thorough. The measure of information is not what the teacher can give, but what the child can receive.*
6. *Let every lesson have a point; either immediate or remote.*
7. *Develop the idea, then give the term—cultivate language.*
8. *Proceed from the known to the unknown, from the particular to the general, from the concrete to the abstract, and from the simple to the more difficult.*
9. *First synthesize, then analyze—not the order of the subject, but the order of nature.*

As readers may notice, Sheldon mentions some ideas that we associate with Comenius (item 8), Pestalozzi advocated (items 1, 2, 7), and John Dewey (items 2, 3, 5). Some of Sheldon's ideas appear in Mr. Hiramatsu's practice, as well. Even though the student-centered way of education in Japan was interrupted by World War II, the flow was inherited, from my point of view, from a few university demonstration elementary schools. Chiba University is one of them. This discovery was an unexpected coincidence, but I was excited to find the origin of my teaching sense that I derived from my teaching practice in the past.

Mr. Hiramatsu talked about why he developed the lesson. He said there was a survey of junior high school students on their understanding of electromagnets. It revealed that 76% of junior high school students agreed that a fake coil, made with wire which had its cover coating scraped off, had a stronger magnetic force. He realized that the essential understanding of electromagnets among students was missing, so he developed the lesson that started with a single enameled wire. This is why he also improved the relevant description of the 1989 Course of Study as one of the committee members. However, he lamented that his thoughtful expression was immediately replaced by the previous one in the next 1998 revision.

5 Closing

Once, while Mr. Hiramatsu and I were chatting at a table, Prof. Kinya Shimizu of Hiroshima University came and spoke to us. "Are you the teacher from the video?" Prof. Shimizu has worked in science education internationally, mainly in developing countries. He told us that he has been using the video as a good example of science teaching in Japan. Since then, we have been sharing the transcript, and I was glad to know that other science education researchers also use the video.

In a local city, Toyama, there is a legendary elementary school science teacher who raised a Nobel Prize winner. That is Mr. Kyojo Sawagaki, a retired superintendent of Kamiichi City. When Mr. Sawagaki was young, he stayed in Tokyo and attended the demonstration elementary school University of Tsukuba, working hard with Mr. Hiramatsu, to brush up their teaching. In other words, the child-centered way of problem-solving in Japan can be said to be an educational method that has also nurtured a Nobel laureate. I prefer to leave the detailed research to a GATE (gifted and talented education) specialist.

As I mentioned at the beginning of this chapter, I ask my prospective teachers to be conscious of their experience in the past and observe current teachings in front of them. Similarly, our generation is responsible for (a) the succession to the next generation of a quality science education, and (b) for its spread to neighboring countries that need to be more aware of the way Japanese science education has been developed, implemented, and supported by its practitioners.

In addition to following the analytical or historical approaches of the Western research style, it would be better for us to adopt mind manipulation process; thereby approaching the drama (i.e., the phenomenon of teaching) from the inside and outside, which reveals its essence of ordinary unconsciousness.

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An Alternative Interpretation of Preservice Science Teachers' Views of Science

Kazumasa Takahashi

Abstract Previous international science education research has explored preservice teachers' views of both science and science and technology. In Japan, science education research has mainly focused on preservice teachers' views of science. Research, both international and Japanese, into views of science have tended to explore the topic from a Western perspective. Based on a review of existing literature, this chapter presents an alternative theoretical framework for the investigation of Japanese preservice science teachers' views of science and technology. The framework emphasizes the possibility that Japanese preservice teachers' views of science and technology differ from those of their Western counterparts. Therefore, the framework takes account of embracing multiple culturally embedded forms of science and technology. A sample of 75 Japanese preservice science teachers responded to a questionnaire survey in 2016 and 2017. Participants were asked to provide written descriptions of their perceptions of science and technology, which were then analyzed using quantitative content analysis. Based on these findings, this chapter proposes a possible interpretation of Japanese participants' views on science.

1 Introduction

A vast body of science education research has investigated preservice teachers' understanding of the nature of science (Lederman, 2007; Lederman and Lederman, 2014). Some studies focused on views of the nature of not only science but also technology (e.g., Tairab, 2001). Although these studies have looked at both Western[1] and non-Western preservice teachers, none have adequately reviewed the views of Japanese preservice teachers. In this chapter, the author did not distinguish precisely among views of science, views of the nature of science, conceptions of science, conceptions

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[1] According to Kawasaki (1996), Western countries include the United States, Canada, and the countries of Western and Southern Europe.

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of the nature of science, understanding of the nature of science, and others. All of them were characterized broadly as what the participants think about science. The same applies to the case of technology.

This chapter begins with a compellation of previous international and Japanese science education research, which has, for the most part, explored preservice teachers' views of both science, and science and technology. Next, a case study of the science and technology views of Japanese preservice science teachers is presented, offering an alternative theoretical framework for the investigation of Japanese subjects. In this chapter, the author explored and illustrated Japanese participants' views of science and technology from an alternative perspective that admits multiple views of science and technology, alongside Western views, on an equal footing. Kawasaki's (1996) framework serves as a lens to interpret Japanese participants' views of science.

This is an exploratory case study. The author recognizes that further refinements are necessary. For example, an increase in the number of participants would enable a broader database to improve the power of the study, as would adding question items and revising the existing ones. Moreover, the interpretation of participants' views of technology remains to be seen.

2 Previous International Science Education Research on the Views of Science and Technology

Preservice teachers' views of science have long been of interest to scholars of international science education. Investigations of their views of science have been conducted in Australia (Murcia and Schibeci, 1999),[2] China (Wan et al., 2018), Malaysia (Fah and Hoon, 2011), Singapore (Thye and Kwen. 2004), Taiwan (Liu and Lederman, 2007), and the United States (US) (Abell and Smith, 1994; Carey and Stauss, 1968; Cobern and Loving, 2002; Liang et al., 2008). Haidar (1999) investigated preservice and in-service teachers' views on the nature of science (NOS) in the United Arab Emirates. A few cross-cultural studies of preservice teachers' views have also been performed. Cobern (1989) investigated Nigerian and the US preservice teachers. Liang et al. (2009) compared views of the nature of scientific knowledge among preservice teachers in the US, China, and Turkey. Park and Lee (2009) explored preservice teachers' conceptions of NOS in the US and Korea.

Various types of instruments were used in the aforementioned research. For example, the Thinking about Science survey instrument; the Student Understanding of Science and Scientific Inquiry (SUSSI); the Views of the Nature of Science Questionnaire-Form C (VNOS-C); the Nature of Science Questionnaire (NOSQ); and the Nature of Science Scale (NOSS) were used for views of science. The Thinking about Science survey instrument developed by Cobern and Loving (2002)

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[2] Murcia and Schibeci's (1999) explanation of education in Western Australia suggests that it was conducted in Australia.

reflected the public image of science, constructed of nine categories: Epistemology; Science and the Economy; Science and the Environment; Public Regulation of Science; Science and Public Health; Science and Religion; Science and Aesthetics; Science, Race, and Gender; and Science for All. The SUSSI, which was developed by Liang et al. (2008), targets six NOS themes, reflecting national and international science education documents such as the American Association for the Advancement of Science (1993) and previous NOS instrument research. The six themes were observations and inferences, tentativeness, scientific theories and laws, social and cultural embeddedness, creativity and imagination, and scientific methods (Liang et al., 2008). The VNOS-C was based on the following NOS aspects: the empirical nature of scientific knowledge; observation, inference, and theoretical entities in science; scientific theories and laws; the creative and imaginative nature of scientific knowledge; the theory-laden nature of scientific knowledge; the social and cultural embeddedness of scientific knowledge; the myth of the scientific method; and the tentative nature of scientific knowledge (Lederman et al., 2002). The NOSQ, developed by Liu and Lederman (2007), comprised seven items taken from the VNOS-C and one additional item. The NOSS, developed by Kimball (1967), was founded on eight declarations, which were referred from philosophers of science, such as Conant, Bronowski, Killian, Nagel, Holton, Bridgman, Schwab, and Whitehead (Kimball, 1967).

Some studies did not employ readymade instruments. For instance, Abell and Smith (1994) analyzed participants' written responses to general questions concerning the meaning of science. Wan et al. (2018) interviewed participants about eight topics corresponding to five aspects of NOS: scientific knowledge; scientific evidence; experimentation; scientific process and methodology; and communication in scientific research. The participants' responses were classified into three categories: classical, contemporary, and alternative views. Descriptions of the classical and contemporary views were drawn from previous research and the US science curriculum documents.

Other studies have considered not only preservice teachers but also in-service teachers as research subjects in the investigation of participants' views of science and technology. Some of them investigated into the manner in which preservice teachers view science and technology in New Zealand (Heap and France, 2013), Turkey (Yalvac et al., 2007), and the UK (Botton and Brown, 1998). Others explored both preservice and in-service teachers in Brunei (Tairab, 2001) and presumably in the US (Rubba and Harkness, 1993).[3]

As is the case with the investigation of the views of science, various types of instruments were used in the aforementioned research. For instance, the Teachers' Belief about Science-Technology-Society (TBA-STS); the Views on Science-Technology-Society (VOSTS); and the Nature of Science and Technology Questionnaire (NSTQ) were employed. The TBA-STS was developed by Rubba and Harkness (1993). The VOSTS instrument (Aikenhead and Ryan, 1992; Aikenhead et al., 1989) was tested

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[3] Considering their instrument development process, this study is assumed to be carried out in the US.

by Botton and Brown (1998) and employed by Yalvac et al. (2007). The VOSTS items were developed to reflect the viewpoints of Canadian high school students (Aikenhead and Ryan, 1992). The NSTQ, comprising modified VOSTS items, was developed and used by Tairab (2001).

Instead of using readymade instruments, Heap and France (2013) required participants to describe two aspects each of NOS and the nature of technology from their course material, present concrete examples, and explain why these examples successfully illustrated each aspect.

Preservice teachers' views of both science and science and technology have long been investigated with various instruments, such as multiple-choice-type and free-description-type questionnaires. These studies were conducted not only in Western countries but also in non-Western countries. Even though non-Western preservice teachers continued to be research subjects in the international science education community, the Japanese have been left out.

3 Japanese Science Education Research on the Views of Science and Technology

A few studies have focused on the current status of Japanese preservice teachers' views of science. Kadoya (1990) modified the Nature of Scientific Knowledge Scale (NSKS), originally developed by Rubba and Andersen (1978), and tested its validity. He administered the revised NSKS to participants predominantly comprising preservice teachers. Kadoya's (1990) revised NSKS was adopted by Saruta (2016), who surveyed the views of preservice elementary teachers and university students. Toda (1992) conducted a questionnaire survey to investigate preservice science teachers' views of science and the relation between their views and their selection of science teaching methods, using an instrument he developed, based on a Western philosophy of science. Tsuzuki and colleagues (2013) implemented a university class on NOS, as part of a secondary science teacher teaching methodologies course, and investigated how preservice science teachers' views on science changed after taking the class. A total of 18 items presented by the University of California Museum of Paleontology (2012) were used for a classroom discussion about NOS and data collection.

Tanzawa and colleagues (2003) conducted wide-scale research into the characteristics of Japanese views of science and technology and how the views of high school science teachers related to students' views. A questionnaire survey, which referred to previous Western European research, was conducted with approximately 1,500 subjects, including high school students, university students majoring in education, middle and high school science teachers, and general citizens.

Using the text mining method, Kawakami, Koshiro, and Sakata (2007) investigated Japanese university students' views of science and nature. Participants were asked to write about their image of science and nature, and high-frequency words and clusters were extracted from these free descriptions. Kawakami et al. (2007)

presented a conference paper without including the theoretical framework, the specific analysis method, and the results of participants' views of nature. Later, the same authors (Kawakami et al., 2008, 2009) developed and revised a scale to measure university students' views of science and nature on the basis of these free descriptions, resulting in six factors. One of these factors is "future-promising science" (Kawakami et al., 2009, p. 69), which embodies the practical value of science. This series of studies is notable for its attempt to draw Japanese views of science from the participants' viewpoint rather than to apply a framework pre-established by researchers or a readymade instrument reflecting researchers' views.[4]

In the case of domestic research in Japan, the major research approach was to borrow the NOS lens made in Western countries.

4 Theoretical Framework

It is clear that Western scientific perspectives were highlighted in each domestic case except for Kawakami and colleagues' series of studies. In other words, each of these research projects attempted to clarify Japanese participants' views of science within the Western science framework reflecting how Westerners view science. However, Western science is not the only form of science. Two Japanese science education researchers (Kawasaki, 1996; Ogawa, 1995) have provided alternative science frameworks.

Ogawa (1995) proposed "science education in a multiscience perspective," suggesting three different types of science: "indigenous science," "personal science," and "Western modern science." He described "indigenous science" as "a culture-dependent collective rational perceiving of reality" (Ogawa, 1995, p. 588); "personal science" as "a rational perceiving of reality, which is unique to each individual" (Ogawa, 1995, p. 588); and "Western modern science" as "a collective rational perceiving of reality, which is shared and authorized by the scientific community" (Ogawa, 1995, p. 589).

From this pluralistic perspective and based on structural linguistics, Kawasaki (1996, p. 2) argued: "The Japanese view of science is entirely different from that of the West because the social and historical situations relating to science in Japan are different from those of the West." He distinguished between three entities: "Western ethnoscience (W-science)," "Japanese science," and "Japanized W-science." He defined "W-science" as follows:

> Science treats a set of scientific realities. The set of scientific realities is nothing but what the scientific viewpoint has created. The set originates from the articulation valid for SAE [Standard Average European] languages only. Only in these languages the name 'science' is given to an investigation of the set of realities and also to the system of knowledge obtained as

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[4] A similar approach to instrument construction was employed in Aikenhead and Ryan (1992). They attempted to produce an instrument that reflects the viewpoints of Canadian high school students in their instrument.

> result of the investigation. Similarly to SAE languages, a non-SAE language also constitutes a set of realitics [sic] and the set originates from its own way of articulation.… In order to be impartial, in the treatment of cross-cultural phenomena, science should be called Western ethnoscience from the Japanese perspective. (p. 9)

While "W-science" is derived from what Westerners associate with nature, "Japanese science" is derived from what Japanese associate with *Shizen (自然)* (Kawasaki, 1996). *Shizen* is the Japanese translation of the term "nature." Kawasaki pointed out that what Japanese people associate with the term *Shizen* differs from what Westerners do with the term "nature." In recognizing the purely scientific and technological aspects of "W-science," Kawasaki (1996) explained how "W-science" was Japanized as follows:

> Japanese seem to simply believe in the applicability of W-science to Japan for the purpose of modernization. To Japan, the term 'modernization' has meant development in technology. In Japan, science teachers tend to… disregard the pure-scientific aspect of W-science in their teaching…. However, Japan has appreciated only the technological aspect of W-science since the beginning of modernization. Consequently, Japan began to Japanize W-science in accordance with shizen-associated relations… (p. 14)

According to this, "Japanized W-science" is based on what the Japanese associate with *Shizen*, emphasizing the technological application of "W-science."

The research presented in this chapter takes a similar position on this view of technology, drawing particularly on the following discussions by Japanese scholars. Murakami (1986) argued that technology is context-sensitive. Relying on previous studies, Murata (2009) deciphered technology from the perspective of "non-essentialism" and argued that technology could be interpreted within certain cultural and social contexts. Murota (1985) argued that the differences between the Japanese and Western views of nature are reflected in the way Japanese and Western people think about technology. He elaborated on the differences between Japanese and Westerners' views of technology through the use of concrete technological examples. Therefore, as with science, these scholars are in agreement that technology is perceived differently in Japan and in the West.

Based on these considerations, the author set out to uncover and interpret Japanese preservice science teachers' views of science and technology. Therefore, the following case study does not prioritize perceptions of science and technology developed in the Western context and does not use instruments for Westerners. Instead, the case study sought to bring various views to light.

The author attempted to decipher views of science and technology by using the text mining method. This method is defined as seeking "to extract useful information from data sources through the identification and exploration of interesting patterns" (Feldman and Sanger, 2007, p. 1). More specifically, quantitative content analysis (Higuchi, 2004, 2014, 2016, 2017), including a step similar to text mining, was employed to analyze participants' free descriptions. Citing Higuchi (2004, 2014), Higuchi (2016) described the following two phases of this analysis:

> Step 1: Extract words automatically from data and statistically analyze them to obtain a whole picture and explore the features of the data while avoiding the prejudices of the researcher.

> Step 2: Specify coding rules, such as "if there is a particular expression, we regard it as an appearance of the concept A", and extract concepts from the data. Then, statistically analyze the concepts to deepen the analysis. (p. 77)

Higuchi (2016) pointed out the similarity between Step 1 and the text mining method.

5 Case Study Method

The participants were Japanese freshmen university students with a major in science education attending a teacher training course. A questionnaire was distributed to a total of 75 participants at the beginning of the first semester in 2016 and 2017.

The questionnaire was written in Japanese and comprised of five general questions (Q). Q1 and Q2 employed a 5-point Likert-style scale, exploring subjects' general interest in science and technology (i.e., 1. I am not interested, 2. I am somewhat uninterested, 3. I am neither interested nor uninterested, 4. I am somewhat interested, 5. I am interested). Q3–Q5 were open-ended, requiring subjects to freely express their opinions. Q3 examined the image of science, Q4 examined the image of technology, and Q5 explored the perceived relation between science and technology. It took 10 to 15 min to complete. The question items translated into English are as follows:

Q1. Are you interested in science? Please circle the number that most accurately expresses your opinion.
Q2. Are you interested in technology? Please circle the number that most accurately expresses your opinion.
Q3. Please explain concretely and freely what science is.
Q4. Please explain concretely and freely what technology is.
Q5. Please explain concretely and freely how science and technology are related.

5.1 Methods of Analysis

The Q1 and Q2 data were statistically analyzed using the Wilcoxon signed-rank test, using EZR statistical software (Kanda, 2013). Quantitative content analysis was used to analyze the free descriptions of Q3 and Q4 (Higuchi, 2004, 2014, 2016, 2017), using KH Coder software, which is freely available online (http://khcoder.net/en/). This software was developed for quantitative content analysis and text mining and is compatible with multiple languages, including Dutch, English, French, and Japanese. The version used is KH Coder 2.

In the first phase of analysis, the KH Coder automatically creates a list of the top 150 most frequently used words, a list of the top 10 characteristics words, and a co-occurrence network. This network is a visual representation of relations between frequently occurring words and each question. Using this information, the author could make sense of the text data as a whole.

In the second phase, coding rules were made and applied (e.g., "If there is a particular expression, we regard it as an appearance of the concept A") (Higuchi, 2016, p. 77). Based on the lists and network created in the first phase, the coding rules were developed. Based on these rules, participants' responses to each question were analyzed and interpreted. The free descriptions in Q5 were categorized according to the written relation between science and technology.

6 Results and Interpretations

6.1 Interest in Science and Technology

Participants were asked about their interest in science or technology using a five-point Likert-style scale that ranged from "I am interested" (five points) to "I am not interested" (one point). The median (interquartile range) of Q1 and Q2 were four pts (4–5 pts) and four pts (3–4 pts). Wilcoxon signed-rank test showed a significant difference between these scores ($p < .001$), and analysis revealed that participants were more interested in science than technology.

6.2 Views of Science and Technology

6.2.1 First Phase

In preparation for the analysis, the responses to each question were added together. Obvious typographical errors and omissions were corrected. *Hiragana* descriptions were transformed into *kanji* (Chinese characters) without changing the meanings of the original words. The author selected some words to be extracted forcibly because these words, such as proper nouns and technical terms, are important but not automatically extracted. Table 1 shows the 20 most frequent words out of the top 150 in combined responses to Q3 and Q4. Both science-oriented and technology-oriented words were found. The data for Q3 and Q4 were analyzed together, aiming to highlight the differences between Japanese participants' views of science and of technology.

Next, the top 10 characteristics words in Q3 and Q4 responses were identified by KH Coder. For example, characteristics words of Q3 were "science/科学," "think/思う," "life/生活," "certification/解明," and "research/研究" and those of Q4 were "technology/技術," "human being/人間," "need/必要," "human/人," and "knowledge/知識."

Table 1 The top 20 high-frequency words

Word	In Japanese	Counting
Science	科学	79
Think	思う	67
Technology	技術	55
Human being	人間	41
Life	生活	41
Research	研究	25
Knowledge	知識	21
Human	人	20
Rich	豊か	20
Certification	解明	19
Need	必要	18
Things	物	17
Convenience	便利	17
Phenomena	現象	16
Discipline	学問	15
Development	発展	14
Substance	物質	14
Various	様々	14
Consider	考える	13
Use	使う	13

Finally, KH Coder automatically drew a co-occurrence network (Fig. 1), which presented the relation between frequently occurring words and each question. Words were shown as a circle. The size of the circle represented how many times the word occurred. Two squares represented each question, and a line linking square to circle meant that specific words appeared frequently in responses to the particular question. The line weight shows the relation between each question and word, with a thicker line representing a closer relation. Overall, this network presented words occurring frequently in response to each question or in response to both questions. For example, while the word “universe/宇宙” was only connected with Q3, “things/物” was connected with both Q3 and Q4. The words co-occurring in response to both questions were as follows: “things/物,” “think/思う,” “rich/豊か,” “research/研究,” “life/生活,” “science/科学,” and “human being/人間.” While words such as “phenomena/現象,” “certification/解明,” and “discipline/学問” co-occurred only with Q3, the words such as “use/使う,” “technology/技術,” and “convenience/便利” co-occurred only with Q4.

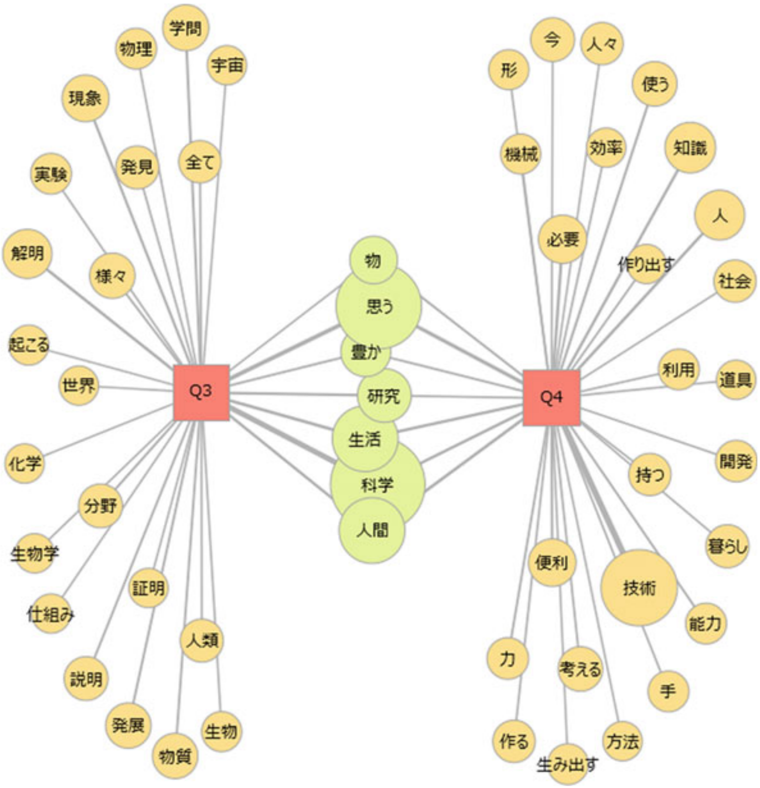

Fig. 1 Co-occurrence network presenting the relation between frequently occurring words in response to each question

6.2.2 Second Phase

The author began by making tentative coding rules. This was achieved by categorizing significant words found in the top 10 characteristics words' list and the co-occurrence network. Some words representing similar concepts were classified into the same category. Next, some of the top 150 most frequent words representing concepts similar to the created categories were selected and classified into the relevant category. To establish validity, the tentative rules were reviewed by a technology education researcher and a science education researcher. With their agreement, the final coding rules were determined (Table 2).

Some considerations should be explained. Table 2 includes the code which comprised only one or two words. The code *Need/必要* included just one word, and the code *Machine & Tool/機械や道具*, *Knowledge/知識*, *Ability/能力*, and *Things/物* included just two words each. However, these words appeared to be essential and could not be ignored. For example, "need/必要" was one of the top 10 characteristics words in response to Q4, one of the top 20 high-frequency words (Table 1),

Table 2 Coding rules

Code/Japanese noun	Brief description of the included words
Research/研究	Words which represent starting points, processes, and products of research, such as "experiment," "discovery," and "explanation."
Discipline/学問	Words showing academic disciples and fields, such as "physics," "chemistry," and "biology."
Human/人	Words which relate to human, such as "human being," "human," and "people."
Progress/進歩	Words which suggest progress, such as "development" and "convenience."
Production/生産	Words related to a process of producing something, such as "manufacture," "make," and "production."
Society/社会	Words involving nouns which represent society and life, such as "society" and "daily life."
Nature/自然	Words representing nature and phenomena in nature, such as "universe," "living organisms," and "phenomena."
Practicality/実用性	Words related to use and utilization, such as "use," "utilize," and "application."
Machine & Tool/機械や道具	Artifacts, including "machine" and "tool."
Need/必要	The word "need," which shows necessity of something.
Knowledge/知識	Words which represent a body of knowledge: "knowledge" and "wisdom" only.
Ability/能力	Words which connote abilities: "ability" and "power" only.
Things/物	Words which connote the existence of something, such as "substance" and "things."

and co-occurring word with Q4 (Fig. 1). The words "knowledge/知識," "substance/物質," and "things/物" were also top 20 high-frequency words. Moreover, "things/物" co-occurred in response to both questions, and the words"knowledge/知識," "machine/機械," "tool/道具," "ability/能力," and "power/力" co-occurred with Q4 and the word "substance/物質" co-occurred with Q3. It also should be noted that the coding rule was not absolute. As the process developed, the rules adapted to the text data obtained. Therefore, it was open to revision as new data were considered.

6.2.3 Q3 Responses: Participants' Views of Science

Appearance Frequency of Codes in Q3 Responses. Code-given sentences in the responses to Q3 were counted. The results are shown in Table 3. The most frequently appearing code was *Research/研究*, followed by *Nature/自然*. The codes *Discipline/学問*, *Human/人*, and *Society/社会* were each found in more than 30 sentences.

Co-occurrence Network for Q3 Responses. Figure 2 shows the relatedness of the codes. English names of codes were added. The closeness of two unlinked circles

Table 3 Appearance frequency of codes in Q3 responses

Code	Counting sentences (ratio)
Research/研究	57 (37.3)
Nature/自然	36 (23.5)
Discipline/学問	33 (21.6)
Human/人	33 (21.6)
Society/社会	32 (20.9)
Progress/進歩	24 (15.7)
Things/物	14 (9.2)
Practicality/実用性	13 (8.5)
Production/生産	10 (6.5)
Knowledge/知識	6 (3.9)
Need/必要	3 (2.0)
Ability/能力	1 (.7)
Machine & Tool/機械や道具	0 (0)
No code	30 (19.6)

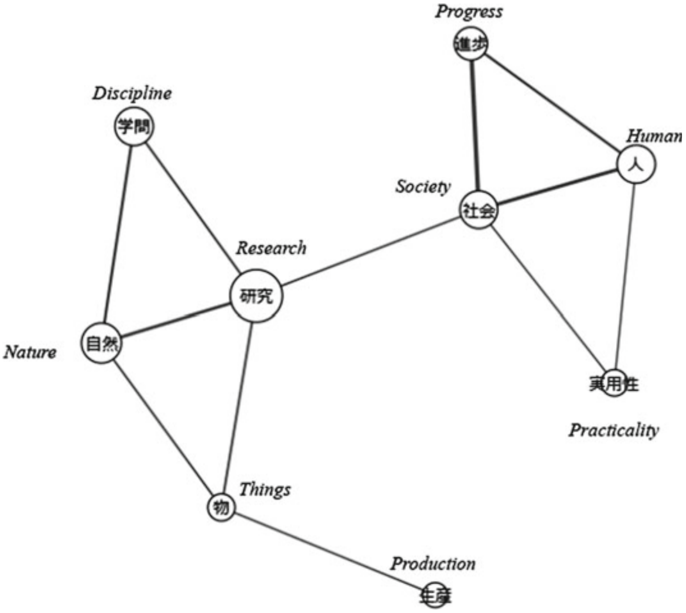

Fig. 2 Co-occurrence network for Q3 responses

does not indicate their strong co-occurrence relation. The author did not use the color of circles for interpretation, thereby showing the co-occurrence network in monochrome. In accordance with Table 3, high-frequency codes, such as *Research/研究* and *Nature/自然*, were presented in the network. The size of the circle represented the number of sentences that included the code. The *Research/研究* circle was the biggest, as this code appeared with *Nature/自然*, *Discipline/学問*, *Society/社会*, and *Things/物*. Given the line weight, *Research/研究* had a strong co-occurrence relation with *Nature/自然*. On the right-hand side of the network, the collocation relation between *Society/社会* and *Progress/進歩* and *Human/人* was substantial.

Preservice science teachers held two views of science linked by *Research/研究* and *Society*/社会, as shown in Fig. 2. The first view was interpreted from the co-occurrence relation constructed by *Research/研究*, *Nature/自然*, and *Discipline/学問*, on the left of Fig. 2. This view is that *science is a discipline for investigating the natural world*. Typical sentences involving all of *Research/研究*, *Nature/自然*, and *Discipline/学問* are listed below. Codes contained within each statement were shown in parentheses.

- The fields which investigate and clarify all things and every phenomenon in the Earth and universe. (*Research/研究*, *Nature/自然*, *Discipline/学問*, and *Things/物*),
- The fields which logically explain phenomena in the natural world. (*Research/研究*, *Nature/自然*, and *Discipline/学問*),
- The disciplines which research and clarify phenomena and living things in this world. (*Research/研究*, *Nature/自然*, and *Discipline/学問*).

The second view was interpreted from the co-occurrence relation constructed by *Society/社会*, *Progress/進歩*, and *Human/人*on the right side. This view is that *science improves human society and life*. Typical sentences involving all of *Society/社会*, *Progress/進歩*, and *Human/人* are listed below.

- [Science] also enriches human life by making new things based on what science elucidates. (*Research/研究*, *Human/人*, *Progress/進歩*, *Production/生産*, *Society/社会*, and *Things/物*),
- [Science] clarifies a wonder around us and enriches human life. (*Research/研究*, *Society/社会*, *Progress/進歩*, and *Human/人*),
- Science is produced with the aim of enriching human life more than now. (*Society/社会*, *Progress/進歩*, and *Human/人*).

6.2.4 Q4 Response: Participants' View of Technology

Appearance Frequency of Codes in Q4 Responses. The code-given sentences in the responses to Q4 were counted, and the results are shown in Table 4. The most frequently appearing code was *Human/人*, followed by *Practicality/実用性*, *Society/社会*, *Production/生産*, and *Progress/進歩*. Q4 high-frequency codes were different from those of Q3. For instance, *Research/研究* and *Nature/自然*, which were high-frequency codes for Q3, were less frequent for Q4.

Table 4 Appearance frequency of codes in Q4 responses

Code	Counting sentences (ratio)
Human/人	40 (31.0)
Practicality/実用性	29 (22.5)
Society/社会	27 (20.9)
Production/生産	25 (19.4)
Progress/進歩	20 (15.5)
Knowledge/知識	18 (14.0)
Ability/能力	16 (12.4)
Need/必要	15 (11.6)
Research/研究	12 (9.3)
Machine & Tool/機械や道具	12 (9.3)
Things/物	10 (7.8)
Nature/自然	4 (3.1)
Discipline/学問	3 (2.3)
No code	29 (22.5)

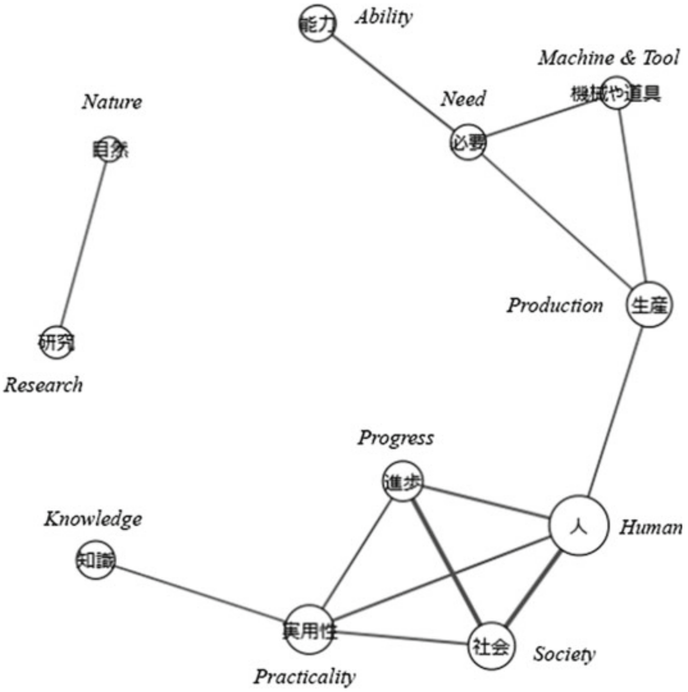

Fig. 3 Co-occurrence network for Q4 responses

Co-occurrence Network for Q4 Responses. In accordance with Table 4, Fig. 3 shows high-frequency codes such as *Human/人*, *Practicality/実用性*, and *Society/社会*. Given the line weight, *Human/人*, *Society/社会*, and *Progress/進歩* had a strong co-occurrence relation on the lower side of the figure. In the upper right, *Production/生産*, *Need/必要*, and *Machine & Tool/機械や道具* also had a co-occurrence relation. In the upper left, a co-occurrence relation between *Nature/自然* and *Research/研究* was found. This co-occurrence relation was excluded from the analysis because of the small number of sentences included in these codes.

From the two co-occurrence relations, two views of technology were interpreted. The first view relates to the strong co-occurrence relation between *Human/人*, *Society/社会,* and *Progress/進歩* at the bottom of Fig. 3. This view is that *technology makes our lives better*. Typical sentences involving all of *Human/人*, *Society/社会*, and *Progress/進歩* are listed below.

- [Technology] makes people’s lives more convenient. (*Human/人*, *Society/社会*, and *Progress/進歩*),
- [Technology] makes human life more convenient, prosperous, and safer by combining and applying things that are already known. (*Human/人*, *Progress/進歩*, *Society/社会*, *Practicality/実用性*, and *Knowledge/知識*),
- [Technology] makes human life more prosperous. (*Human/人*, *Society/社会*, and *Progress/進歩*).

The second view was interpreted from the co-occurrence relation between *Production/生産*, *Need/必要*, and *Machine & Tool/機械や道具* in the upper right. This view is that *technology produces the needed machines and tools, or it is machines and tools themselves.* Typical sentences involving any of *Production/生産*, *Need/必要*, and *Machine & Tool/機械や道具* are listed below.

- I think that technology develops the tools and machines needed by research. (*Production/生産*, *Need/必要*, and *Machine & Tool/機械や道具*),
- Abilities and tools necessary to research. (*Research/研究*, *Machine & Tool/機械や道具*, *Need/必要*, and *Ability/能力*),
- Technology is the ability needed to do and make something. (*Production/生産*, *Need/必要*, and *Ability/能力*).
- Technology creates tools and products to make human life more prosperous and efficient. (*Human/人*, *Progress/進歩*, *Production/生産*, *Society/社会*, and *Machine & Tool/機械や道具*).

6.3 Relation Between Science and Technology

Three different relations were found in the written responses of Q5. The first of these was that *science contributes to technology* and included more than half of all descriptions (53%). The second was that *technology contributes to science*, contained in only a small number of descriptions (4%). The third was that *science and technology interact with each other*, contained in approximately one-quarter of descriptions. Approximately 17% of the responses to Q5 could not be categorized.

7 Discussion and Implications

The case study intended to decipher Japanese preservice science teachers' views of science and technology through an analysis of written descriptions. Japanese participants regarded science as a discipline for investigating the natural world and thought that science improves human society and life. Regarding technology, they wrote that technology makes our lives better and produces the machines and tools required, or it is the machines and tools themselves. Japanese participants recognized utilitarian value not only in technology but also in science. This utilitarian view of science was also found in Kawakami and colleagues (2009). The relation between science and technology that was pointed out most often was that of the contribution of science to technology, with their interaction with each other coming in second. This order is plausible, given the emphasis on utilitarian values in their views of science. In the following, the author applies Kawasaki's (1996) framework to interpret participants' views of science and provide the further challenges of this interpretation.

As mentioned above, Kawasaki (1996) presented three different types of science: "W-science," "Japanese science," and "Japanized W-science." It appears that "Japanized W-science" was present in the results of this case study. Japanese preservice science teachers' views of science as improving human society and life, and their most frequent description of the relation between science and technology, reflect the utility of science in society and for humankind. Thus, their view of science is quite similar to "Japanized W-science," which emphasizes the technological application of "W-science."

Moreover, Dzama and Osborne's (1999) observation and the situation of Japanese science education support this interpretation with some degree of persuasiveness. Dzama and Osborne (1999, p. 396) stated, "The Japanese have adopted the technological and ontological components of Western science, but the epistemology of Western science is essentially alien to the Japanese worldview and is rarely given explicit treatment in their science education." In fact, the technological application of science appeared in the Course of Study[5] (学習指導要領) for junior high school science announced in 2008 (Ministry of Education, Culture, Sports, Science and Technology, 2008a, 2008b). The Course of Study 2008 version regulated and influenced research participants' learning of science in junior high school. In the 2008 version, for instance, making things (ものづくり), such as a simply structured camera or motor, was recommended to deepen students' scientific understanding (MEXT, 2008b, p. 99).

This chapter challenges Kawasaki's (1996) framework and the case study considered in this chapter and points to a future task for research in this area. First, Kawasaki's (1996) framework needs to be elaborated and refined because it fails to substantially explain Japanese preservice science teachers' views of science as a discipline for investigating the natural world. One could argue that this view reflects

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[5] The Course of Study for junior high school was first announced in 1958 and has been revised approximately every decade. This is legally binding and usually prescribes objectives, learning contents, and handling contents.

the purely scientific aspect of "W-science." However, Kawasaki's (1996) definition of "W-science" in the section Theoretical Framework implies that the possibility is quite low.

Second, the challenge for this case study was to carry out an investigation of Japanese views of nature along with one on their views of science and technology. Even though the views of science found in this case study and "Japanized W-science" are similar, the confirmation of *Shizen*-associated relations in Japanese participants is required.

Finally, the future task is to explain the reasons for which preservice teachers in non-Western countries other than Japan emphasize a utilitarian view of science and confuse science with technology with an alternative perspective on the boundaries and nature of science. Preservice teachers who take a utilitarian view of science have been reported in research carried out in Brunei (Tairab, 2001), Nigeria (Cobern, 1989), and Turkey (Yalvac et al., 2007). The phenomenon of preservice teachers confusing science with technology has been found in Brunei (Tairab, 2001) and Taiwan (Liu and Lederman, 2007).

It is understandable that preservice teachers in Western countries have the aforementioned views when regarding "W-science" as follows. Ziman stated that it was becoming difficult to distinguish between science and technology (Ziman, 1984). Furthermore, he argued that science, even when regarded as "W-science," has transformed from an academic science to a post-academic science (Ziman, 2000). He explained some of the factors of this transition, one of which is the increase in pressure on utility within scientific research. This pushes academic science toward post-academic science, where scientific findings are required to have practical value for society.

The case with preservice teachers in non-Western countries, however, demands different explanations. Possibly, the development of a different framework such as XXX-ized W-science embedded in each country could shed light on the interpretation of this situation.

8 Concluding Remarks

Some studies did not assess favorably or positively participants' views that emphasized the utilitarian value of science, highlighted the technological aspect of science, and equated science with technology (Carey and Stauss, 1968; Cobern, 1989; Constantinou et al., 2010; Liu and Lederman, 2007; Rubba and Harkness, 1993). These judgments might be reasonable if interpreted from "W-science" with only purely scientific aspects. Accepting the existence of alternative sciences, as Kawasaki (1996) and Ogawa (1995) have done, allows researchers to positively acknowledge and scrutinize views of science using culturally familiar perspectives. There are already many useful and valid instruments for clarifying Westerners' views of "W-science." However, there is a great deal of room for the development of alternative methods to mine non-Westerners' views of alternative sciences.

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The issue of authorship of the present chapter has been cleared with the co-author.

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Towards the Identification of ESD Competencies Required for Pre-service Science Teachers

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Abstract The purpose of this study was threefold. First, a thorough review of models related to ESD competencies was completed. Second, the study developed and conducted a prospective science teachers' course ("Elementary Science Education Methodology Development") that targets Education for Sustainable Development (ESD) based on Lesson Study methodology. And third, the study evaluated the course's merits and values based on the process of students' understanding of science lessons. Stufflebeam's (2003) Context, Input, Process, and Product (CIPP) evaluation model guided the development and assessment of this two-month course for third-year undergraduate students in the university's science education department. When conducting a trial of the course, diverse evidence was acquired that suggests it promoted students' understanding of and a capacity to accomplish, what science teachers should do in order to teach science lessons incorporating ESD. Consequently, this trial empirically identified essential competencies that are found as key components to the domains "Facilitate Learning" and "Continue to Learn and Create" located in the study's draft version of an Asia-Pacific ESD Teacher Competency Framework.

1 Introduction

ESD occupies a prominent place on the United Nation's 2030 Agenda for Sustainable Development and for the Sustainable Development Goals (SDGs) adopted in 2015. ESD is a key enabler to achieving all the SDGs, according to the UN General Assembly's resolution 72/222. Teachers play the most important role in this global pursuit of ESD. For example, in the UNESCO's ESD promotion framework "Global Action Programme on ESD" (for the period 2015–2019) and the subsequent "ESD for 2030" (for the period 2020–2030), the spread and development of ESD teacher education is taken up as a priority action area.

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Recognizing the critical importance of teachers in the context of the SDGs, Okayama University has tackled teacher education on ESD by advancing pre-service teachers' training programs at the undergraduate and graduate levels, as well as advancing the in-service teachers' training programs in cooperation with various boards of education (Yutani & Fujii, 2014). Okayama University holds the only UNESCO Chair on ESD in Asia, and it participates in the Okayama Regional Centre of Expertise on ESD, a center authorized by the United Nations University in Shibuya, Tokyo.

Our pre-service science teacher programs were enhanced by incorporating such content as follows: (a) the ideas and purposes of ESD, (b) the linkage between science education and ESD, and (c) examples of science lessons on ESD. These are now taught in two compulsory courses, "Elementary Science Education Methodology" and "Secondary Science Education Methodology." For example, in the linkage between science education and ESD topics, we introduced how to connect science education and ESD by considering the purposes, content, and activities of science either as a subject, or individually, or as a learning system. Through these program developments, we discovered that science teacher education on ESD should be based on Lesson Study[1] and it should also be linked to teachers' professional knowledge of education and scientific literacy with respect to the major themes in ESD, such as climate change/energy problems, biodiversity, prevention of natural disasters, and sustainable consumption and production.

Presently, we have been developing two new elementary and secondary pre-service training programs on ESD. The first program serves pre-service students. It offers a special emphasis on Lesson Study during a compulsory two-month course. Students choose either "Elementary Science Education Methodology Development" or "Secondary Science Education Methodology Development." In both courses, third-year undergraduate students enroll and participate directly following their one-month school practice. In these two courses (the focus of this chapter), undergraduate students conduct a Lesson Study such as creating a lesson plan, practicing a sequence of demonstration lessons, and reflecting on the lessons that are practiced. Such rigorous engagement leads students in learning science education methodology in a practical way. Also, students are required to incorporate the ideas and purposes of ESD into units and topics of science lessons in such a way that motivates themselves to practice and complete the lessons.

In the second program, we focus on an elective course offered at both the undergraduate and graduate levels, "Science Education and ESD," which aims to train talented science teachers. The course helps them learn about the development and utilization of bioenergy. The students registered in this course: (a) attend a lecture which addresses junior and senior high school chemistry lessons focused on sustainability (Fujii & Ogawa, 2016), and (b) visit sites where bioenergy based on woody biomass is developed and utilized. Also, they are required to describe how to incorporate ESD ideas and purposes into the topics of science lessons.

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[1] A rigorous sequential process for developing a lesson plan collaboratively with colleagues.

As mentioned just above, the *pre-service* science training program's development, trial, and evaluation are examined further in this chapter. What sort of competencies are required by ESD science teachers for attaining successful outcomes to their teaching?

2 Competencies for Sustainability and ESD

2.1 Competency for Sustainability

To achieve the SDGs, UNESCO has been developing ESD to date and advocating a new idea, Education for Sustainable Development Goals (ESDGs). This describes an ideal way for education to achieve the SDGs with ESD at the core. It assumes that the SDGs constitute a big agenda, and the SDGs cannot be achieved without education. According to a report entitled "Education for Sustainable Development Goals: Learning Objectives" (UNESCO, 2017), "sustainability citizens" is the image of humanity that ESDGs propose. Sustainability citizens are those who can connect, communicate, create, and engage in a change in today's complex and uncertain society. Similarly, the Japanese school curriculum guidelines expect that sustainability students will have rich creativity to become creators of a sustainable society.

Subsequently, the UNESCO report (2017, p. 10) lists the following "key competencies for sustainability" as necessary competencies for such citizens: systems thinking, anticipatory, normative, strategic, collaboration, critical thinking, self-awareness, and integrated problem-solving (see Table 1). This list of competencies is considered to be a milestone in light of the competencies discussed over the past few decades. Furthermore, these competencies overlap with "abilities that students should develop in ESD" as shown by the Japan National Commission for UNESCO: specifically, (1) values on sustainable development, for example, respect for humans, respect for diversity, non-exclusivity, equal opportunity, and respect for the environment; (2) system thinking, for example, understanding the background of problems and phenomena and multifaceted and comprehensive perspective; (3) critical thinking, for example, ability to criticize; (4) data and information analysis ability; (5) communication skills; and (6) leadership improvement. Moreover, it is noteworthy that key competencies for sustainability include those of anticipation, strategy, and self-awareness. The SDGs emphasize: to capture the complex relevance of the issues from the aspects of environment, economy, and society; to set goals and indicators, and to review the process of the realization; to set priorities and to work on for a desirable future; and to expand partnerships from the bottom up. These are new approaches of the SDGs, and the key competencies for sustainability reflect this approach.

Following key competencies for sustainability, the report lists the learning objectives in the cognitive, socio-emotional, and behavioral domains for each goal of the

Table 1 Key competencies for sustainability

Systems thinking competency: the abilities to recognize and understand relationships; to analyze complex systems; to think of how systems are embedded within different domains and different scales; and to deal with uncertainty	*Collaboration competency*: the abilities to learn from others; to understand and respect the needs, perspectives, and actions of others (empathy); to understand, relate to and be sensitive to others (empathic leadership); to deal with conflicts in a group; and to facilitate collaborative and participatory problem-solving
Anticipatory competency: the abilities to understand and evaluate multiple futures—possible, probable, and desirable; to create one's own visions for the future; to apply the precautionary principle; to assess the consequences of actions; and to deal with risks and changes	*Critical thinking competency*: the ability to question norms, practices, and opinions; to reflect on own one's values, perceptions, and actions; and to take a position in the sustainability discourse
Normative competency: the abilities to understand and reflect on the norms and values that underlie one's actions; and to negotiate sustainability values, principles, goals, and targets, in a context of conflicts of interests and trade-offs, uncertain knowledge, and contradictions	*Self-awareness competency*: the ability to reflect on one's own role in the local community and (global) society; to continually evaluate and further motivate one's actions; and to deal with one's feelings and desires
Strategic competency: the abilities to collectively develop and implement innovative actions that further sustainability at the local level and further afield	*Integrated problem-solving competency*: the overarching ability to apply different problem-solving frameworks to complex sustainability problems and develop viable, inclusive, and equitable solution options that promote sustainable development, integrating the above-mentioned competencies

SDGs. This composition of the domains is based on an understanding of the importance of non-cognitive skills and behavioral abilities in ESD. For example, Goal 13 is "Take urgent action to combat climate change and its impacts," the learning goals for each domain are as shown in Table 2.

The cognitive domain requires a basic knowledge and understanding of the phenomena of climate change, its artifacts and consequences, and addressing climate change (i.e., prevention, mitigation, and adaptation). Of particular note is the attempt to make learners understand the consequences of climate change from multiple perspectives: ecological, social, cultural, and economic. This understanding will require anticipatory and system thinking competencies.

The socio-emotional domain mainly requires a connection with others for climate protection, as well as the reflection on one's own values and actions. To address these requirements, it is important to correlate various competencies, such as collaboration, self-awareness, norms, critical thinking, and strategy.

The behavioral domain requires the following: to start from reviewing one's own actions, to determine what actions should be taken, and to develop individual actions

Table 2 Learning objectives for SDG 13 “Climate Action”

Cognitive learning objectives
1. The learner understands the greenhouse effect as a natural phenomenon caused by an insulating layer of greenhouse gases 2. The learner understands the current climate change as an anthropogenic phenomenon resulting from increased greenhouse gas emissions 3. The learner knows which human activities—on a global, national, local, and individual level—contribute most to climate change 4. The learner knows about the main ecological, social, cultural, and economic consequences of climate change locally, nationally, and globally and understands how these can themselves become catalysing, reinforcing factors for climate change 5. The learner knows about prevention, mitigation, and adaptation strategies at different levels (global to individual) and for different contexts and their connections with disaster response and disaster risk reduction
Socio-emotional learning objectives
1. The learner is able to explain ecosystem dynamics and the environmental, social, economic, and ethical impact of climate change 2. The learner is able to encourage others to protect the climate 3. The learner is able to collaborate with others and to develop commonly agreed-upon strategies to deal with climate change 4. The learner is able to understand their personal impact on the world’s climate, from a local to a global perspective 5. The learner is able to recognize that the protection of the global climate is an essential task for everyone and that we need to completely re-evaluate our worldview and everyday behaviors in light of this
Behavioral learning objectives
1. The learner is able to evaluate whether their private and job activities are climate-friendly and—where not—to revise them 2. The learner is able to act in favor of people threatened by climate change 3. The learner is able to anticipate, estimate and assess the impact of personal, local, and national decisions or activities on other people and world regions 4. The learner is able to promote climate-protecting public policies 5. The learner is able to support climate-friendly economic activities

into actions of the whole society. The behavioral domain also mentions empathy and empathetic leadership to others. In order to achieve the behavioral learning objectives, it is therefore important to make full use of competencies, such as critical thinking, self-awareness, collaboration, and strategy, as well as to exert integrated problem-solving competency.

These learning objectives will be a guideline in designing ESDGs with a focus on ESD. With reference to the guidelines, it is important to promote ESDGs in elementary and secondary schools as well as teacher education institutions.

2.2 Teachers' Competencies for ESD

Various models have been proposed for the competencies required of ESD teachers. Sleurs' (2008) model is one of the key examples, the result of a project of the United Nations Economic Commission for Europe (UNECE). Named "Dynamic model for ESD competences in teacher education," it incorporates ESD into the curricula of teacher education institutions. Teachers are seen not only as an instructor, but as a person in dynamic relationships with students, colleagues, and the wider society. Teachers' competencies for ESD are described at the intersection of (a) three professional dimensions: teachers as individuals, teachers at educational institutions, and teachers in society; and (b) three overall competencies: teaching, reflecting/visioning, and networking. The ESD competencies that shape the learning process for sustainable development are knowledge, system thinking, emotions, values and ethics, and action.

The "KOM-BiNE" (Competences for ESD in Teacher Education) model proposed by Rauch, Streissler, and Steiner (2008) consists of three behavioral areas for teachers: instructional setting, institutional setting, and society at large. This is similar to the professional dimensions of Sleur's (2008) model. The competency elements for ESD are in order from the center of the circle: (1) knowing & acting and valuing & feeling; (2) communicating & reflecting; and (3) visioning, planning & organizing, and networking.

Subsequently, Bertschy, Künzli, and Lehmann (2013) proposed the ESD-specific professional action competency in kindergarten and primary school, referring to UNECE's (2012) and Sleur's (2008) ESD competency models. Bertschy's model focuses on the knowledge found in complex and multifaceted topics of ESD, and on the ability to turn them into teaching/learning materials, as well as to constructively cope with conflicts associated with such topics. In addition, Bertschy's model highlights ethical judgment as an educational goal and as a central part of the co-creation competency that students should develop.

Another influential teacher competency model for ESD was derived from UNESCO Bangkok's project "Integrating Education for Sustainable Development (ESD) in Teacher Education in South-East Asia" (UNESCO, 2018). The model adopts a review tool focused on the extent to which ESD is integrated into teacher education (UNESCO, 2010). Seven teachers' competencies to be evaluated in ESD practice are shown in Table 3: ESD concept, ESD content, ESD methods, ESD curriculum mainstreaming, ESD policies, ESD and communities, and ESD institutional mainstreaming.

UNESCO (2017) described learning objectives that teachers as practitioners of ESDGs should promote (Table 4). These objectives can be grouped into three main areas. The first objective is to learn about the key issues of sustainable development and to develop multifaceted and multidisciplinary perspectives on them, which means developing a basic understanding of sustainable development and many viewpoints concerning it. The second objective is to apply the essential elements of

Table 3 ESD competencies proposed by Southeast Asia ESD teacher educators' network

1. ESD concept Are teachers developing an understanding of the philosophy, objectives, and characteristics of ESD?	*5. ESD policies* Are teachers developing an appreciation of the relevance of ESD and an awareness of the current policies and initiatives aligning ESD to national development and education goals, specifically in terms of quality education?
2. ESD content Are teachers developing their knowledge to understand and explain these local and global issues that impact on achieving sustainable development?	*6. ESD and community* Are teachers developing appropriate strategies for identifying and engaging with communities and local issues in relation to global issues?
3. ESD methods Are teachers developing the skills to use a variety of effective teaching and learning approaches to achieve the wide range of ESD objectives?	*7. ESD institutional mainstreaming* Are teachers developing an awareness of the institutional structures and processes that are crucial for successfully integrating ESD?
4. ESD curriculum mainstreaming Are teachers developing an understanding of how to implement ESD as a cross-curricular theme and how ESD can enrich subject teaching?	

sustainable development (e.g., cultural diversity, gender equity, social justice, environmental protection, and personal development) to one's educational practices, as well as to assess and evaluate the development of learners' sustainability competencies during those practices. This constitutes facilitating ESD education practices. The third objective is to cooperate and act to spread ESD practices with others in schools and communities, both of which constitute expanding ESD engagements.

Teachers are required not only to gain competencies for sustainability citizens (e.g., knowledge, skills, attitudes, values, motivation, and commitment) but also to obtain profession-general competencies in order: (a) to help students gain those competencies as a result of innovative teaching practices and (b) to expand these practices to people around the students and teachers.

Based on these competency models, we have been promoting a project in the Asia-Pacific region that creates a competency framework for ESD teachers (Okayama University, 2019) (see Fig. 1). The model centered on shaping the future, and it consists of three domains: (a) facilitate learning, (b) continue to learn and create, and (c) connect, collaborate, and engage.

In practice, what is a profession-specific ESD competency required for science teachers? The following case study illustrates an answer.

Table 4 Learning objectives for teachers to promote ESD

Know about sustainable development, the different SDGs, and the related topics and challenges
Understand the discourse on and the practice of ESD in the local, national, and global context
Develop their own integrative view of the issues and challenges of sustainable development by taking into account the social, ecological, economic, and cultural dimensions from the perspective of the principles and values of sustainable development, including that of intergenerational and global justice
Take disciplinary, interdisciplinary, and transdisciplinary perspectives on issues of global change and their local manifestations
Reflect on the concept of sustainable development, the challenges in achieving the SDGs, the importance of their own field of expertise for achieving the SDGs, and their own role in this process
Reflect on the relationship of formal, non-formal, and informal learning for sustainable development, and apply this knowledge in their own professional work
Understand how cultural diversity, gender equality, social justice, environmental protection, and personal development are integral elements of ESD and how to make them a part of educational processes
Practice an action-oriented transformative pedagogy that engages learners in participative, systemic, creative, and innovative thinking and acting processes in the context of local communities and learners' daily lives
Act as a change agent in a process of organizational learning that advance their school towards sustainable development
Identify local learning opportunities related to sustainable development and build cooperative relationships
Evaluate and assess the learners' development of cross-cutting sustainability competencies and specific sustainability-related learning outcomes

3 Case Study: Prospective Science Teachers' Training Programs for ESD

3.1 Program Development

For our development process, we adapted a framework informed by Stufflebeam's (2003) Context, Input, Process, and Product (CIPP) evaluation model that has been used for the evaluation of curricula and educational programs as a management-oriented evaluation tool. The CIPP evaluation model can provide the key information necessary for making a decision on how to develop curricula and educational programs. Therefore, the model provides a systematic perspective on the development, practice, and evaluation of ongoing program development (Nozawa, 2012).

The CIPP evaluation model is composed of four components: context, input, process, and product evaluation. The context evaluation is often referred to as needs

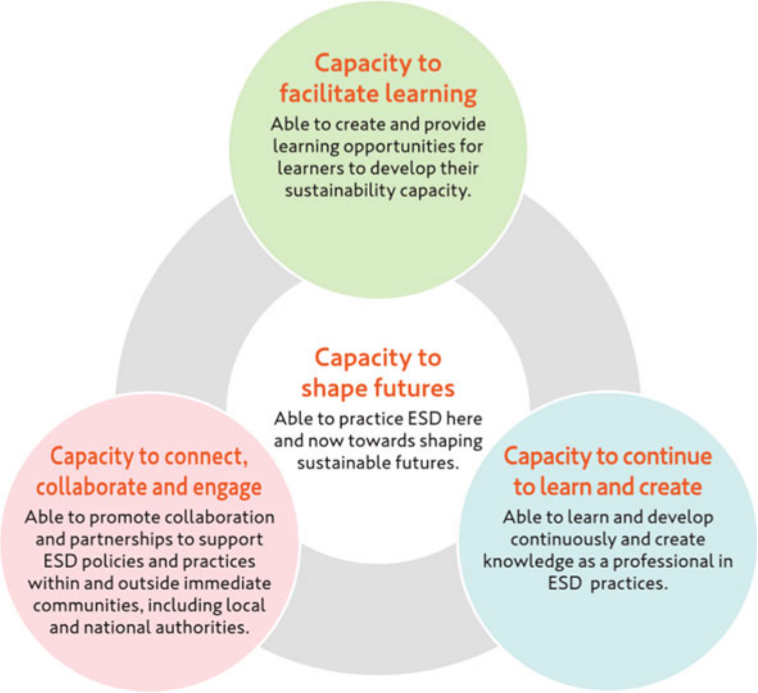

Fig. 1 Draft of Asia-Pacific ESD teacher competency framework

assessment. It asks the question, "What needs to be done?" It helps with the assessment of problems, assets, and opportunities within a defined community and environmental context (Stufflebeam & Shinkfield, 2007). It clarifies the objectives of program development. The input evaluation requires a project to address its identified needs. It asks the question, "How should it be done?" and identifies procedural designs and educational strategies that will most likely achieve the desired results. It defines the structure and content of the program. The process evaluation monitors the project implementation process. It asks the question, "Is it being done?" and provides an ongoing check on the project's implementation process. It documents the process and provides feedback regarding (a) the extent to which the planned activities of the program are carried out and (b) whether adjustments or revisions to the plan are necessary. The product evaluation identifies and assesses project outcomes. It asks the question, "Did the project succeed?" and is similar to an outcome evaluation. It measures, interprets, and judges a program's outcomes by assessing their merit, worth, significance, and probity.

Referring to examples of program development (e.g., Zhang et al., 2011) used the CIPP evaluation model, we conducted a procedure to analyze the information obtained in each component and to carry out the development, practice, and evaluation of the program (Table 5).

Table 5 Procedure of program development adapting the CIPP evaluation model

Context evaluation
We identified the needs of students for school science lessons incorporating ESD and the things that students must learn to be able to provide such science instruction; therefore, we conducted an initial qualitative assessment using a questionnaire
Input evaluation
We created a plan for the teacher training program corresponding to the identified needs, reviewed relevant literature, and considered the advice and expertise of individuals such as other university teachers. Also, we created a framework to evaluate the plan and confirmed whether it meets the needs that were identified
Process evaluation
We monitored the program process and potential procedural barriers and identified students' needs for program adjustments, that is, their current questions and difficulties related to the processes of Science Lesson Study incorporating ESD. Therefore, we observed Lesson Study activities and kept a log of activities, interviewed the students, and reviewed their self-reflections. Also, we provided advice relevant to the students
Product evaluation
We measured, interpreted, and judged teacher training program outcomes; therefore, we conducted an initial qualitative assessment using a questionnaire for students and reviewed the students' self-reflection through group interviews and their final reports

3.2 The "Elementary Science Education Methodology Development" Course

As mentioned above, we organized a compulsory two-month course titled "Elementary Science Education Methodology Development" as part of the training program for third-year prospective science teachers. The course consisted of 32 h in total (four hours per week for eight weeks, December 6, 2016 to February 7, 2017), following the students' one-month school practice. Sixteen students registered, all belonging to the Department of Science Education, Faculty of Education, Okayama University.

Table 6 shows the learning objectives and syllabus planning of the course. Based on their school practice experience, the students conducted a Lesson Study, which included making lesson plans, practicing a sequence of demonstration lessons, and reflecting on these practiced lessons. This resulted in a practical understanding of this science education methodology. In addition, they were required to (a) incorporate their own ideas and the purposes of ESD into science lesson units and (b) pick topics they wanted to practice.

3.3 Context Evaluation

In order to set up the purposes of the program, we conducted the initial qualitative assessment by administering a questionnaire to 16 students (Table 7). When

Table 6 The "Science Education Methodology Development" course

Learning objectives	
The students will learn science education methodology through Lesson Study	
Syllabus planning	
1st	(1) Reflection on experienced school practice and completed science education courses, and (2) Attendance of a lecture on the social background of the promotion of ESD, ideas and purposes of ESD, and an exemplar of elementary science integrating ESD
2nd to 4th	(1) Selection units and topics for lesson design, and then (2) Development, presentation, and modification of lesson plan
5th to 7th	Demonstration of a lesson and reflection of its effect
8th	Presentation of learning outcomes

Table 7 Questionnaire used for context evaluation and product evaluation

Question 1 Is it necessary to conduct elementary science lessons incorporating ESD? Why do you think so?
Question 2 What kind of elementary science lessons incorporating ESD should be practiced?
Question 3 What should you learn to practically conduct the above-mentioned elementary science lessons in school?

describing the responses to the questionnaire just below, the following two-part protocol is followed: the *number* of respondents who wrote a similar idea to the one stated is noted in brackets (x), and a *representative* response example is indicated by quotation marks (" ").

Regarding Question 1, all the students responded positively. The total number of responses to the question "Why do you think so?" was 17 (multiple responses, same for other questions). A variety of reasons were provided, which were derived from various aspects of society, especially tackling environmental problems (9) (e.g., "The environmental problems are causing a grave situation."). In addition, there were reasons based on the children's development (7) (e.g., "The pupils can think about systems of environment, energy, and so on.").

Regarding Question 2, the total number of reasons was 23. These related to aspects of the learning objectives (9) (e.g., "In the lessons, we should help pupils think about what they can do to the natural environment."). In addition, they were described in terms of learning content (9), especially natural disasters (4) (e.g., "Emphasis on natural disaster topics"), and resources/energy (3) (e.g., "We should discuss the period of years within which energy will be depleted."). Some were also described on the basis of learning methods (5) (e.g., "In the lessons … we should help pupils solve problems involving the natural environment, along with the law of nature. This is an advantage of science lessons.").

Regarding Question 3, the total number of responses was 24. The reasons described were based on aspects of research (12), especially research on materials for the lessons (7) (e.g., "I need to understand the business efforts extended in the development of energy.") and research on ESD (5) (e.g., "I should gain knowledge on the essentials of ESD through my own efforts."). In addition, the relevant descriptions were based on research concerning teaching methodology (6) (e.g., "I have to understand the results of ESD and the points in it that can be improved; I should also understand what ESD lessons are currently being carried out in schools."). On the other hand, some responses were related to the students' own behavior (4) (e.g., "I will take action with regard to energy problems and thus show these actions to pupils.").

Therefore, we believe that

(1) Many students understood the necessity for science lessons that incorporated ESD, based on the aspects of tackling environmental problems, as well as on children's development of thinking;
(2) Respondents thought that these science lessons should deal with natural disasters, energy/resources content, and enabling pupils to think how to act; and
(3) Respondents thought that by conducting these science lessons, they would gain an understanding of ESD itself through the examples in lessons and related teaching materials.

3.4 Input Evaluation

Corresponding to the needs identified by the questionnaire responses, we planned our teacher training course in three phases. We referred to the relevant literature and expert advice provided by university teachers from the Department of Science Education.

Phase 1. In order to enhance the students' understanding of ESD, we explained the social backgrounds of the promotion of ESD and its idea of sustainability. We introduced examples of elementary science lessons that incorporated ESD (Shinkosyuppansya Keirinkan, 2015).

Phase 2. We supported the students' Lesson Study activities, which they utilized to enhance their understanding of the main topics in ESD, such as climate changes/renewable energy, biodiversity, and natural disasters. We also supported their understanding of why and how we incorporated ESD into science lessons; that is, we introduced them to learning objectives and to the learning contents and methods of ESD science lessons.

Phase 3. Finally, we created a check sheet in order to evaluate and confirm whether these plans met their needs.

Table 8 Units and topics of elementary science lessons incorporating with ESD

Third grade	Working of wind and rubber
	Pupils try to stop the handmade car at a specific location through the use of energy of rubber, in order to understand the way their project conceptualizes energy
Fourth grade	Season and living things
	Pupils understand that animals and plants are changing their shape and surviving, corresponding to the four seasons
Fifth grade	Running water
	Pupils consider levees that are the strongest and eco-friendly and understand the relationship between nature and human beings
Sixth grade	Landscape and its change
	Pupils reflect on why a famous Japanese volcano, "Sakurajima," has connected to the main island and discover the greatness of nature
	Utilization of electricity
	Pupils understand the bidirectional linkage between electricity and energy converted into electricity

3.5 Process Evaluation

Throughout the processes of the course, we helped students reflect on their school practice experience and on the science education courses they completed. Four types of events were subsequently experienced by the students:

1. They attended a lecture about the social foundation for promoting ESD, the ideas and purposes of ESD, and examples of elementary science lessons that had incorporated ESD.
2. They selected units and topics for lesson making (Table 8) and then presented and modified their lesson plans.
3. They demonstrated their lessons and reflected on their own lessons taught.
4. They presented the learning outcomes throughout the course.

During the second event described just above, we conducted the process evaluation and monitored the course's process while placing a special emphasis on the students' activities. Students often asked themselves the question, "What is ESD?" They also had many questions and difficulties regarding setting up the learning objectives and the framing of the content pupils should learn. We provided them with a minimum amount of necessary advice, but we helped them improve their own problem-solving.

3.6 Product Evaluation

We conducted the same initial qualitative assessment by administering the questionnaire (Table 7) to sixteen students in the last week of the course. Regarding Question

1, all the students responded positively again. The number of responses to the item based on the aspects of children's development was nine. Those responses focused on promoting children's cognitive development and behavior, for example,

"Because through science lessons that incorporate ESD … I think that children might change and deepen their view of nature and the environment near them as well as living things. Moreover, the children might change their behavior and their attitude towards the environment near them, so that a spot is extended to a face."

Regarding Question 2, the total number of responses was 26. The responses related to learning objectives of science lessons with ESD (6), for example,

- "Science lessons that incorporate ESD should help children acquire the competencies necessary for the future and basic ways of thinking about these competencies,"
- "I think that, considering science lessons from various aspects, we need to carry out education and lessons in order to enable our decision making," and
- "In science lessons that incorporate ESD … it is necessary to help children change their recognition from being *human being centered* to being *human being in nature*."

Furthermore, the responses based on aspects of learning content (11) were included not only in those related to the subject matter itself (e.g., energy/natural resources) but also in those related to the organization of teaching materials, for instance, "If we find a familiar natural phenomenon that is useful for ESD, we should incorporate it into science lessons as teaching material." There were also various responses regarding learning methods (9). These were placed into two categories: (a) problem solving, for example, "(For science lessons incorporating ESD) … it is very important for children themselves to inquire how to solve problems by using the basis of previous learning experiences;" and (b) lessons with realistic emotion, for example, "The lessons should provide an opportunity to help children think about how the learning content is relevant to their own lives and helps them gain real feelings."

Regarding Question 3, the total number of responses was 26. The responses about researching the subject matter of science lessons with ESD (13) were categorized on the basis of learning materials for lessons (5), learning what ESD itself means (3), learning how to incorporate ESD into teaching materials (3), and so on. An example of the last category was "The most important thing is researching the subject matter. I need to inquire about, and determine the parts of, the science lesson units into which we can incorporate aspects of ESD." Moreover, there were responses about the teaching methods (9), especially with regard to learning how to incorporate ESD into teaching methods (4) (e.g., "I need to consider what content we allow children to grasp, in terms of approaching aspects of ESD."). Furthermore, there were some responses on research concerning children (4), especially children's thinking in ESD lessons (3) (e.g., "Considering children's thinking … I have to be able to look at and think about things from various viewpoints and standpoints.")

Subsequently, we reviewed the students' self-reflections at the end of the course (verbal data) and their final written reports (descriptive data). These qualitative data were very similar to the responses to Question 3 of the questionnaire.

By conducting and assessing this two-month trial of the elementary science education methodology development course, three results showed clear evidence that the program promoted the students' understanding of science lessons incorporating ESD.

The First Result. The students better understood the necessity of science lessons incorporating ESD, especially in terms of children's development. Regarding the reasons for elementary science lessons incorporating ESD, the students pointed out both the promotion of children's thinking and their behavior.

The Second Result. Regarding "desirable practices for science lessons incorporating ESD," the students imagined various ideas for learning objectives, content, and lesson methods. For example, they pointed out that when writing learning objectives, one should place special emphasis on developing necessary skills for the future, such as making decisions and promoting a view of nature in accordance with the motto "Human beings in Mother Nature." Moreover, students mentioned that it was necessary to organize their teaching materials.

The Third Result. The students understood more clearly the necessity of their own learning in order to conduct science lessons with ESD. In particular, they mentioned the importance of research: the subject matter, the teaching methods, as well as the processes and expandability of children's thinking.

Thus, by understanding what ESD is, the students enhanced their understanding of what science teachers should help pupils acquire from science lessons that incorporate ESD. Put simply, the students gained an understanding of setting up appropriate learning objectives for ESD science lessons. This is an educationally significant merit of the trial course that was developed.

4 Findings

The changes that occurred to prospective teachers during this intervention program identified the required ESD competencies needed by science teachers. With the help of our competency framework (Fig. 1), Asia-Pacific ESD Teacher Competency Framework (Okayama University, 2019), elements of these competencies were also identified.

In the first domain, that is, the Capacity to Facilitate Learning, one essential element is the pedagogical knowledge for creating science lessons that incorporate the concept of sustainability. Science teachers are required to have competencies in *adjusting* their objectives, the content, and their methods in order for their students to build the competencies needed for their future. These competencies include rational and reasonable decision-making, taking wise actions, all with the view of *human beings in nature.* A knowledge on disciplinary, interdisciplinary, and transdisciplinary perspectives on science education is required for these adjustments to be successful. Thus, science teachers need to acquire knowledge and abilities about making lesson-specific adjustments to supplement the work of colleagues in other subjects and learning areas who have multifaceted contacts with ESD.

In the second domain, that is, the Capacity to Continue to Learn and Create, science teachers need the abilities: (a) to reflect on their accumulated knowledge, (b) to conduct science lessons incorporating the concept of sustainability, and (c) to innovate with teaching materials and various pedagogical methods. These abilities are closely linked to the motivation and volition for being a teacher who constantly learns.

Looking to the future, the third domain, that is, the Capacity to Connect, Collaborate and Engage, requires competencies that have not been identified in our intervention program. They connect with the work of Sleurs (2008) and the KOM-BiNE model of Rauch, Streissler, and Steiner (2008). These models for ESD competencies in teacher education have a dynamic relationship with students, colleagues, and a wide range of societies. ESD teachers will play a role as a transformer towards a sustainable society. To foster the competencies needed for such teachers, other intervention programs should be envisioned and designed so that prospective teachers are directly connected to the real-life setting of schools and society. It should probably be developed as a science teacher training program for ESD, with a special emphasis on open learning environment, as exemplified by Kater-Wettstädt, Bruhn, Bürgener, and Barth (2019).

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Science Education as Gifted Education: Can We Conduct Gifted Education with Non-gifted Students?

Manabu Sumida

Abstract In this chapter, by examining gifted education from the viewpoint of science education and education in the historical and cultural context of Japan, I discuss a new notion of gifted education, different from the conventional one that screens specific students to provide them with special programmes. At its core, gifted education has included students that have been differentiated, such as with the identification of 'gifted' children in a pull-out system of teaching. In other words, the concept of 'gifted children' inevitably creates the dilemma of setting apart 'non-gifted' children. After WWII, in 1947, the Ministry of Education of Japan enacted the national course of study from primary to high school, and since then, all public and private schools in Japan have followed that course of study, for over half a century, through several revisions. On the other hand, the Ministry of Education, Culture, Sports, Science and Technology Japan (MEXT) encourages national and international science contests and the number of participating students has tripled in the last decade. There are 217 high schools designated as 'Super Science High Schools' all over Japan in 2020. This contemporary double-standard science education in Japan is discussed as a first step in overcoming the paradox between standardised education and gifted education. Finally, the chapter discusses the fact that science education has great potential for the plurarisation of 'giftedness' and proposes an unique 'Meson Model' of education for the gifted.

1 Introduction

During the Edo period in Japan (1603–1868), there was a fixed social class system: residence was decided on the basis of social class, and its originated status could not be changed until death, in principle. The revolution that took place at the end of the Edo period is known as the 'Meiji Restoration;' it refers to the 15 years between Perry's arrival (1853) and the Restoration of Imperial Rule (1878). One of the most important reasons for the end of the Samurai administration (Military Government),

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in which 'generals' had continued to dominate Japan for more than 700 years, was Perry's Western science and technology-laden warships, with which the United States forced Japan to open its borders in the midst of the world's industrial revolution.

On September 20, 1868, Emperor Meiji left Kyoto Imperial Palace and entered Edo Castle in Tokyo on October 13. The new government began to create a centralized country that worked to import Western science and technology, as well as Western culture, and promoted the development of its civilization and economic development. Over the next 150 years bout, 22 Japanese scientists have received the Nobel Prize for sciences. Since the beginning of the twenty-first century, Japan has become the world's second-largest champion in the discipline of natural sciences.

In 1947, after WWII, Japan's Ministry of Education established a national course of study from primary to high school. For over half a century since then, all public and private schools in Japan have followed that course of study through several revisions. All textbooks in science classrooms have been inspected by the government. In the standardised educational context of Japan, no criteria for gifted education existed in the system.

On the other hand, the Ministry of Education, Culture, Sports, Science and Technology Japan (MEXT) promotes national and international science contests for high school students. The number of participating Japanese students increased by 6.4 hold between 2004 and 2014 (Sumida, 2017). Historically ground-breaking forms of gifted education have generally been implemented and researched in Japan. Science education, in particular, has played an important role. In the Third Phase of the Science and Technology Basic Plan, approved by Japan's Cabinet in 2006, the term 'gifted students' was included explicitly in a public policy document for the first time (The National Cabinet, 2006). There were 217 high schools designated as 'Super Science High Schools' all over Japan in 2020. This contemporary dichotomy between standardised and gifted education has been discussed in Japanese science education.

Japan is not the only country in which scientific innovation has greatly influenced its education policy reform. In the United States, for example, three years before the Soviet Union launched Sputnik in 1957, the National Association of Gifted Children (NAGC) was established. In response to their so-called 'Sputnik crisis,' the quality of American science personnel and science education was re-examined. A large budget was invested in discovering gifted students who could study advanced mathematics, science, and technology. The 1958 Nation Defence Education Act is considered to be the American federal government's first major support for gifted education (Jolly, 2009).

In this chapter, I examine the education of the gifted from the viewpoint of science education and education in the standardised context of Japan. Moreover, I discuss a new notion of education for gifted students, different from the conventional notion that screens specific children for special programs. From a historical, cultural, and scientific perspective, this chapter explores the fact that science and science education have great potential for creating transitions to gifted education. This new perspective on education for gifted students contributes to the reconciliation between gifted and mainstream children.

2 Dilemmas of Education of the Gifted

Curiosity regarding the lives and works of gifted children probably dates back to the time when people first showed an interest in why they differed from each other. Among ancient Greeks and medieval Europeans, there existed a popular notion that great intellect is a divine gift, a touch of omniscience enabling one to penetrate deep truths (Tannenbaum, 1983). The Renaissance awakening was of crucial importance in setting the direction in which Western culture would foster high-level talent.

It is fairly at ease to *recognize* young children who show a strong interest in natural phenomena and who demonstrate an outstanding ability to think creatively and in abstract terms. Yet there is no single universally accepted definition of the terms 'gifted,' 'talented,' or 'giftedness.' Nevertheless, the traditional method in many countries for identifying a gifted child has been an IQ test. Although a score of 130 or higher continues to be a common basis for identification, sometimes a certain upper percentage of scores (e.g., the top 1 or 10%) is used as the standard. Both standards are based on the assumption that a gifted child is someone who performs better than other children of the same age and with the same level of experience.

In the United States, for example, the proportion of children identified as gifted is estimated as 6% in the public schools (NAGC, 2020). This is approximately the same percentage of special-needs children who require specific education, such as they are not to be ignored in ordinary school education activities. School education for the gifted in the United States was formally addressed in the 1972 Marland report to Congress. This was the first time that giftedness was defined, and it was done so rather broadly. For instance, in addition to academic and intellectual talent, the definition included leadership capacity, visual and performing capacity, creativity, and high ability in specific academic areas (Davis, 2006).

At its core, gifted education has included students who have been differentiated, such as with the identification of 'gifted' children in an out-of-the-classroom setting. In other words, the concept of 'gifted children' inevitably creates the dilemma of isolating them from 'non-gifted' children. An early identification of children as 'gifted' can imply children's 'inborn' differences.

However, even a child who is identified as gifted is not regarded as being 'perfect' or able to demonstrate excellence in every area (Winner, 1996). Such children may exhibit imbalances in their socio-emotional development, experience difficulties in their interpersonal relationships, or be underachievers in fields not of interest to them. Among the scientists who have made their mark on history, quite a few are known to have had not only outstanding talent and brilliance but also some kind of learning difficulty. Children who are both gifted and have special needs such as a disability are referred to as 'twice-exceptional (2E)' or 'dual-exceptional' children. Sumida (2010) used his original gifted behavioral checklist in the field of science and Sumida (2012) implemented science lessons for 2E children, insisting that thoughtful inclusive science lessons could enable both 2E students and regular students to study together for mutual benefit and respect.

3 The Cultural Fusion of Science Education for the Gifted and the Japan Original

3.1 'Oyatoi Foreiners'

In Japan, the formation of the modern society and the enculturation of the western world occurred simultaneously. It is important to know that the Meiji Restoration was controlled mainly by lower-class warriors who had risen amidst the fall of feudal identity discrimination (Umetani, 2007). Japan created a new society without any explicit class structure barriers like the United Kingdom had. Thus, gifted Japanese people have been able to climb the ladders of society and become members of the upper class regardless of their original status.

The most important task for the new government, which was formed in the Meiji Restoration, was to build a nation that would rival the Western powers. The Japanese cabinet invited highly skilled foreigners to teach the gifted Japanese, who then trained others in the Japanese population. These highly skilled foreign professionals were called 'Oyatoi.' The new Meiji government concentrated its efforts on preventing Japan from being colonized the way its neighbors were in Asia, and at the same time, on pushing for the enrichment of the nation to catch up with developed countries.

The Oyatoi were employed in different fields, ranging from railways and civil engineering, politics and laws, agriculture, forestry, fishery, education, and so on. Their countries of origin included the United Kingdom, the Netherlands, Germany, France, the United States, the Philippines, and China. Table 1 shows the number of 'Oyatoi' from different countries in education. Science and technology were the main educational fields, excluding language education, that characterized the criteria for inviting the Oyatoi.

Of the 2,625 Oyatoi professionals who were employed between the end of the Edo era (1868) and 1886, the United Kingdom provided the most, accounting for 42.3% of the total (Uemura, 2004). Around the end of the nineteenth century, many modern engineering technologies that originated in the United Kingdom had moved

Table 1 The number of 'Oyatoi Foreigners' from different countries in education

	UK	USA	Germany	France	Netherlands	China
Language Education	154	144	43	59	12	13
Engineering	16	6	10	3		1
Science	8	12	10	8	1	
Medicine	2	5	23	2	6	
Agriculture	4	11	3			
Law & Education	3	7	3	5		
Others	18	14	5	3	1	

(data from Uemura, 2004).

to the rest of the world. The success of the United Kingdom's technology transfer to Japan was an extremely rare historical accomplishment, given the two countries' major differences in race, language, culture, thought, lifestyle, etc. Henry Dyer, who came to Japan in 1873 at the age of 25, directly after graduating from the University of Glasgow in Scotland, laid the foundation for Japanese industrial technology education and was honored as the father of modern Japanese science and technology education (Shimada, 1987).

What should not be overlooked is that some of the Oyatoi harbored a deep sympathy for the sophistication of the Japanese spirit and culture, while others have learned a lot from Japan and have become pro-Japanese people (Dyer, 1904). They touched Japanese culture and, at the same time, enabled Japanese students and citizens to recognize its aesthetics. Furthermore, even after returning to their home country, they must have been highly appreciated at home for enlightening and conveying the aesthetics of Japanese culture. For example, American Edward Sylvester Morse, who collected 2,900 items of Japanese pottery at his own expense while staying in Japan, deposited a large part of his collection at the Boston Museum of Art (Katano, 2011). The existence of such Oyatoi has led Japanese people to recognize their own culture and to foster their countrymen who are active on the global stage, some of whom are indeed gifted in sciences (e. g., Ueno, 1968; Katano, 2011; Shimada, 1987).

3.2 *The First Japanese Nobel Laureate, Hideki Yukawa, and Kyoto School*

The Nobel Prize, established in 1901 in accordance with Alfred Nobel's will, is a world-renowned prestigious award in the field of science, literature, and peace. It is known for its rigorous selection process and the large amount of prize money (Larsson, 2001). The first winners of the prize in the year 1901 were Wilhelm Conrad Röntgen for Physics, Jacobus H. van't Hoff for Chemistry, and Emil von Behring for Physiology and Medicine. It took nearly 50 years from the year of initiation for a Japanese to win the Nobel Prize. Hideki Yukawa was the first Japanese to be awarded the Nobel Prize for Physics in 1949, when Japan was still under occupation after the end of World War II.

Dr. Yukawa won the Nobel Prize for his theory that solved the following problem: an atom's nucleus has positively charged 'proton' particles that repel each other, and it has 'neutron' particles that have no electrical charge, they are electrically neutral. So what holds them all tightly together in an atom's nucleus? Yukawa predicted the existence of another type of elementary particle called a 'meson.' He imagined that they somehow interacted with the protons and neutrons in a way that holds them tightly together in the nucleus. That is Yukawa's meson theory: neutrons and protons attract each other through the exchange of mesons, and since this force is greater than the repulsion of the protons, the atomic nucleus remains stable.

Hideki Yukawa was born in 1907. He was the second son of Takuji Ogawa, a professor at Kyoto Imperial University (now Kyoto University). In a family of five sons and two daughters, four became university professors. One son died during the war in China. The two older sisters married eminent researchers. Hideki married Sumi Yukawa and was adopted by the Yukawa family. Yukawa spent his childhood in Kyoto and was known to be quiet, docile, introverted, and ordinary as a boy rather than a child prodigy who attracted people's attention. He was called 'Iwan-chan' at home because 'Iwan' means 'do not speak anything' (Yukawa, 1958). Hideki would often remain silent because he did not express interest in explaining things and hence the name. His father is said to have remarked, 'I never know what Hideki is thinking.' However, when Hideki's father consulted his junior high school principal Mori regarding his son's career, Mori, who had also been Hideki's Mathematics teacher, is reported to have said, 'Hideki's brain works very swiftly. He is very sharp. He is far ahead of his classmates. I assure you: he is a genius' (Yukawa, 1958). Hideki graduated in Physics from the Imperial University of Kyoto in 1922 and went on to specialise in theoretical physics.

Besides being a specialist in physics, Yukawa is known to have deeply imbibed a culture of philosophy. One of the reasons is his education in Chinese classics when he was young tutored by his grandfather. Yukawa liked to apply Eastern thoughts to Physics, such as those of Zhuang Zhou. For example, the rational perspective of 'being aware of things as they are' in Zhuang Zhou's philosophy was called 'the chaos recognition method' by Yukawa. He argued that by going back to the primitive state of an object through retrodictive reasoning, unwanted prejudices may be eliminated, and their intrinsic nature can be seen (Cai, 1992). It was his belief that this way of thinking will help scholars to break out of established laws and run-of-the-mill methods and thereby discover new ideas. From the perspective of quantum mechanics as well, the world is considered to be chaotic. While classical mechanics regards vacuum as a space of nothingness, quantum mechanics does not. Instead, quantum mechanics regards it as a state of chaos in which elementary particles and their antiparticles are pair-produced or pair-annihilated repeatedly. Yukawa linked the theory of elementary domains with Li Bai's statement (Yukawa, 1989, p. 24).

「天地万物逆旅 光陰百代過客」: (This world is like an inn that welcomes everything, and the passage of time is like an eternal traveller).

Hideki explains that if we visualise a tiny area such as a room of the smallest hotel in space–time (think of it as a 'plain area'), the characteristics of the particles are determined by which room (space) is filled and what is known as time is the manner in which the room is filled. In his later years, Yukawa was also engaged in the peace movement.

Followed by Hideki Yukawa from Kyoto University, the next Japanese individual to win the Nobel prize was Shinichiro Tomonaga in the year 1965, who was also from the same university. Thus, there are several factors that link Kyoto University with the Nobel Prize in Science. In fact, Kyoto University boasts of the largest number of Japanese scientists who have won the Nobel Prize in Science to date (8 out of 22). This may be attributed to various factors of the University environment such as (a) its 'free academic style' (Yonezawa & Nagata, 1999; Hirose, 2019), (b) focusing on being ‘the only one’ rather than being ‘the number one’ (Yoshida, 2003), (c) an ‘emphasis on basic research’ (Furukawa, 2017), (d) the town of Kyoto itself, which is warm and welcoming to learned scholars, researchers, and students (Yoshida, 2003), and (e) other such factors that create a conducive environment for gifted education.

Kyoto Imperial University is the second imperial university to have been established following Tokyo Imperial University. A newspaper published the following report when the university was expanding its departments in 1903: ‘Tokyo University specialises in producing people with practical talent, while Kyoto University is inclined towards producing scholars’ (Amano, 2017, p.28). Thus, in terms of the style of functioning, Tokyo University is similar to the University of Paris, while Kyoto University is a great reflection of the University of Berlin (Amano, 2017, pp. 28–29). Unlike the Department of Law at Tokyo University, Kyoto University has established courses in philosophy and oriental history and the Kyoto School for liberal arts.

4 Japanese Perceptions of Giftedness and Scientists

‘Giftedness’ is a socio-cultural concept, and its definitions and components differ across time, reflecting progress in literature and the historical context. In the early twentieth century, researchers such as Lewis Terman saw giftedness as synonymous with a high IQ (Terman, 1925). In the late twentieth century, Howard Gardner (1993) proposed the theory of multiple intelligence, while Joseph Renzulli (1978) proposed a three-ring model that defined giftedness as a combination of above-average ability, creativity, and task commitment. Subsequently, Joyce VanTassel-Baska (1986) proposed a concept that emphasised domain-specific strengths. In a review of the literature on gifted children, Dai (2009) identified five criteria for determining whether a child is gifted: excellence, rarity, productivity, demonstrability, and value. The demonstrability criterion states that giftedness must be demonstrated in tests that can be considered valid assessments. Notably, this criterion essentially rejects hidden, unrecognised talents (as long as the special abilities are undemonstrated, they will not be recognised). The value criterion states that the child must show superior performance in something that is seen as value for that person by their society. The key point here is that it is insufficient for the child to excel at just anything; the thing at which the child excels must be valued by society. Studies such as these have provided plenty of insights. However, this literature tells us little about how giftedness is perceived in Japan or how Japanese people define the term. Accordingly, this section introduces examples of early Japanese literature on gifted children to illustrate how Japanese people have perceived giftedness.

Early Japanese research predated the use of the term ‘gifted’ (Japanese: sainō); the term used instead was ‘genius’ (Japanese: tensai). The first example of the early research was Shikiba (1930). While researchers in other countries emphasised heritable factors of genius, Shikiba took a more circumspective approach. Specifically, he cited two perspectives on genius, arguing that both were valid: (1) genius is an exceptional ability, meaning that a genius is someone who achieves outstanding performance in quantitative metrics; (2) a genius as someone with inborn talent that sets themselves far apart from ordinary people. Shikiba then stated, ‘When we start to recognise our abilities and apply ourselves, then we grow ever more akin to and even become geniuses. When we do so, the world will be full of geniuses; then, no one will be a genius anymore’ (pp. 101–102). Here, Shikiba offers us valuable insights that are relevant to our efforts to improve education for all children, including gifted children.

The next example is that of Hagiwara (1952). Although Hagiwara accepted the prevailing view that emphasised heritable factors, he made the following argument, in which he introduced the concept of ‘competencies’ (soshitsu) and ‘talent’ (sainō): ‘Granting equal educational opportunities to the masses to unearth all the untapped qualities and talents embedded therein and then develop and refine them—this is a vital and significant approach to engendering genius’ (p. 23). As used by Hagiwara, ‘competencies’ refers not to something that is fixed by family lineage or genes, but something that is gradually nurtured in interactions with the environment. Thus, Hagiwara argued that importance lies not in the innate abilities per se but in the application of effort through which the individual hones and elevates their competencies and talents to the genius levels.

Other Japanese terms for ‘genius’ (apart from tensai) include eisai and sainō-ji. (Shimizu and Mukaibo 1969) noted that the terms tensai, eisai, and sainō-ji were used interchangeably and were confused with each other. They argued that the confusion arose because Japanese translations had failed to differentiate between the English concepts of ‘genius’ and ‘gifted.’ Regarding the latter term, they argued that the original meaning of ‘gifted’ is ‘intellectually superior’ but that it encompasses the longstanding Japanese view on sainō (literally, ‘talent ability’)—a concept that implies all children, however ordinary, are potential ‘prodigies.’ They cautioned that this concept of yūshūji (‘exceptional child’) should be differentiated from the traditional notions of early bloomers and precocious children. A Japanese proverb says that one is a prodigy at 10 years, talented at 15 years, and ordinary in adulthood.

Miyagi (1967) provides the next example. Miyagi proposed a model that highlighted a mediocre kind of giftedness called bonsai (literally, ‘ordinary talent’) by distinguishing it from other kinds of giftedness: nōsai, isai, tensai, and musai. Nōsai (‘brain talent’) connotes a productive person. When solving a problem with a correct answer, a nōsai-person would find the solution swiftly and accurately. In the case of manufacturing, the person would raise productivity, act adaptively, and avoid waste. Isai (‘abnormal talent’) connoted a talent for innovation; an isai-person was someone who excelled exclusively at something unusual, as opposed to someone who could efficiently adapt. Tensai referred to creative genius; a tensai-person, on account of their genius, may need to sacrifice everyday life. Finally, musai (‘no talent’) refers to someone who has even less talent than the average bonsai.

The final example in the literature is that of Otomo (1968). Otomo argued that tensai, as used in the context of children (tensai-ji—a ‘gifted child’), should be differentiated from the same word as used in the context of adults (tensai-jin—a 'man of genius'). This emphasises the difference between giftedness and possessing gifts—and the flourishing of genius.

The researchers I described above—who represent early Japanese research on the nurturing of talent—frequently cited Galileo Galilei, Albert Einstein, Isaac Newton, Charles Darwin, and Hideki Yukawa. Science education in Japan has an unusual history in that Japan, as a national policy, places weight on nurturing talent in a specific area: Science and Technology. In 1944, Japan enacted a law to establish educational institutions for nurturing talent during wartime. Under this law, children who showed exceptional promise in science were enrolled in a special science curriculum (Sumida, 2017). The purpose of this advanced science curriculum was to achieve a leap forward in Japan's scientific and technological prowess. In a 1963 publication, the Industrial Planning Council (Sangyō Keikaku Kaigi) outlined a proposal for industrial-academic collaboration that would put Japan's scientific and technological talent at a level where it could compete with that of other countries. The proposal emphasised that Japan required home-grown scientists and that its scientific talent must be innovative, diverse, and have high standards. Accordingly, the council defined talent, in the context of science and technology, as 'the creative ability and fighting spirit necessary to take the plunge into the unknown domains, overcome all adversities, and accomplish creative tasks' (p. 23). Thus, the creativity required of scientists was a key concept in the literature on nurturing talent, suggesting that, historically, the nurturing of talent, in general, has gone hand-in-hand with the nurturing of scientific talent in particular. It was expected that the synergy between the two would lead to a better quality of education and more innovation.

5 Japanese 'Super Science High Schools' (SSH)

In Japan, 'Super Science High School' (SSH) is a highly prized *designation* awarded by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) to only certain high schools that provide advanced science, technology, and mathematics education with the objective of training future international human resources in these fields. In addition to implementing project research and developing and implementing curricula outside the official curriculum, these schools support empirical and problem-solving learning by cultivating a number of skills, including observation and experimentation. Initially consisting of 26 designated schools in 2002, the SSH project has since expanded to comprise 217 schools as of 2020. Figure 1 shows the schools designated by the prefecture. The initial overall budget of around ¥ 700 million (approx. US$ 6.4 million) in 2002 increased to ¥ 2.2 billion (approx. US$ 20 million) in 2020.

As Fig. 1 shows, SSH exists in all 47 prefectures. Looking at the numbers by prefecture, Tokyo (14), Osaka (14), Hyogo (14), Aichi (11), and Hokkaido (10) each have ten SSH or more. Fukui and Tokushima have a relatively high proportion of SSH, accounting for more than 10% of the total number of high schools in the prefecture. In terms of school type (i.e., national, public, or private), the majority (184/217) of

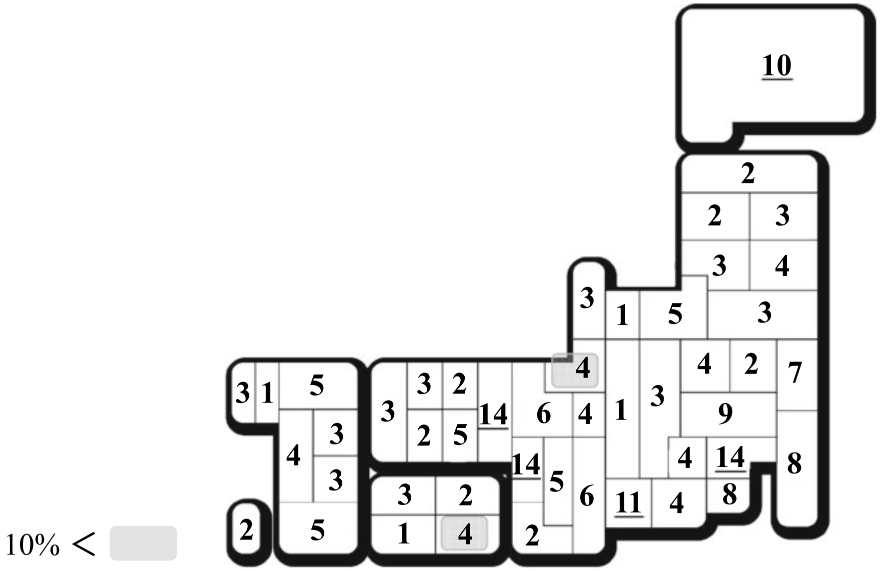

Fig. 1 The Distribution of SSHs in 2020 (N = 217)

SSH are public schools; however, considering the proportion of designated schools in the total number of high schools in the same category reveals that national high schools actually account for the highest percentage (11/17) of SSH.

A front runner among Japan's gifted education policies, the SSH program that has been rolled out nationwide is characterized by its support not for students with acknowledged individual talents, but for schools that have been approved as research and development bodies. Basically, designated schools do not select only specific students for the program. The SSHs designated by MEXT receive the support needed to carry out their activities from the Japan Science and Technology Agency (JST). The JST supports activities at the SSHs by purchasing equipment along with paying the cost of training for the schools, as well as planning and running academic conferences and disseminating information to the public.

At present, SSH can be broadly divided into two categories (JST, 2020): (1) basic SSH and (2) SSH with a focus on developing science and technology human resources.

1. Basic SSH comprises three types:
    a. The 'development-style' SHH tends to focus on developing and verifying research hypotheses and novel curricula.
    b. The 'practice-style' SSH focuses on the practical application of these novel research hypotheses, typically providing data regarding the efficacy of novel curricula.

   c. The ‘leading reform-style’ SSH engages in ambitious research and development initiatives, enabling them to identify systemic issues in science and technology human resource training.

The duration of the highly prized SSH designation by MEXT for the first and second styles of SSH is five years, while that for the third type is three years.

2. SSH with its focus on developing science and technology human resources comprises five types:
   a. The ‘high school–university linkage’ type involves the development and implementation of consistent top-level human resource training for science and mathematics through cooperation between high schools and universities.
   b. The ‘wide-area collaboration’ type involves curricula development and dissemination via SSH practice and networks with related organisations in order to improve the quality of science and mathematics education throughout the surrounding area.
   c. The ‘international collaboration’ type involves the construction and maintenance of regular collaborative relationships with overseas research institutes and schools to cultivate an international spirit as well as train human resources able to engage in joint research activities despite linguistic and cultural differences in the future.
   d. The ‘global society joint-development’ type involves school organised and implemented initiatives focus on fostering proactive student engagement with scientific studies about global social issues. Developed in collaboration with local universities and companies, these initiatives are intended to foster a desire to pursue new value creation in future human resources.
   e. A miscellaneous ‘other’ type includes special initiatives to contribute to the training of science and technology human resources. All five types have a maximum designation period of five years.

With respect to the highly prised designations by (1) Basic SSH in 2020, 28 schools were selected from 56 applications: specifically, 9 ‘development-style’, 17 ‘practice-style’, and 2 ‘leading reform-style’ schools. In regard to (2) SSH with a focus on developing science and technology human resources, 5 schools were selected from a pool of 16 applications (15 schools and one consortium). More specifically, two schools from the ‘global society joint-development’ type, two schools from the ‘wide-area collaboration’ type, and one school from the ‘other’ type were selected.

5.1 Case Examples

The SSH initiative is intended to train science and technology human resources who are able to advance future society by fostering students' scientific skills and scientific thinking through advanced science, technology, and mathematics education. As such, it aims to further develop students' individual characteristics and abilities. To this end, designated schools proactively implement initiatives based on their own strengths, such as the promotion of subject studies and inquiry learning activities; the development and implementation of curricula focusing on science, technology, and mathematics; science classes and presentations in English so as to cultivate an international spirit; and the development of teaching methods and materials intended to improve logical thinking, creativity, and originality. SSH also exhibits a spirit of cooperation, including efforts to disseminate findings to other schools, collaborate with institutions and firms in the local area and overseas, and in the evaluation of research findings.

In December 2020, MEXT selected a number of schools from those designated in 2015–2017 based on interim evaluations. MEXT then published a collection of cases that introduced some unique practice initiatives (2020a, b). Table 2 presents an overview of the 28 school cases introduced by MEXT. Over a hundred pages in length, MEXT's collection of SSH cases is expected to contribute to the inquiry teaching/learning practices of high schools and further improve these initiatives by allowing the designated schools to reference one another.

As mentioned, Japan's SSH project started in 2002. However, of the original slate of designated schools, only two schools retain their SSH designation as of 2021: namely, Ritsumeikan High School (private) in Kyoto Prefecture and Matsuyama Minami High School (public) in Ehime Prefecture. Both were selected as 'leading reform style' basic SSH in 2020. Both schools aptly illustrate the SSH initiative and some of its outcomes.

Ritsumeikan High School (RHS) is a driver of science and mathematics education globalisation with the research theme 'Research, Development, and Dissemination for Raising Future Researchers with a Global Mind.' Of a total student population of 1,053, RHS had 275 SSH students in years two and three and 116 SSH students in year one in 2020. Per 2019 data, which include the middle school, a total of 706 students were studying abroad, while 326 international students had been accepted by the school (MEXT, 2020b). RHS has promoted collaborative subject studies by teaming up with students at the Korea Science Academy of KAIST (South Korea), the Mahidol Wittayanusorn School (Thailand), Chitralada School (Thailand), National Junior College (Singapore), Kaohsiung Municipal Kaohsiung Girls' Senior High School (Taiwan), and Shawnigan Lake School (Canada) (RHS, 2020). In the fifth round, which started in 2020, RHS has established an International Joint Subject Study Centre, which is preparing an educational environment for high school students from around the world to study together and continue to spread international science education across Japan.

Table 2 Overview of case studies discussed in MEXT's SSH case collection (MEXT, 2020a, b, c)

School	Case overview
Sapporo Keisei	Promoting inquisitive activities (curricula that focus on the 'Keisei' science and mathematics courses and 'Future Vision' Regular course, which are highly collabarative), international collabarative inquiry and conferences using remote systems
Fukusima	Subject Studies (basic inquiry) and collabarative with local industry as well as elementary, middle, and high schools and universities
Meikei	Subject Studies consistent across the middle and high school curriculum (curriculum for fostering inquiry at the middle and high school level), mini studies high school year one), and individual subject studies (high school year two)
Koishikawa	Subject Studies across six years, initiatives to improve the quantity of subject studies, and changes in the evaluation and awareness of subject studies
Tokyo Tech	Creation and use of school-specific classes and original teaching materials as well as collaboration with Tokyo Institute of Technology and overseas educational institution.
Komatsu	System for developing and teaching subject studies (research support programmes), foresting students' inquisitive ability through subject studies and their assessment, collection of research findings and data on the development of students' inquisitive ability
Wakasa	Fostering science and technology human resources that connect the local area and the world through inquisitive learning using local resourses, developing curricula fostering the ability to define and solve problems, and identifying measures to improves guidance for all school management centring on an 'SSH and Research Division
Kofu Minami	All school system pertaining to the SSH project, as well as independent initiatives to deepen the proactive and collaborative subject study programme 'Frontier Inquiry'(e.g. original portfolio handling)
Kariya	Establishing a global leader training programme full of 'miryoku' (competency, fascination) of science ability, as well as humanities subject studies
Nagoya University	Science and mathematics curriculum that centres on subject studies across six years of middle and high school, science clusters in support of subject studies (e.g. the overnight Nakatsugawa project), and initiatives to improve teaching pertaining to subject studies and relevant subjects
Meijo University	Developing and deepening subject study activities (assessment and high school-university collaboration) and the SSH Tokai Festa
Zeze	Measures and approches to create an all-school system and teaching assessment and approaches based on standard rubrics, as well as advance inquisitive activities in both the regular and science and mathematics courses

(continued)

Table 2 (continued)

School	Case overview
Momoyama	Enhancing the combined subject ‘Global Science’ (GS), school-specific classes, and SSH events centring on ‘GS inquiry’; incorporating and assessing ‘GS inquiry’ teaching
Horikawa	Disseminating inquisitive teaching methods, the subject study process (cooperation across lines of subjects and departments), developing a guidance system for the whole school (sharing and training guidance methods) and assessing inquisitive activities
Ritsumeikan	Developing and spreading education to produce globally minded future research, overview of ‘Subject Studies’ and the Japan Super Science Fair
Ikuno	Examining the relationship between developing subject studies and improving subject training (including the use of inquiry advisors), and developing research the ethics guidelines and experiments guidance
Toyonaka	Overview of SS subject studies, assessment and guidance for rubrics of the mind; Toyonako Owners and leaders
Amagasaki Oda	Provinding stepwise guidance for subject studies over three years, and developing subject studies inn collaboration with the local area (e.g. student-leg high school students summits)
Toyooka	Inquisitive activities in collaboration with local society titled ‘Inquiry I’, and holding of the public presentation meeting ‘Toyonaka High School Academia’ (creating opportunities for intellectual exchange in the Sea of Japan Rim Region)
Kurashiki Amaki	Developing and using flows, schedules, ‘roadmaps’. and ‘rubrics’ for subject studies in both regular and science and mathematics courses, creating guidelines, and foresting teachers’ teaching ability
Tamashima	Developing curricula for school-specific subjects at Tamashima High School (SSH), developing curriculam for subject studies, effectively advancing subject studies, and creating the Tamashima Science Supporters
Sajio Agricultural	Enhancing research activities and strengthening communicative ability by merging agriculture and science, fostering and assessing grit, and acquiring an inquisitive process for the school-specific subject, ‘Agriscience’
Tokuyama	Students training to raise the school’s overall level and go global, realising high-quality curriculum and subject studies (using external funds, including the ‘Campus Scientific Research Grant’ Scheme), and implementing the SSH subject, ‘Introduction of AI Research’
Takamatsu Daiichi	Creating a curriculum centring on subject studies, and building an in-school system to improve teaching and a flow for developing teaching materials
Matsuyama Minami	Creating the school specific subject ‘Data Science’. and instructing subject studies in collaboration with companies and universities to achieve high-quality subject studies, thereby exhibiting high school-university linkage and collaboration
Kasumigaoka	The uniform development of training and skills assessment methods for ‘Scientific Inquiry’. and ‘Integrated Scientific Inquiry’, efficient ‘proper use’ and ‘joint use’ of teaching and coaching, as well as demonstrating the use of the Plan-Do-Check-Action cycle to improve teaching and in subject studies

(continued)

Table 2 (continued)

School	Case overview
Daini	Subject studies with all-school students from the research and math course, the art course, and the regular course, the Daini High School Ideas-Connections-Extensions Model that combines instruction and assessment, developing and sharing inquistive teaching, Plan-Do-Check-Action cycle
Kinkowan	Logically and scientific designing lifestyles, developing and implementing a programme to train global inquisitive human resourses, transforming and developing the school's organisational structure and management, and advancing subject studies (identifying enhancing, and expanding themes)

With respect to these objectives, RHS has held the Japan Super Science Fair since 2003. This event intended to boost Japan's status in science and technology education by providing a space in which students can engage in international science exchange, present international subject studies, and network—thereby training as the future leaders of the science and technology sector. Excluding RHS students, participants of the 2019 Japan Super Science Fair comprised 44 schools (34 overseas, 10 Japanese) and 150 students (128 overseas, 22 Japanese) from 22 countries and regions. Planned and implemented by teachers and students from Japan and abroad, the event saw the creation of a student executive committee and strengthening of networks with overseas schools focusing on science and mathematics education (RHS, 2020).

Matsuyama Minami High School (MMHS)—the only other school selected as an SHH in all five rounds—is pursuing the research theme of 'Training science and technology human resources with international competitiveness able to generate new value: STEAM (science, technology, engineering, art, and mathematics) education to realise the new society', with 1,078 students from years one to three across both regular and science and mathematics courses participating (MEXT, 2020c). Utilising their close high school-university collaboration and link with Ehime University, which they have had from the first selection round, MMHS has proactively introduced data science as a school-specific class and are engaging in STEAM education, collaborating with companies, and working to cultivate human resources able to use and apply data. The school is also promoting better science and mathematics education in the local area by contributing and giving back to society, including elementary, middle, and high school students both within and beyond the prefecture. MMHS has capitalised on the benefits of its repeated selection by establishing a mentor system with former students. As of the fourth round, MMHS has also made unique contributions to teacher training by providing opportunities for university students who wish to become science and mathematics teachers to conduct experiments and practice at the school (Sumida, 2016).

5.2 The Influence of SSH Results on the Curriculum

Initiated with 26 schools in 2002, the SSH project has since expanded across Japan—with some 217 designated schools in 2020. However, there are 4,930 high schools (including secondary education schools) in Japan, which means that SSH accounts for no more than 4.4% of high schools in the country. Nonetheless, SSH has had a remarkable influence on high school education in Japan, as illustrated by a series of new course of studies for high schools announced in March 2018 (MEXT, 2018a).

The most recent revision to the course of study for Japanese high schools includes the creation of 'Science and Mathematics' as a subject common to all courses and the creation of two classes, 'Basic Inquiry-Based Study of Science and Mathematics' (1 credit) and 'Inquiry-Based Study of Science and Mathematics' (2–5 credits). Subject studies by SSH have significantly influenced the basis for creating these new subjects and classes.

The new class, 'Basic Inquiry-Based Study of Science and Mathematics' is intended to equip students with basic knowledge and techniques for conducting an independent inquiry, foster an understanding of the significance of generating new value, and enhance students' desire to actively engage in inquiry. The other new class, 'Inquiry-Based Study of Science and Mathematics' involves the application of the qualities and skills acquired in 'Basic Inquiry-Based Study of Science and Mathematics', with students guided to identify and investigate issues while further honing these qualities and skills. In particular, 'Inquiry-Based Study of Science and Mathematics' focuses on enhancing students' ability to identify and define issues based on their own intellectual curiosity and interests, as well as recognise the value of novel and bold inquiry in the research process. However, rather than the production of new insights or values (i.e., the results of the inquiry), the focus is placed on students' thinking and attitude in the inquiry process as well as their ability to engage in and conduct research (MEXT, 2018b, p. 16).

Both 'Basic Inquiry-Based' and 'Inquiry-Based' Study of Science and Mathematics examine (1) natural and social phenomena, (2) advanced technologies and interdisciplinary fields, (3) the natural environment, (4) science and technology, and (5) mathematical phenomena (MEXT, 2018b). In other words, both classes investigate a broad range of phenomena with a high affinity for STEM (science, technology, engineering, and mathematics) subjects.

6 Plurarisation of 'Giftedness' Based on a 'Meson Model' for the Gifted

Any appreciation of giftedness must be expressed in a socio-cultural context. Human beings spread their inventions, skills, and knowledge, and they themselves are finely modified and optimized by others through the use of language, imitation, and the desire for, and execution of, education (e.g., Konner, 2010; Grabiner, 2021). All these can be understood as the accumulated cultural capital through many generations. Despite this accumulation, not many people expected that Japanese high school students, even average level students in the country, to reproduce the invention of Sir Isaac Newton's theory of dynamics, which was said to represent a revolutionary progress of knowledge in human history. This is unquestionably due to the evolution of science education, which also can be viewed as 'standing on the shoulder of giants.'

As mentioned in the first part of this chapter, from the end of the Edo period to the Meiji era, Japan accepted several 'hired foreigners' from the United Kingdom, the United States, France, China, Germany, the Netherlands, and others to promote new industries and enrich the nation. The fields undergoing development were diverse, including science and technology as well as medicine, agriculture, art, law, and finance. In that sense, the Japanese can be considered as having a 'rich soil' for facilitating the plurarisation of science itself, as proposed by Ogawa (1995). For example, there is no sense of discomfort or misfit regarding the way that different science can be thought about in the United Kingdom, the United States, and France (e.g., British-science and American-science). The Japanese understand and feel that such multidimensional sciences can coexist and that unique science and technology can be developed by layering the dimensions. This is in line with the Japanese view of the concept of 'giftedness' itself, which emphasises not only hereditary and innate factors but also environmental and acquired factors. At the same time that the Japanese plurality concerning the concept of 'giftedness', it is possible to believe that students who are recognised as 'gifted students' by a certain standard and those who are not can coexist and produce synergistic effects.

Since 2002, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan has designated some schools as 'super;' however, it does not certify students at such schools as 'super.' This is the characteristic of Japan in gifted education. There are diverse students and schools even in the Super Science High Schools. What connects them? Rather than following a dichotomy between gifted students and ordinary students, I would add a category called 'intermediate student' who is somewhere in between as in Fig. 2.

I am proposing that the intermediate student connects both the gifted and the ordinary student, as shown in Fig. 2. The intermediate student's character and proficiencies can change depending on the conditions. Even a gifted student will be the same as an intermediate student or an ordinary student when trying new things. An ordinary student will become no different from a gifted student or an intermediate student when he/she has been motivated, educated, and acquired high knowledge and skills. This can be described by Hideki Yukawa's meson metaphor from particle physics, introduced briefly in this chapter. Yukawa's elementary particles, called 'mesons,' interact with positively charged protons and uncharged neutrons to stabilize the nucleus. Even in our society, there are people who are gifted in certain fields, and there are those who are not. Science learning can be considered as such a state transition, like the fundamental particles' force fields.

Now that there is increasing uncertainty, growing inequality, growing diversity, and challenges regarding human well-being, we may be able to discover the new

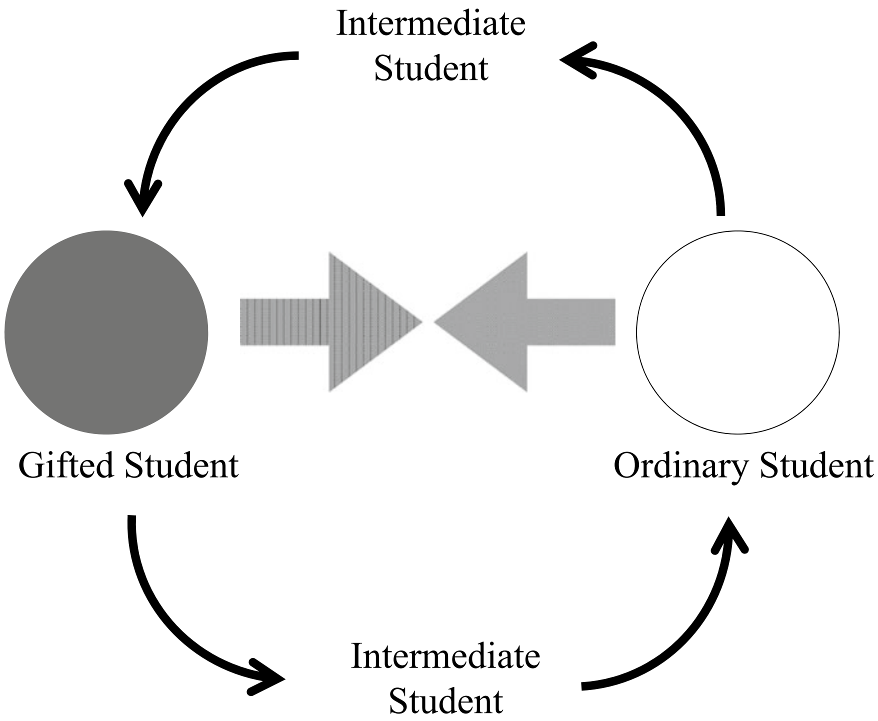

Fig. 2 ‘Meson’ Model of Education for the Gifted

strengths of science education and schools in the same way physicists have discovered the subatomic strong force and the weak force, now added to gravitational and electromagnetic forces.

Science education has the potential to break the inequities of opportunity and the reproduction of gifted education. Science education has continued to act as a meson between scientists and non-scientists and has been fostering people who can make new innovations while widely spreading the thoughts and experiences of eminent scientists of the past.

Japan’s experience in rapidly advancing a new type of science education, while integrating Western science and technology with its own culture after the Meiji Restoration, will be able to provide an important lesson for reconsidering contemporary issues in the education of the gifted. Beyond the dichotomy between gifted students or ordinary students, there are students who can interact with the intermediate gap (like mesons) between gifted students and regular students. These intermediate students are truly the gifted ones, but all of the three groups are changeable. There is a great need for a reform in science education not just in terms of inclusion but also in inter-crossing of different thinking among the pluralism of sciences.

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Epilogue: Communicating Innovative Research

Glen Aikenhead

On March 26, 2019, a meeting was held in Tokyo for three reasons: first, to honor Professor Ogawa's impending retirement; secondly, to celebrate his upcoming new title, "Professor Emeritus" at both Kobe University *and* the Tokyo University of Science; and thirdly, to commemorate his exceptional achievements throughout his career. It was my privilege at the beginning of the meeting to surprise (more accurately, to shock) Professor Ogawa by my secretive arrival from Canada. My privilege continues with the honor of writing this epilogue.

There was no better way to honor, celebrate, and commemorate Professor Ogawa than to produce a festschrift aimed at an international audience of science education researchers. The afternoon meeting was devoted to each festschrift author presenting a synopsis of their intended chapter, followed by collegial advice from others in the room. The celebration continued into the evening as we enjoyed a magnificent traditional Japanese dinner.

I thank the festschrift editors, Professor Isozaki and Professor Sumida, for making all of this happen. They must also be congratulated on their decision to allow each author the freedom to craft their chapter so it explored their work in depth as seen from their own unique perspective. The authors were unencumbered by dictates from the editors for a theme-driven book.

The editors' confidence was rewarded by chapters that offer readers an opportunity to gain insight into research related to Rika in contemporary Japan and East Asia. Readers will be able to contemplate many features of Rika research by heeding the

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[1] I was inspired by Professor Otsuji's chapter to draw upon this Western author's well-known book, *The Little Prince*, whose timeless story of an intra-galactical travelling boy prince introduces us to a wise fox.

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wisdom of de Saint-Exupéry (1943, p. 70)[1]: "It is only with the heart that one can see rightly; *what is essential is invisible to the eye*, said the fox."

In their passionate dedication to science education research, the festschrift's authors have articulated research methods and results, from which readers can gleam subtle essential truths about Japanese Rika research. The authors' particular ways of communicating are best captured by a now-famous expression coined by Canadian philosopher Marshal McLuhan (1964): "The medium is the message[2]." The festschrift entices the reader to reflect on what may be invisible to the eye, within a specific research context.

In other words, the book's rich array of messages invites us to ponder how the authors' innovative research could inform some global science education agendas. These rich messages lie in a combination of the book's research and the reader's participation in making the invisible visible. Such is a subtle intricacy of Japanese culture, I would suggest.

In the Foreword to this book, Professor Ogawa did just that: he made his invisible professional motives visible. By walking a path of self-disclosure, he crafted his McLuhan-like message. Moreover, by working at the margins of science education research during his career, he productively sustained diverse professional agendas; two of which seemed to be: let graduate students find their own margins, and encourage colleagues to do the same.

In a diversion from American globalized science education research, Professor Ogawa's pluralistic strategy sustained his efforts at the outer regions of the academy in order to reveal its inner regions of conventionality, for his purpose of critiquing them very subtly. In a natural way, his strategy is repeated by this festschrift's pluralism, which in itself represents an essence of *Rika* research in Japan and elsewhere in East Asia.

In Chap. 1, Professor Isozaki made a strong case for science educators to be grounded in the history of their profession. His depiction of the origin and evolution of Rika introduced a web of socio-cultural influences, such as the UK and US school science project movement. I was moved to ask myself: What are some "invisible" political and socio-culture influences on school science and its research community that could be revealed today?

In 1986, Professor Ogawa encouraged his colleagues to investigate "the problems that are associated with the introduction of science (based on Western culture) into a non-Western society," a quotation with which Professor Song began Chap. 2. Professor Song went on to make visible the work of the East-Asian Classroom Culture of Science and Mathematics (ECCO-SM) project; that is, its socio-cultural approaches to understanding science classroom culture. This work ultimately led to the development of the Korean Science Education Standards (KSES) to meet and overcome some negative political and socio-culture influences on Korean science

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[2] This expression means that the *form* of a message can communicate the intended message itself. For example, in Ms. Yoshida's chapter she writes, "This process [of expressing what a drawing means] shows that unless an opportunity for reflecting on their own views [is provided] …, the expression of ideas on an abstract [invisible] topic is difficult." Here, the act of reflecting is the medium, as I understand it, for arriving authentically at an understanding of Japanese science education research.

education. What I found essential to Chap. 2 was the implicit and gradual emancipation of East Asian science educators from the American globalized version of school science education research. Simply put, intellectual sovereignty was an invisible essential in Chap. 2 for me.

In the context of widespread support for inquiry-based instruction in school science, Dr. Larroder's Chap. 3 treats us to an articulate summary of its scope worldwide, as well as to an in-depth case study of one Pilipino special inquiry-based program among the 16 Sciene High School Campuses offered in the Philippines. The programs are dedicated to living up to the standards and expectations of professional scientists in the international scientific community—from creating their own research question to publishing the results. Its authentic hidden essential seems to be its emphasis on science's humanistic side: forging personal relationships between science-oriented learners and their mentoring scientific professionals, inside and outside the laboratory. It turns out that prioritizing this feature generates high grades on scientific knowledge assessments.

Many features of this program's holistic professional development in science are about learners nurturing their own self-identities guided by a host of diverse scientific support staff. Student participants valued the following most of all about the curriculum content they learned: manipulative skills, scientific concepts, the application of science, social issues, problem-solving skills, and the history of science—a humanistic science education, to be sure. Future Pilipino scientists will likely be bringing home a Nobel Prize in science for the first time.

Ms. Yoshida searched for essential messages under the most challenging circumstances: (a) in the abys of what gets lost in translation between the Japanese language and an Indigenous South African language; and (b) the "liminal space" (Hogue, 2018, p. 92) between Japanese and Indigenous South African worldviews. All of this translation took place in the context of a five-year project aimed at collaboratively creating an educational module in Education for Sustainable Development. The translation problems were partially resolved by changing the medium from words (and the translators of those words) to drawings by participants, in answer to the question: "What is your idea of the relationship between science and nature?" These drawings, along with semi-structured interviews and discussions with the artists of the drawings, became the focus of the research "because drawings transcend language." Ms. Yoshida carried out a highly detailed analysis of those interviews and conversations with participants who interpreted (i.e., projected their worldviews onto)[3] what was communicated by: (a) their own drawings, (b) their compatriots' drawings, and (c)

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[3] In 1930, Einstein shared his fundamental insight into the process of perceiving when in the act of interpreting (quoted in Director, 2006):

> It seems that the human mind has first to construct forms independently, before we can find them in things. Kepler's marvelous achievement is a particularly fine example of the truth that knowledge cannot spring from experience alone, but only from the comparison of the inventions of the intellect with observed fact. (p. 113).

The pre-observation form independently constructed in one's mind plays a pivotal role in perception.

the drawings by those of a foreign worldview. Inferences were made to tease out important similarities and differences in the participants' worldviews, in the midst of a degree of inconsistency detected by Ms. Yoshida's intricate series of analyzed interviews with Japanese participants. Imagine how much "truth" would have eluded Ms. Yoshida had her analysis been a mathematical one (e.g., various analyses of variance) instead of the qualitative one she designed. It would have *reduced* the essential features of her results. Does this mean that the heart would have a problematic place in Western mathematics when applied to research of Rika?

When a science educator with a bamboo heart became conscious of science-thinking citizens who had been marginalized by the conventionality of Western science education, she chose to investigate these citizens thoroughly; citizens beyond the margins of research in science education. Dr. Kimura explored literature published outside the usual academic library of science education researchers. She collected her own data in order to confirm the complex models she created to describe, predict, and prescribe the interests of various non-professional scientists. Thanks to Dr. Kimura's research, there is no longer an invisible relationship between school science learners and this pluralistic field of amateurs, hobbyists, dabblers, and novices; all of whom participate differently in Western science. She animated several ways to encourage school science learners to value a rewarding adult role as a non-professional scientist contributing to society. In short, Dr. Kimura's innovative, essential, research program is no longer invisible.

The title of Professor Otsuji's chapter could have been "Serendipity Profits from a Prepared Mind." Being assigned an office next to Professor Ogawa at Ibaraki University serendipitously led to Professor Otsuji's possession of a video that illustrated superior Rika. The fact that Professor Otsuji recognized its content as being essential to his science methods students shows a highly prepared mind at work. His instructional strategy for using the video demonstrates how guided contemplation by his university students is a journey in making the invisible visible. At the same time, Professor Otsuji also demonstrated that such a journey never ends. He discovered a new message in the videotape when he was preparing his manuscript for this festschrift. Moreover, his manuscript preparation seems to have been guided by a McLuhan-like agenda: create the chapter's structure and presentation so they exemplify an otherwise subtle, invisible, intended message for the reader to ponder.

Dr. Takahashi's research continued the theme that science education and its research community in Japan could be culture-based locally rather than imitating globalized Western-based research (Ogawa, 1986). He investigated pre-service science teachers' views concerning the meaning of science and technology. Three open-ended questions allowed his respondents to communicate their ideas in their own words. Coding and sophisticated algorithms analyzed their words within a Japanese language framework. The results (a) confirmed the culture-based pluralism of views on science and technology held by university students, and (b) identified a degree of variation within his respondents. Presumably, mathematics-based algorithms are objective while Dr. Takahashi's personal analysis of the respondents' words would have been tainted with subjectivity. However, knowing that humans create algorithms in the first place, based on a plethora of reductionist assumptions, we might ask: Could our presumption of objectivity be based on the Eurocentric ideology of quantification (Aikenhead, 2008; Ernest, 2016)? As an alternative to assuming the algorithm's objectivity, one could presume that the informed human mind is the most sophisticated analytical instrument for the task at hand.

This was the assumption in a study of Japanese and Canadian science teachers responding to an internationally developed instrument, Science and Culture Nexus (Aikenhead & Otsuji, 2000). One *essential* result of the research would likely have been *invisible* to any digital algorithm analyzing the teachers' written responses. The instrument required teachers to first describe "views held by my colleagues" concerning a given statement, and then express "My personal view" (p. 286). On the one hand, the researchers detected that a large majority of the Japanese teachers actually reversed their responses; that is, the teachers' colleagues' view was written as their own view, and visa versa. This reversal of what the instrument requested was explained by Jegede and Ogawa (1999) in terms of the Japanese concepts Honne and Tatemae. On the other hand, the Canadian teachers followed the directions as given. Simply put, whether or not to follow the instrument's directions turned out to be a culture-based decision. I doubt that a programmer of a word-analyzing algorithm would take such a cultural nuance into consideration. Thus, I wonder what Dr. Takahashi's results would have looked like had he analyzed the students' responses with his prepared mind. However, a comparison of the results generated by each method would not have necessarily resolved the issue of objectivity. However, it would make an interesting follow-up publication concerning objectivity—an essential that remains invisible at this time.

Following Professor Ogawa's pathway of "being marginal," Professor Fujii's research illuminates a much-needed relationship between science and society in teacher education. This research explores the pedagogical *and personal* competencies required for science teaching in "education for sustainable development" (ESD); probably the most prominent socio-scientific issue facing humanity today.

Professor Fujii's forward-looking research used a Lesson Study methodology to design components in methods courses for prospective science teachers. "ESD teachers will play a role as a transformer towards sustainable development," Professor Fujii wrote. He has identified what is *essential*.

Let me suggest what is *invisible*: our global, open-market, economic system that transformed an eighteenth century society based on social values into a society based on profit at any cost. This I learned from a lecture given by economist Dr. Carney (2020a), former Governor of the Bank of England, and before that, the Bank of Canada. In a subsequent lecture, Dr. Carney (2020b) revealed a related invisible essential: we are entering an equally global transformation "from a profit society to a sustainable society" (a transcription website quote), led by a growing number of key industrial leaders and investment brokers. Therefore, the work of Professor Fujii and his Japanese colleagues are helping to prepare international science education for this imminent transformation into a sustainable society.

And finally, a highly informative chapter by Professor Sumida offers historical insights into Japan's nineteenth century Technological Revolution and its positive influences on today's Rika[4]. By 1949, Japan's scientific excellence in research and development was recognized by Kyoto University's Dr. Hideki Yukawa winning the Nobel Prize in Physics for his meson theory and the identification of the meson fundamental particle that holds an atom's nucleus together. To date, eight out of the 22 Japanese science Nobel laureates worked at, or graduated from, Kyoto University; where Professor Masakata Ogawa completed his doctorial studies.

Professor Sumida describes how Japan's pride in its science and technology accomplishments, along with the innovative scientific ambiance of Kyoto University, are linked to a revised educational policy. A government decision in 2002 designated a 3-year award ("Super Science High Schools") to selected schools to motivate gifted education in the sciences and mathematics. As Professor Sumida explores the notion of giftedness, he simultaneously highlights a Japanese cultural dilemma in having students *dichotomized* into a gifted versus non-gifted identification; dichotomies follow a Western epistemological tradition. His Japanese alternative is to recognize a holistic continuum that embraces the qualities of a diversity of students. These qualities are so vast that Professor Sumida considered chaos theory in fundamental physics to conceptualize the reality of all students: from those excelling in the Super Science High Schools designated programs, to those whose life trajectories will not take them into science and technology in any significant way.

He resolves the cultural dilemma by invoking the following three student categories represented in his Fig. 2: gifted, intermediate, and ordinary. They comprise an innovative holistic perspective. The *intermediate* students are characterized as moving between being a *gifted* and being an *ordinary* student, depending upon a student's situation—momentary or long lasting.

Another example of Japanese science and technology influencing Rika is Professor Sumida's invoking Dr. Yukawa's meson theory. The *intermediate* students behave like mesons in an atom's nucleus—they stabilize a holistic social structure of a high school's student body, in which *gifted* and *ordinary* students are a dynamic equitable part of the whole science program because of the existence of the *intermediate* (meson-like) students. This is another "invisible essential" that animates this Festschrift for Professor Ogawa.

Professor Sumida's chapter is a very thoughtful roadmap that justifies reforming science education in Japan, based on Japan's historical successes as a post-industrial nation with an equitable diversity of science students in high school Rika.

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[4] Rika refers to a Japanese educational way of knowing nature; perhaps more accurately named "Japanese ways of knowing seigyo-shizen" (Aikenhead & Ogawa, 2007, p. 578).

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