

An Analysis of Sustainable Activities in Japanese, Korean, and Singaporean Elementary Mathematics Textbooks

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Abstract

The purpose of the study was to explore how contents related to sustainable development were presented in Japanese, Korean, and Singaporean elementary mathematics textbooks. For this purpose, the contents in the textbooks were analyzed at both macro and micro levels through a mixed method research. The results showed that the sustainability-related contents were included from the third or fourth grade in all the textbooks. The related contents were involved to mathematics content domains of Numbers and Operations, Pattern, and Data and Possibilities. The sustainability-related contents were used both to introduce and to apply mathematical concepts or principles. Most of the sustainable development activities led students to solve problems by using the mathematical contents they had learned, while some other activities induced students to consider sustainability as well as to solve problems. This study is expected to give implications for textbook developers and teachers to connect sustainable development meaningfully to elementary mathematics education.

Keywords: comparative study, education for sustainable development, elementary mathematics textbooks, sustainable activity

INTRODUCTION

Sustainable development is the key idea that meets the needs of both present and succeeding generations by reconciling economic growth, social development, and environmental protection (The World Commission on Environment and Development, 1987). The United Nations (UN) has suggested the 2030 agenda which highlights 17 sustainable development goals (UN, 2015). The fourth goal of the agenda indicates that Education for Sustainable Development (ESD) makes it possible to promise inclusive and equitable education and to encourage lifelong learning opportunities for all. Several countries have made educational approaches to sustainability such as developing sustainability-related activities or changing a curriculum to focus more on sustainability development (Kennelly et al., 2011; Miedijensky & Abramovich, 2019; Prince, 2010; Woo et al., 2012).

According to United Nations Educational, Scientific, and Cultural Organization (UNESCO), ESD is not just

another auxiliary education, but an overarching paradigm that guides and transforms the existing disciplines so that they can contribute to a more sustainable future (UNESCO, 2012). Many topics inherent in sustainable development are already part of the formal education curriculum (UNESCO, 2012; Yuniarti et al., 2019). Considering that environment, society, and economy are three spheres of sustainable development, multiple issues related to these spheres are incomplete without using mathematics. Mathematics interwoven in those issues is helpful in understanding economic, social, and environmental issues. In fact, several concepts in sustainability require mathematics skills such as measuring, converting units, and mathematically modeling patterns of growth and decline (Barwell, 2018; Roe et al., 2018). Moreover, analyses of sustainability rely on mathematical representations such as tables, graphs, and mathematical equations. Levin (2015) presented equations which analyze sustainability-related situations. Furthermore, Renert (2011) suggested characteristics of sustainable mathematics education, emphasizing that mathematics

Contribution to the literature

- This study explores ESD-related contents presented in elementary mathematics textbooks in Japan, Korea, and Singapore.
- Considering that ESD is an indispensable aspect of students' lives now and in the future, the first step is to examine how ESD is presented in the main subject matters such as mathematics.
- This study proposes suggestions for guidance for ESD in elementary school using mathematics textbooks.

education of today can act to reconcile the urgent needs of the future.

Given the imperative nature of sustainability issues, mathematics educational approaches for sustainability need to be set from the primary levels. As young children will become the adults of the next generation, it is critical that they be developed about sustainability issues in order to take a significant role in preserving their future. Actually, there have been movements to educate children to act in a sustainable way (Bartusevica & Cedere, 2003; Elliott & Davis, 2009; Hedefalk et al., 2015; Serow, 2015). However, few studies have focused on mathematics education for sustainability in elementary school. Rather, the studies related to ESD usually focused on environment education (Kang, 2010), social science education (Martínez-Medina & Arrebola, 2019), high school students (Yuniarti et al., 2019), and prospective teachers (Joutsenlahti & Perkkilä, 2019; Zehetmeier & Krainer, 2011). Exceptionally, Serow (2015) suggested mathematical activities drawn from the mathematics curriculum in Australia and New Zealand for ESD in primary mathematics education.

With the importance of introducing mathematics education for sustainability development from elementary school, we need to find specific ways to do so. As textbooks are one of the main instructional materials (Choy et al., 2020; Rezat et al., 2021; Stein et al., 2007) and textbook comparative analysis can give insights on developing textbooks by identifying the similarities and differences among textbooks (Bayda & Sutliff, 2020; Fan et al., 2013), it is necessary to scrutinize how ESD-related contents are presented in mathematics textbooks across different countries. This study investigated mathematics textbooks of Japan, Korea, and Singapore from the perspective of sustainability, with the aim of suggesting implications for how to address sustainability in elementary mathematics instructional materials.

LITERATURE REVIEW

Education for Sustainable Development

The concept of sustainable development was first introduced in the 1987 Brundtland Commission Report (The World Commission on Environment and Development, 1987). According to the report, sustainable development is "development that meets the needs of the present without compromising the ability of

future generations to meet their own needs." (p. 42). For sustainable development, environmental, social, and economic dimensions have to be considered and balanced in the pursuit of meeting the needs of both present and future generations. Liu et al. (2020) explained these three dimensions of sustainability: environmental sustainability means to ensure that we are consuming our natural resources at a sustainable rate; social sustainability includes principles such as trust, reciprocity norms, and equity; economic sustainability can be achieved by limiting the waste of resources so that they can be managed in a sustainable way to reduce operational costs. These three aspects of sustainability are in a lockstep relationship in which each is influenced by and in turn influences the others.

As an imperative mean in achieving sustainable development, ESD is not merely teaching and learning knowledge and principles related to sustainability. Rather, ESD is, in a broad sense, "education for social transformation with the goal of creating more sustainable societies." (UNESCO, 2012, p. 33) A study by Hedefalk et al. (2015) defined ESD in two ways: one is ESD as a threefold approach to education based on questions concerning education about, in, and for the environment; the other is ESD as an approach to education that includes three interrelated dimensions of environment, society, and economy. Compared to the former which is a narrow definition related to environmental education, the latter has a broad aim which is defined regarding environmental, social, and economic issues. As ESD is going to be considered to have a broad aim in this work, different aspects of ESD can be found in many fields of education. Thus, it is necessary to deliberate what is taught and how it is taught with sustainability as the central theme.

Contents for Education for Sustainable Development

With high interest in sustainable development, there has been a movement to emphasize the need to educate it in schools. UNESCO (2012) emphasized reorienting curriculums from early childhood up to higher education as a main priority in implementing ESD in schools. To reorient curriculums, it is important to select and present the appropriate issues and contents in the textbooks. In this regard, the Australian Curriculum (2015), emphasizing sustainability as one of mandatory cross-curriculum priorities, connects and relates sustainability to relevant content domains and subjects.

Some studies suggested the issues and contents regarding the three dimensions of sustainability: environment, society, and economy. For instance, Kang (2010) analyzed the content and organization of ESD reflected in the Korean environment textbooks for middle school. The analytic criteria used in the study were comprised of three dimensions of sustainable development and its related contents and topics by dimension. The following are examples of the contents in each dimension: natural resources, energy, and biodiversity are related to the environmental dimension; human rights, security, and culture are related to the social dimension; consumption and market are related to the economical dimension. The analytic criteria presented in the study are noteworthy of being able to better understand ESD as they were organized around three dimensions and their concomitant components.

In addition, McKeown et al. (2002) divided the issues of sustainable development into four sections: social and economic dimension; conservation and management of resources; strengthening the role of major groups; and means of implementation. This study suggested related issues for each section. For instance, combating poverty and changing consumption patterns related to the social and economic dimension section, while protecting the atmosphere and conservation of biological diversity related to the conservation and management of resources section. This classification is meaningful in guiding the issues of sustainable development and specific efforts to realize ESD.

Meanwhile, Martínez-Medina and Arrebola (2019) analyzed the sustainability-related activities in the social sciences textbooks of Spanish elementary education. The study suggested categories which were inductively determined to classify activities in the textbooks. The activities were categorized as human modification of the environment, energy, recycling, ethical consumerism, environmental issues, and general activities. The results of the study found that environmental issues are the most frequent in the textbooks, highlighting the importance of understanding a wider range of contents related to sustainability.

Liu et al. (2020) proposed an evaluation framework of elementary school teaching materials in Taiwan for sustainable development comprised of four levels. Each of levels in the framework corresponded to a goal, teaching scopes, learning indicators, and learning topics respectively. The study set sustainable development as a goal in level 1 and regarded ecology, energy conservation, waste reduction, and health as the teaching scopes in level 2. The learning indicators in level 3 included 10 indices such as biodiversity and vegetation amount. The final step was to relate sustainability dimensions to each learning topic. Unlike Kang (2010) which categorized contents and related topics according to sustainability dimensions, this framework first established the four levels and lastly

connected them with three dimensions of sustainability. This implies that a learning topic can be used in any sustainability dimension if possible. Using the evaluation framework, educators or textbook developers can determine if the textbooks cover all the sustainable development materials and, if necessary, design additional teaching materials for areas not covered in the textbooks.

Efforts to Implement Education for Sustainable Development in Elementary School

A gradual and structured process of change is needed to implement ESD in school levels (Miedijensky & Abramovich, 2019). UNESCO (2012) developed the ESD Toolkit which outlined basic initial steps toward creating ESD programs. They emphasized five components that could reorient a curriculum and design lessons: knowledge, issues, skills, perspectives, and values. This is meaningful in that the toolkit could assist in initiating ESD in schools, institutions, and communities and in reorienting the existing curriculum. A study by Miedijensky and Abramovich (2019) examined the process of educational change to implement education for sustainability. It reported that successfully implementing ESD into schools depends on a number of factors such as motives for change, persons involved, actions carried out, and follow-up activities.

Meanwhile, teachers need to understand how to translate and implement ESD in their instruction. Summers and Kruger (2003) described recognition and conceptualization of ESD by primary school teachers in their teaching. Nine primary school teachers were interviewed individually about how they understood sustainable development, what topics they chose for teaching, and how they set learning objectives. One of the results reported that different topics were selected depending on the grade levels. For upper level pupils, global topics such as energy and the tropical rainforest were chosen, in which the teachers needed to know a wide range of content knowledge and teaching strategies. Conversely, for lower level students, local based topics such as waste and recycling, environment in our area, and nature conservation were chosen. The study also suggested that teachers need to move from beyond a narrow focus on regarding ESD as simply protection of environment and to consider social and economic issues as well.

Few studies go beyond the connection of ESD with elementary school mathematics teaching. Exceptionally, Serow (2015) presented mathematics activities for educating sustainability in elementary education, drawn from the broad curriculum strands of measurement and geometry, numbers and algebra, and statistics and probability. Considering that each of these strands is applicable in many other countries, the recommended activities can be incorporated in mathematics classrooms. For example, “packaging” can be a

Table 1. Japanese, Korean, and Singaporean textbooks selected for analysis

Country	Textbook*	Year published	Publisher
Japan	新しい算数 [New Arithmetic] 3-1, 4-1, 4-2, 5-1, 5-2, 6-1, 6-2 (Tokyo Shoseki, 2011a-g)	2011	東京書籍 [TOKYO SHOSEKI]
Korea	Mathematics Textbook 3-2, 4-1, 4-2, 5-2, 6-1, 6-2 (MOE, 2020a-f)	2020	Visang
Singapore	Shaping Maths Coursebook 3A, 5A, 5B, 6A, 6B (Collars et al., 2014a-e)	2013	Marshall Cavendish Education

*Textbooks from third to sixth grades were analyzed. Textbooks not including ESD-related contents were omitted from further analysis

measuring activity to alert students to the optimum use of resources while calculating the surface area and volume and determining the choice for reducing amounts of packaging used. Another notable example is the “garden beds” activity, targeting the strand of patterns and algebra, which focuses on recording, analyzing, and describing geometry and number patterns. The garden beds activity can link to sustainability issues in that it explores why producing local food has particular environmental benefits. The study is significant as it presents specific contents implementing ESD in relation to elementary school mathematics.

Framework for Analyzing Textbooks

There is a close relationship between the conceptualizations of a topic used in mathematics textbooks and the opportunity to learn for students afforded by the textbooks (Charalambous et al., 2010; Choy et al., 2020; Törnroos, 2005). Textbooks, as a concrete embodiment of mathematics curriculum, help make the curriculum intentions specific (Li et al., 2009; Rezat et al., 2021). Numerous studies investigated textbooks from various perspectives such as content topic coverage (Martínez-Medina & Arrebola, 2019) and exercise problems (Fan & Zhu, 2007; Li, 2000). More recently, in analyzing three textbooks in terms of context, content, and instructional variables, Choy et al. (2020) created a visual representation, called *textbook signature*, to demonstrate either the distinct conceptualizations of a topic presented on each textbook page or the layout for the frequencies of occurrence.

Generally, textbooks can be analyzed at two levels: overall structure analysis and topic-specific analysis. For example, Li et al. (2009) implemented a content analysis of textbooks at two different levels: macro and micro level. A macro level analysis explores the inclusion of content topics, performance expectations for students, content presentations, and organizational features. This type of analysis can provide a broad picture of content structures in textbooks. A micro level analysis examines mathematical treatment of specific content topics and captures the mathematical nature of the topics and their connections with other topics.

This study expands on previous studies by examining the ESD-related contents in elementary

mathematics textbooks in Japan, Korea, and Singapore at both macro and micro level. Initially, a macro exploration was conducted to explore the overall structure and distribution of ESD-related contents in the textbooks. A micro exploration was followed to scrutinize the connection of the ESD-related contents with mathematics. Specifically, the study addressed the following research questions:

1. What is the overall structure of the ESD-related contents presented in the textbooks?
2. How are the ESD-related contents distributed in the textbooks?
3. How are the ESD-related contents connected to mathematics in the textbooks?

METHODOLOGY

Materials

To investigate how ESD-related contents were presented in elementary mathematics textbooks series, textbooks in Japan, Korea, and Singapore from grades 3 to 6 were selected. Japan, Korea, and Singapore are the countries that rank in the top five in TIMSS 2019 (Mullis et al., 2020). The countries have a national curriculum respectively and textbooks are aligned with the curriculum. In Korea, there is only one series of mathematics textbooks developed by the Ministry of Education (MOE). In Japan and Singapore, however, private authors or publishers have developed textbooks based on the curriculum guidelines. The series published by TOKYO SHOSEKI was chosen as the Japanese textbooks for the analysis in the study. The series, originally written in Japanese, was translated into English as needed for analysis. The Singaporean series published by Marshall Cavendish Education was chosen, which was originally written in English. In total, the following 18 mathematics textbooks in Japan, Korea, and Singapore were examined (see Table 1).

Procedures

A mixed method research was employed to include both quantitative and qualitative methods. Hesse-Biber (2010) asserts that using quantitative and qualitative data allows researchers to gain a fuller understanding of the research problems through triangulation and

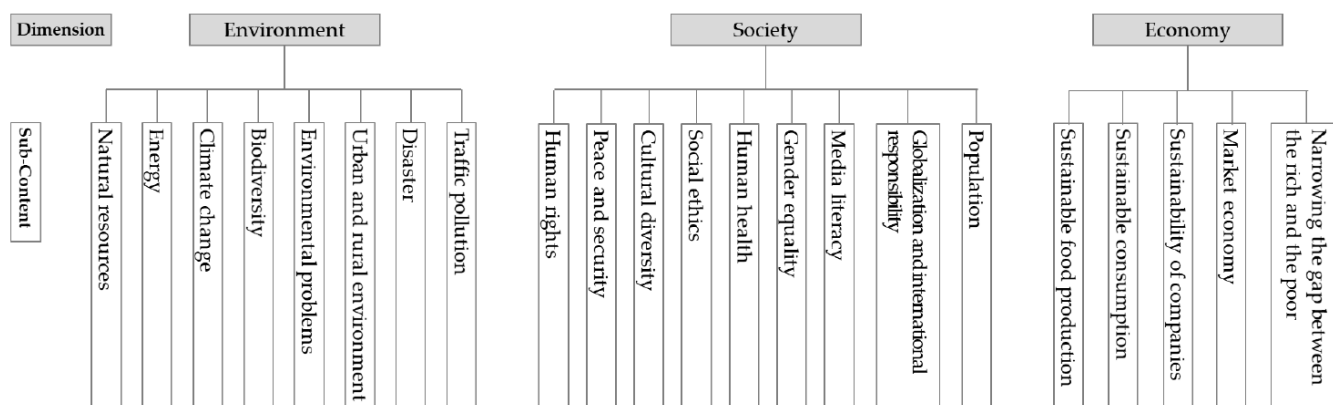


Figure 1. Organization framework of ESD-related contents

complementarity of data. In this study, a quantitative method was used to analyze how the ESD-related contents were distributed in the textbooks. Note that a quantitative analysis in the study was not to compare the focused textbooks one another. As the curriculum and organization of the textbooks in the three countries were different, the contents in the textbooks were qualitatively compared to understand in detail how the ESD-related contents were presented.

An organization framework of ESD-related contents was developed to extract and examine ESD-related contents in the textbooks. As shown in the literature review, few studies have presented an analytic framework for exploring mathematical content from an ESD prospective. In addition, as ESD requires contributions from many disciplines, not a single isolated subject, there are few studies which have distinguished ESD-related contents focusing only on mathematics. Based on the previous studies which dealt

with ESD-related contents or frameworks (Kang, 2010; Liu et al., 2020; Martínez-Medina & Arrebola, 2019; McKeown et al., 2002), sub-contents and their related topics of ESD were established. Specifically, environmental, social, and economic dimensions consisted of eight, nine, and five sub-contents, respectively (see Figure 1). The detailed topics related to each sub-content were also established to distinguish ESD-related contents in the textbooks (see Table 2).

Data Analysis

All textbooks selected for this study were analyzed in their original languages and then translated into English if necessary. The organization framework of ESD-related contents presented in Figure 1 and Table 2 was used for data analysis. Two researchers categorized and coded the contents in the textbooks independently and compared the coding results. Interclass correlation coefficient was 0.974, indicating very high inter-rater

Table 2. Related topics by sub-contents of ESD

Dimension	Sub-content	Related topic
Environment	Natural resources	Water, atmosphere, soil, minerals, plants, animals, natural scenery, natural resources conservation
	Energy	Energy types, renewable energy, energy conservation
	Climate change	Global warming, greenhouse gases, abnormal climate
	Biodiversity	Ecosystem equilibrium, endangered species, biodiversity, biological conservation
	Environmental problems	Awareness of environmental issues, efforts to solve environmental problems, nature of environmental problems
	Urban and rural environments	Urban functions, urban problems, the aging of villages, improvement of residential environment, environmental problems, rural-urban gap
	Disaster	Types of disasters, causes and solutions of disasters
	Traffic pollution	Traffic pollution, traffic safety, environmentally friendly traffic solutions
Society	Human rights	Human respect, human rights respect
	Peace and security	Understanding nonviolence, nonviolence activities, dialogue and compromise, safety education
	Cultural diversity	Respect cultural diversity
	Social ethics	Correct social ethics, readjustment of legal systems
	Human health	Exercise, health, disease prevention and treatment, obesity, drugs, AIDS, food safety and security
	Gender equality	Gender discrimination issues
	Media literacy	Information communication ethics, media literacy
	Globalization and international responsibility	Understanding globalization, problems of globalization, international solution
	Population	Population growth, population distribution by region

Table 2 (continued). Related topics by sub-contents of ESD

Dimension	Sub-content	Related topic
Economy	Sustainable food production	Eco-friendly production, resource-circulating waste management, sustainable agriculture, eco-friendly agricultural products
	Sustainable consumption	Green consumption
	Sustainability of companies	Corporate ethics, corporate responsibilities and duties
	Market economy	Understanding market economy, market economic activity, sustainable commercial sales
	Narrowing the gap between the rich and the poor	Eradication of poverty, combating poverty

Table 3. Analytic framework

Level	Aspect investigated	Foci of question
Macro	Overall structure	[Grade level] In what grade level are the ESD-related contents presented? [Dimension of ESD] Which dimensions of ESD are related? [Mathematics content domain] Which mathematics content domains are connected?
	Distribution of ESD-related contents	What sub-contents and topics are presented in the ESD-related contents?
Micro	Connections of the ESD-related contents with mathematics	[Mathematical feature] Which mathematical feature is observed in the ESD-related contents? [Expectation from students] What expectations from students are embedded in the ESD-related contents?

Table 4. Example of analyzing the content in the textbook

Content	As the temperature of the earth is rising due to carbon dioxide, the carbon footprint should be reduced. If you use a plastic bag, 11 grams of carbon are necessary. However, if you use a reusable shopping basket, no carbon is used. If you use a reusable shopping basket once a week, 52 weeks per year, how much carbon footprint can be reduced over a year? Also, think about ways we can use reusable shopping baskets more often. (MOE, 2020b, p. 30)		
Result of analysis	Macro	Grade level	3 rd grade
		Dimension-Related topic	Environment- Climate
	Micro	Mathematics content domain	Numbers and Operations
		Mathematical feature	To apply mathematics principles
		Expectation from students	Context for problem-solving and considering sustainability

reliability. Any inconsistencies in coding were clarified by discussion.

An analysis of the mathematical contents was carried out at both macro and micro level. At the macro level, general characteristics of the textbooks in terms of sustainable development were identified, detailing in what grade level the ESD-related contents were presented; to which dimension the ESD-related contents were related; to which mathematics content domain the ESD-related contents were connected; and what sub-contents and topics were presented in the ESD-related contents. In this study, the mathematics content domains were divided into Numbers and Operations, Geometry, Measurement, Pattern, and Data and Possibilities. At the micro level, mathematical features of the contents and the expectations from students were scrutinized. Mathematical features of the contents referred to whether the focused content was related to the introduction of mathematics or to the application of mathematics. The expectations from students denoted the cognitive requirement needed by students in performing activities: whether the ESD-related content of the activity was used as a sub-material or as a context for problem-solving or a context for considering sustainability along with problem-solving. [Table 3](#)

summarizes the aspects of investigation and focal questions in each analytic level.

To illustrate how the analysis of this study was implemented, an activity in the Korean mathematics textbook (MOE, 2020a) is used. The activity is to calculate how much the carbon footprint can be reduced if a reusable shopping basket is used instead of a plastic bag. The content is related to the climate topic included in the environmental dimension and is related to the Numbers and Operations mathematics content domain, intended for students to solve a given problem situation by applying the principles of calculating 2-digit \times 2-digit multiplication. [Table 4](#) shows an analysis of the content.

RESULTS

Our results show textbooks variations in presenting and structuring the ESD-related contents in the selected textbooks from the three countries. The following sections are structured to provide detailed findings corresponding to the research questions, respectively.

Overall Structure

[Table 5](#) summarizes the organization of the ESD-related contents reflected in the mathematics textbooks.

Table 5. Organization of the ESD-related contents in the textbooks

Country	Grade level	Dimension	Mathematics content domain
Japan	4th, 5th, 6th	Environment, society, economy	Numbers and Operations, Pattern, Data and Possibilities
Korea	3rd, 4th, 5th, 6th	Environment, society, economy	Numbers and Operations, Pattern, Data and Possibilities
Singapore	3rd, 5th, 6th	Environment, society, economy	Numbers and Operations, Pattern, Data and Possibilities

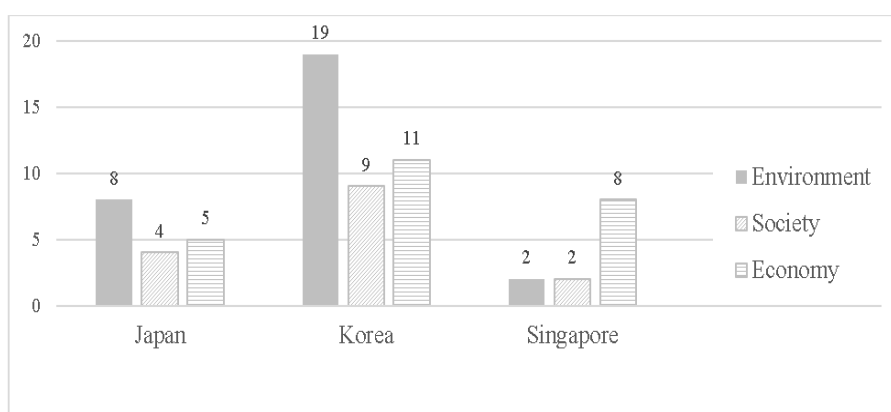


Figure 2. Frequencies of the ESD-related contents by dimension in the three countries

Table 6. Titles of units including ESD-related contents

Mathematics content domain	Textbooks		
	Japan	Korea	Singapore
Numbers and Operations	Multiplication of decimal numbers	Numbers equal or greater than ten-thousands Multiplication of whole numbers Multiplication of decimal numbers Division of whole numbers Division of decimal numbers Estimation	Money
	Division of whole numbers		Whole numbers
	Division of decimal numbers		Operations on whole numbers
	Estimation		Four operations on decimal numbers
Geometry	-	-	-
Measurement	-	-	-
Pattern	Finding patterns	Ratios and proportional relationships	Ratio
Data and Possibilities	Graph	Graph	Percentages
	Organization of data		Average
	Average		Pie chart
	Percentages		

In common, the ESD-related contents were repeatedly presented in the textbooks over several grades, starting from the third or fourth grade. Also, the contents related to environmental, social, and economic dimensions were presented in the textbooks, related mostly to mathematics content domains of Numbers and Operations, Pattern, and Data and Possibilities.

Figure 2 shows the frequencies of the ESD-related contents in the three countries by dimension. It should be noted that the purpose of the study is not for country-by-country comparisons, but for specific details of how the ESD-related contents are presented in the textbooks in each country. Both Japanese and Korean textbooks presented the contents related to the environmental dimension most frequently, whereas the Singaporean ones treated the contents related to the economic dimension most frequently. For all three countries, contents on the social dimension were the least presented. Although the ESD-related contents did not

account for much of the overall contents in the textbooks, it is positive that contents about all three dimensions of ESD were involved in the mathematics textbooks.

Table 6 shows the mathematics content domains and titles of units including the ESD-related contents. Regarding the mathematics content domains, most of the contents were related to Numbers and Operations, Pattern, and Data and Possibilities, while none were related to Geometry and Measurement. Regarding the domain of Numbers and Operations, the contents were usually about whole numbers, decimal numbers, and their operations. The content domain of Pattern involved the activities related to finding patterns and ratios. For the content domain of Data and Possibilities, the ESD-related contents were about representing or interpreting data. This reveals that the ESD-related activities were not addressed evenly in all the mathematics content domains.

Table 7. Distribution of sub-contents in the environmental dimension by country

Country	Natural resources	Energy	Climate change	Biodiversity	Environmental problems	Urban & rural environments	Disaster	Traffic pollution
Japan								
Korea								
Singapore								

Table 8. Contexts of the environmental dimension by grade level in the three countries

Country	3rd	4th	5th	6th
Japan	-	Endangered species Climatic differences between two regions Brushing teeth and water consumption	The amount of non-burnable garbage Deforestation Bottle garbage problem	Rain as a valuable water resource
Korea	Tree planting Turning off the faucet when brushing teeth Collecting wasted milk carbon and recyclable bottles Micro dust and tree planting Reducing carbon footprint	Daily water consumption Domestic water saving Paper use and wood consumption Micro dust days by year Change of annual peak temperature Greenhouse gas emission	Micro dust concentrations Increase in earthquake occurrence	Reusing bottles Ultrafine dust concentrations and ingredients Saving water by using a cup when brushing Electric car Eco-friendly products
Singapore	-	-	Water consumption	Destroyed trees

Table 9. Distribution of sub-contents in the social dimension by country

Country	Human rights	Peace and security	Cultural diversity	Social ethics	Human health	Gender equality	Media literacy	Globalization and international responsibility	Population
Japan									
Korea									
Singapore									

Distribution of the ESD-related Contents in the Textbooks

The ESD-related contents in the textbooks were classified into the sub-contents and their related topics as shown in Figure 1 and Table 2. As previously stated, since the sub-contents and their related topics of ESD are not focused solely on mathematics, there were the sub-contents that were not revealed in the mathematics textbooks. Table 7 shows the distribution of sub-contents in the environmental dimension by country. The shaded cells in Table 7 mean that the corresponding sub-contents are presented in the textbooks. Regarding the environmental dimension, all three countries included the contents related to natural resources. Both Japanese and Korean textbooks covered sub-contents of climate change and environmental problems. In each of the textbooks in Japan and Korea, contents about biodiversity and energy were dealt with respectively. These results imply that some sub-contents were combined with mathematics, while others were not. That is, it is assumed that some sub-contents such as natural resources, climate change, and environmental problems are relatively easy to connect to mathematics, compared to others such as urban and rural environments, disasters, and transportation problems.

Table 8 summarizes detailed contexts of the environmental dimension by grade level in the textbooks from the three countries. Some contexts were presented in common across two or three countries, while others were presented only in one country. Specifically, water conservation, forest destruction, and garbage problems were involved as problem contexts across two or three countries. For example, an activity in the Japanese textbook asked how much water would be wasted per day if water would run while brushing teeth. The Korean textbook proposed a problem of finding out how many trees would be planted at tree planting event, which was held as part of protecting the environment. The Singaporean textbook presented a context of calculating the amount of trees previously planted based on the amount of trees destroyed. Although the focus of these activities was to solve the problems using mathematical concepts or principles, it could provide opportunities for students to recognize environment issues and think about sustainable development.

Table 9 shows the distribution of sub-contents in the social dimension by the three countries. All the three countries covered the contents related to peace and security. Also, the Japanese and Korean textbooks included the contents related to human health, while the Japanese and Singaporean textbooks incorporated the contents related to population. Only the Korean

Table 10. Contexts of the social dimension by grade level in the three countries

Country	3rd	4th	5th	6th
Japan	-	Security accidents in school	Food and healthy life Security accidents in school	Low birth rate and aging population
Korea	Healthy life The amount of sugar in a drink	Decrease in the population and number of students in a village Culture diversity by country	-	Investigating rules for safety school life Fair distribution
Singapore	-	-	-	World population distribution Security accidents in and around homes

Table 11. Distribution of sub-contents in the economic dimension by country

Country	Sustainable food production	Sustainable consumption	Sustainability of companies	Market economy	Narrowing the gap between the rich and the poor
Japan					
Korea					
Singapore					

Table 12. Contexts of the economic dimension by grade level in the three countries

Country	3rd	4th	5th	6th
Japan	-	Making-decisions as a wise consumer	Understanding change in prices Making-decisions as a wise consumer Saving money	-
Korea	Eating school meals and saving money Donation	International children’s sponsorship Donation	-	-
Singapore	Market play	-	Making-decisions as a wise consumer	Donation Charges for water consumption

textbooks included the contents related to cultural diversity and social ethics. Through these results, it could be surmised that some sub-contents of the social dimension are easily incorporated into mathematics; while other sub-contents such as human rights, gender equality, and media literacy are difficult.

Table 10 displays the contexts related to the social dimension by grade level in the three countries. While the Japanese and Korean textbooks presented the contexts related to the social dimension across several grades, the Singaporean textbook showed the contexts only in the sixth grade. Safety-related contexts were dealt with in all three countries. The Japanese textbook asked students to solve problems by analyzing two bar graphs showing the types and percentages of injuries which occurred in two schools. The Korean textbook included a pie chart displaying a result of investigation of the places where safety accidents occurred frequently in schools, followed by a table summarizing the survey results of rules that would be the most essential for safety in school life. The Singaporean textbook showed a pie chart with the causes of accidents in schools and homes. As both home and school are main places for elementary school students, understanding what kinds of safety accidents happen and finding solutions to live a safe life can provide them with a foundation for sustainable development. Furthermore, activities of investigating and analyzing information about safety can be connected with utilizing statistical data in mathematics.

Table 11 shows the distribution of sub-contents in the economic dimension by the three countries. Both Japanese and Singaporean textbooks included the contents related to sustainable consumption, while the Korean textbooks included the contents of sustainable food production and narrowing the gap between the rich and the poor. Compared to the other two dimensions, there were fewer sub-contents for the economic dimension addressed in the textbooks. This implies that connecting economy-related contents with mathematics may not be easy. In this respect, to analyze how the contents of the economic dimension are presented in the textbooks is significant.

Table 12 illustrates detailed contexts of the economic dimension by grade level in the three countries. Sustainable consumption, related to making decisions for finding more reasonable goods and preventing overspending, was included most frequently. These types of activities can give an opportunity for students to consider how to consume limited resources and reuse products for sustainable development. Regarding sustainable food production, the Korean textbook included an activity of calculating money saved when eating all school meals by suggesting the disposal cost of school meals. With reference to the situations of narrowing gaps between the rich and the poor, the Korean textbook suggested contexts in which students could raise money and donate it to neighbors in need.

Table 13. Frequencies of the ESD-related contents in terms of mathematical features and the expectations from students

Country	Mathematical features of the contents		Expectations from students		
	To introduce mathematics concepts, principles etc.	To apply mathematics concepts, principles etc.	Sub-visual material presenting an ESD-related situation without a problem	Context for problem-solving	Context for problem-solving and considering sustainability
Japan	6	11	3	10	4
Korea	22	17	1	31	7
Singapore	0	12	0	12	0

Table 14. Summary of activities in the Japanese textbooks expected for students both to solve problems and to consider ESD

Grade Unit title	Activity topic	Contents of activity	Relation to ESD
5-2 Percentages	A story in arithmetic: Lost forest	Calculate the percentages of forest decline by looking at the areas of forest in 2000 and 2005 in various regions Forecast area of the forest in 2020 based on the data	Recognize the benefits of forests. Anticipate the future of the forest. Have a mindset to protect forest
5-2 (after all units)	Waste reduction and carbon dioxide	Analyze the data about garbage presented in a bar graph, an angled line, and a circle graph Calculate the number of cedar trees based on the amount of carbon dioxide	Understand seriousness of the garbage problem. Confirm that incineration of waste leads to the generation of carbon dioxide, which is the main cause of global warming
6-1 (after all units)	Rain is a valuable resource	Interpret data about daily water use at home presented in a bar graph, a circle graph, and a table Calculate the amount of rainwater stored	After calculating how much water is used at home and how much rain is stored, make a commitment to use water carefully
6-2 Various graphs	Various graphs	Interpret the graphs about population of Japan in 1970 and 2005 Share what you noticed and predict the future of society	Understand the social changes: increase of low birth rate and the increase of aging. Have a mindset for a sustainable society

The contexts show potential to address the sustainability of the economic dimension in mathematics.

Connections of the ESD-related Contents with Mathematics

We analyzed connections of the ESD-related contents with mathematics in two aspects, both the mathematics features of the contents and the expectations from students. Regarding the mathematics features of the contents, we explored whether the ESD-related contents were employed to introduce mathematics or to apply it to mathematics. For the expectations from students, we examined whether the ESD-related contents were merely used as a sub-visual material presenting an ESD-related situation without a problem, or used as a context for problem-solving, or used to consider sustainability as well as problem-solving. Table 13 illustrates the results of analysis in the three countries.

Regarding the mathematical features of the ESD-related contents, the Korean textbooks showed a markedly different result than the Japanese and the Singaporean textbooks. That is, in the Korean textbooks, the ESD-related contents were presented more often as introduction activities than as application activities. In contrast, both Japanese and Singaporean textbooks included more activities of applying mathematical concepts to the problem situations. Contrary to the Korean and Japanese textbooks that contained both introduction and application activities, the Singaporean

textbooks covered only application activities. For instance, in the Korean textbook, the concept of a five-digit number was introduced in the unit, numbers equal or greater than ten-thousands, with the problem situation of donating ₩20,000 and ₩30,000 per month respectively by two families to support international children support organizations. In the Singaporean textbook, the problem in the unit of average was to find out how many cans one person picked up when the other person and another person picked up 18 cans and 12 cans respectively and the average number of cans picked up was 15. The ESD-related situation can be solved by utilizing the previously learned concept of mean. These examples reveal that ESD-related contents can be presented in various ways, such as when introducing or applying mathematical concepts.

Regarding the expectations from students, the percentage of contexts used for problem-solving was the highest for all three countries. It means that the main purpose of the activities with the ESD-related contents was to solve problems using mathematical concepts or principles. Examples of such activities were as follows: finding the amount of protein in food for a healthy diet in the Japanese textbook; computing the number of trees used in tree planting events as part of environmental protection in the Korean textbook; and identifying the price of water consumption to conserve water resources in the Singaporean textbook.

Table 15. Summary of activities in the Korean textbooks expected for students both to solve problems and to consider ESD

Grade Unit title	Activity topic	Contents of activity	Relation to ESD
3-1 Addition and subtraction	Exploratory mathematics: What should we do to live a healthy life?	Calculate how much calories we have in eating snacks Create exercise plans	Create exercise plans for a healthy lifestyle considering date, time, calories consumption, and types of exercise
3-2 Arrangement of data	Exploratory mathematics: Which drink should we choose?	Investigate how much sugar is in different beverages Represent the data in pictogram Share what you felt through the activity	Recognize the amount of sugar in beverages. Pledge to live a healthy life by drinking beverages with less sugar
4-1 Multiplication and division	Exploratory mathematics: How much paper are we using?	Calculate how many trees we need to make a textbook Share what you felt through the activity	Understand that many trees are needed to make paper. Share one's feelings by making advertisements or cartoons
4-2 Angled line graph	Exploratory mathematics: Let's look into our area	Investigate the number of elementary school students and the number of population in the area Choose a topic related our area and explore it Share what you felt through the activity	Choose an interesting topic related to our area (e.g., population, precipitation, student, environment, etc.). Organize research data and represent them in a graph. Endeavor to make our area sustainable
4-2 (after all units)	Seeing the world through mathematics	Explore the data presented greenhouse gas emissions in Korea Create posters to signal the dangers of global warming and talk about ways to reduce greenhouse gases	Recognize the trends in greenhouse gas emissions and the dangers of global warming and make a commitment to reduce them
6-1 Ratio and rate	Challenging mathematics: Let's read the environment through mathematics	Check the reuse status of bottles Calculate the increase in empty bottle deposits and pose a problem	Find the rate of reuse of empty bottles. Commit to reuse bottles to protect the environment
6-2 Proportional expression and proportional distribution	Challenging mathematics: Let's split it up fairly	Calculate the profits of two regions according to the different distribution methods respectively. Think about which is the fairest method Pose a problem that meets the conditions	Consider fair distribution and connect to sustainable society

Meanwhile, both Japanese and Korean textbooks included the activities to make students to consider sustainability as well as to solve problems. These types of activities first allowed students to solve mathematics problems and furthermore to think about sustainability inherent in the activities. This is meaningful in that it can give opportunities for students to understand sustainability and recognize the role of public participation in community from a perspective of sustainable development. Such activities were related to mainly environmental and social dimensions. The Japanese textbooks involved the activities four times. Table 14 summarizes the units, topics, contents of the activities, and relation to ESD in the Japanese textbooks. The themes of those activities were the reduction of forests, the waste problems, the precious resources of rain, and the low birthrate and aging society. These activities were commonly organized to solve the mathematics problems embedded in sustainability-related topics by activating the core mathematical concepts learned. The activities in the Japanese textbooks allowed students to fully understand the issues of sustainable development by explaining the focused

situations in detail or presenting various types of data. After analyzing the presented data in several ways, students had opportunities to share their thoughts on how to act for their sustainable future.

As for the Korean textbooks, the activities including both solving problems and considering sustainability were presented seven times. Table 15 summarizes the units, topics, contents of the activities, and relation to ESD in the Korean textbooks. The contexts related to healthy life, the amount of sugar in beverages, the trend of declining population and number of elementary school students in the region, greenhouse gas emissions, etc. Like the counterparts in the Japanese textbooks, the activities were related to mainly the environmental and social dimensions. The activities in the Korean textbooks asked students to engage in student-led activities such as making exercise plans, making posters, or investigating their own regions.

Looking closely at one of the activities presented in Table 14, an activity titled Lost Forest in the Japanese textbook was supposed to impart an understanding of the benefits of forests and to calculate areas of

deforestation by region. It explained that the area of forests was decreasing due to logging and forest fires despite lots of benefits of the forest and it could lead to global warming. The activity displayed forest areas in various regions in 2000 and 2005 in a table and asked students to calculate the percentages of the deforested areas and to put the calculation results in the blanks of the table. Furthermore, it posed a question to consider what would happen in the future if the forest was reducing in such a way.

As for the Korean activities presented in Table 15, the activity titled Seeing the World through Mathematics aimed at understanding the seriousness of greenhouse gas emissions in Korea by analyzing the data and making a poster to alert people to the dangers of global warming. It first presented the annual greenhouse gas emissions per capita in a table and a graph. Included was an explanation that greenhouse gases make the temperature of the earth as hot as a greenhouse and global warming is a phenomenon in which the earth gets hotter and hotter due to these greenhouse gases. The activity then directed students to compute greenhouse gas emissions per capita and the increase in greenhouse gas emissions from 1995 to 2015. Finally, students were to imagine what would happen if this continues and to create a poster to warn the risk of global warming. Both examples in Japanese and Korean textbooks presented ESD-related issues and gave an opportunity for students to anticipate what would happen if such issues continue. Predicting future is significant in order for students to recognize the seriousness of the sustainability-related issues and to make active participation possible.

Based on the results of the textbook analysis, the connection between sustainability and mathematics can be divided into two ways: passive way and active way. A passive way of connection is to present the issues of sustainable development mainly as the contexts or backgrounds for solving problems, and the opportunity to think further or discuss sustainability is not included explicitly in the activities. In contrast, an active way of connection is to provide detailed explanations about sustainability issues and to present students with sustainability-related activities. In this study, the Japanese and Korean textbooks showed differences in terms of active way of connection: The Korean textbooks focused more on recognition and active participation by students, while the Japanese textbooks focused more on analyzing related data and predicting future trends.

DISCUSSION

Given the importance of ESD in elementary school, this study showed that there were promising results on sustainable development in the mathematics textbooks of Japan, Korea, and Singapore. Some ESD-related activities presented in the textbooks provided opportunities for students not only to solve related

problems mathematically but also to connect them to sustainability. Based on the results, this study provides implications for guidance on ESD in elementary school mathematics.

More active and systematic ways to provide ESD need to be prepared in mathematics curricula and textbooks. This study revealed that the selected elementary mathematics textbooks in the three countries included the ESD-related contents of three dimensions of ESD: environment, society, and economy. Most of the contents were related to the mathematics content domains of Numbers and Operations, Pattern, and Data and Possibilities. On the one hand, these results are positive in that there is a possibility of implementing ESD in elementary school mathematics. On the other hand, there is much room to reflect ESD in mathematics curricula and textbooks more actively and systematically, given that most of the contents were related merely to the environmental dimension and served as the contexts for solving problems.

In order to effectively implement ESD in school mathematics, it is fundamental to reconstruct or reorient the mathematics curriculum. For example, the Australian Curriculum reoriented and emphasized sustainability as a priority of curriculum that connects related contents across learning strands and subjects (Australian Curriculum, 2015; Australian Curriculum Assessment and Reporting Authority, 2015). By prioritizing sustainability in the curriculum, students can have an opportunity to develop the knowledge, skills, values, and world views required to envision a more sustainable life. Mathematics also can be taught in relation to sustainability through a cross-curriculum priority, even though it is not a subject that deals directly with sustainability. According to the Australian curriculum, mathematical understanding and skills are essential in measuring, monitoring, and quantifying changes in ecological, social, and economic systems. Statistical analysis of data also enables to predict probable futures and to advise decision-making for preferred futures. In this regard, efforts should be made to reflect ESD in the mathematics curriculum to highlight the importance of sustainability and guide the direction.

A cautionary remark is that there is no guarantee that ESD-related contents will be implemented in lessons although they are stated in the curriculum document. According to UNESCO (2012), there are inconsistencies in the curriculum in which sustainability topics are presented but are not being taught. The reasons for this included: no obligation to incorporate sustainability into classroom activities; no recognition of the sustainability-related contents by teachers; and lack of teaching skills to implement ESD (UNESCO, 2012). In this respect, we need to find various ways to make ESD more viable and implementable in lessons, such as the development of mathematics textbooks connected directly to

sustainability or the supply of teacher manuals including the significance of ESD and illustrative teaching strategies that can be embedded in mathematics lessons.

Another related aspect involves the necessity for a specific framework to incorporate ESD more systematically in mathematics textbooks. The results of this study showed that the ESD-related contents were included in the selected textbooks, even though the textbooks did not stand for ESD explicitly. The results of this study also showed that both a passive and an active way were employed in connecting mathematics to ESD in the textbooks. While the former provided opportunities for students to encounter sustainable development while learning mathematical concepts and principles, the latter provided opportunities for them to understand and take account of ESD in depth beyond solving the given problems. Which method is more practical or effective may be different depending on how each country would like to incorporate ESD to mathematics textbooks. Nevertheless, what is clear is that the pros and cons of each method need to be understood and utilized in the process of developing textbooks.

Two aspects may be considered in developing mathematics-specific ESD frameworks. One is which mathematical contents will be extracted and organized in relation to ESD, and the other is how the contents will be presented in the textbooks. Regarding the ESD-related contents, the current study found that the contents in the three selected textbook series were involved in the mathematics domains of Numbers and Operations, Patterns, and Data and Possibilities. In other words, the ESD-related contents in Geometry or Measurement were not included in the textbooks. However, other studies introduced sustainable mathematics contents across more various domains. For instance, the Board of Studies New South Wales (2012) suggested the characteristics of mathematical contents for sustainability as follows:

“to measure and evaluate sustainability changes over time and develop a deeper appreciation of the world through such aspects of mathematics as patterning, three-dimensional space, symmetry and tessellations” (p. 42).

Serow (2015) also explained mathematical activities for ESD in detail across measurement, space and geometry, number, statistics, and patterns and algebra. This means that ESD can be linked in different domains of mathematics, leading us to select and organize more various mathematics content domains.

Regarding the presentation of the ESD-related contents in the textbooks, the current study demonstrated different aspects in terms of the cognitive efforts required by students. Some ESD-related contents were used to provide materials or contexts about

sustainability, while others were to require students to solve problems both mathematically and sustainably. The three selected textbook series of this study presented most ESD-related contents as sub-materials or contexts for problems. In-depth consideration of sustainability in mathematics lessons, which are already tight to deal mainly with mathematics contents, requires considerable time and effort. However, this seems essential, weighing the importance of attitude change and motivation of students in ESD development (Rode & Michelsen, 2008).

Of note is that this study did not aim to judge which textbook is the best one for teaching and learning sustainable development in elementary schools. As textbooks are usually regarded as an inseparable part of teaching and learning, the potential impact of textbooks on mathematics instruction cannot be ruled out. By focusing on the contents related to sustainable development in the textbook series, the study is expected to provide information how sustainable development is addressed in the Japanese, Korean, and Singaporean textbooks.

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