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Comparative Study of the Categorization of Items of Statistical Literacy in Mathematics textbooks of elementary, junior high, and high schools in Japan

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Abstract

There are many forms of statistical data; it is necessary for students to acquire reading comprehension and critical thinking skills for them to be able to judge the reliability of such data. The students' reading comprehension and critical thinking abilities pertaining to the assessment of statistical data decreased from the result of the PISA and TIMSS surveys [1] The purpose of this study was to quantitatively analyze a number of issues related to statistical literacy derived from mathematics textbooks in Japan's elementary schools, junior high schools, and high schools. Problems that focus on reading comprehension and critical thinking abilities seldom appear in elementary school arithmetic and junior high school and high school mathematics textbooks. Thus, in this paper, it is suggested that the decrease in reading comprehension and critical thinking skills is partly the result of the lack of opportunities that students have to solve problems that target these skills. For this reason, teachers must teach reading comprehension and critical thinking by using additional teaching materials.

Keywords: statistical literacy; statistical data; critical thinking abilities; reading comprehension; elementary school arithmetic textbooks; junior high school mathematics textbooks.

1 Introduction

There is a plethora of graphs and tables in newspapers, magazines, and other forms of media found on the Internet. However, not all statistical data reflect the facts accurately. Therefore, it is necessary for students to acquire reading comprehension and critical thinking skills in order to judge the reliability of such data. Koguchi et al. stated,"Results of a survey of actual conditions of graph reading for grade 3 junior high school students show that there is a tendency to make errors in judgment in the reading of bar graphs in which some data were omitted"[2].

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These trends are also reflected in the results of domestic and overseas academic research. The Programme for International Student Assessment (PISA) survey assesses whether individuals can solve real-world problems by using the knowledge and skills of 15-year-olds. The Trends in International Mathematics and Science Survey (TIMSS) evaluates knowledge and skills learned through the school curriculum for 10-year-old and 14-year-old children. Maki et al. thus analyzed the results of PISA and TIMSS surveys. Japanese students have a highly rated ability to read numerical values from tables and graphs. However, Japanese students' reading comprehension and critical thinking abilities required for the interpretation of graphs correctly are decreasing [1]. In Figure 1, the survey results for PISA 2015 are portrayed [3]. This bar graph shows the reading comprehension skills of students of OECD member countries. The vertical axis shows the average score, and the horizontal axis shows OECD member countries. In the survey results for PISA 2015, Japan's reading comprehension skills dropped to eighth place from being the world's fourth strongest.

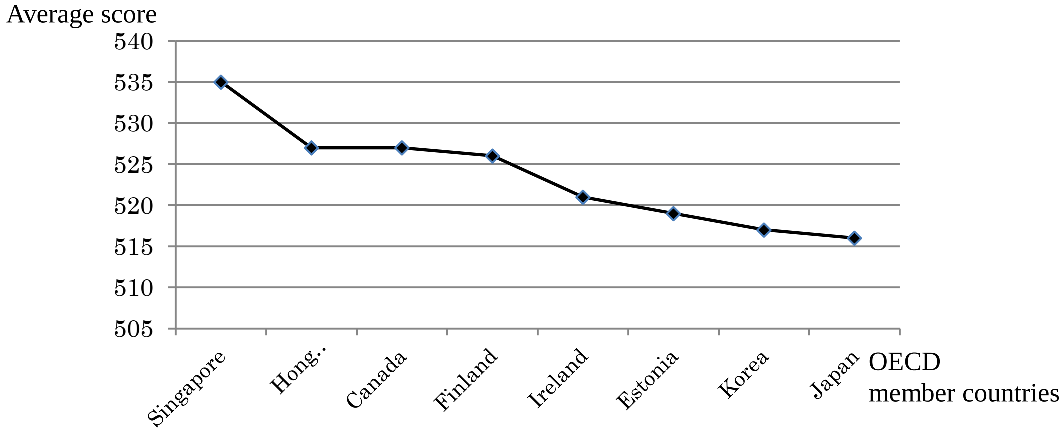


Figure 1: International Comparison of reading skills by the survey results of PISA2015

In Figure 2, the question in the 2003 PISA test is shown [4]. In this question, a portion of the graph scale was omitted.

ROBBERIES

A TV reporter showed this graph and said: "The graph shows that there is a huge increase in the number of robberies from 1998 to 1999."

QUESTION 15

Do you consider the reporter's statement to be a reasonable interpretation of the graph? Give an explanation to support your answer.

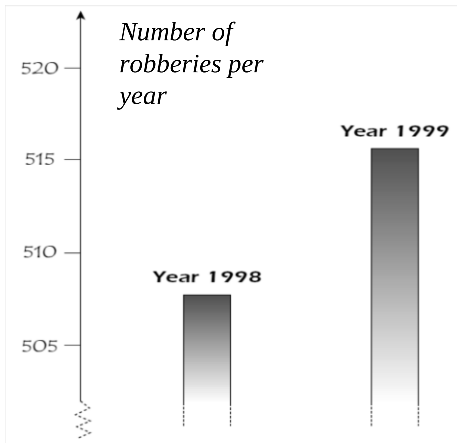


Figure 2: A sample of statistics related items used in PISA

The graph in this question was designed in such a way that the difference in the number of thefts for the year was made to look prominent; it was an example of the task of reading and critically interpreting the graph. The percentage of correct answers for this question was 25% for Japan, which was lower than the average percentage of correct answers for the 29 OECD countries [5].

2 Purpose of Study

The statistical literacy of Japanese students is high when it comes to the ability to read numerical values from tables and graphs and low in the case of the abilities of reading comprehension and critical thinking. In order to investigate the factors, I focused on mathematics textbooks of primary schools, junior high schools, and high schools in Japan. An explanation of Japan's School Textbook Examination Procedure is necessary. The School Education Law enacted in 1947 created the current system of textbook approval. Before a textbook is introduced as a part of school curriculum, it must go through several steps, including government examination and adoption after being compiled by textbook publishers.

According to the Ministry of Foreign Affairs of Japan, textbooks in Japan are produced through the following steps:

1. The publishing company brings together scholars and teachers to form a team to produce the textbook.
2. The team writes the textbook and discusses the editorial policy.
3. The publishing company submits the completed textbook to the Ministry of Education, Culture, Sports, Science and Technology (MEXT).
4. MEXT examines the submitted textbook based on the Textbook Examination Standards.
5. Textbooks that pass the examination are adopted by the Board of Education.
6. For compulsory education, textbooks that are adopted are distributed free of charge to students.

The Ministry of Foreign Affairs of Japan has explained this procedure, as shown in Table 1 [6].

Table 1: Japan's School Textbook Examination Procedure

1.Compilation

The current school textbook system is based on the authoring and compiling of textbooks by private sector publishers. Publishers compile the textbooks they issue on the basis of the courses of study, textbook examination standards, etc., as well as incorporating their own creativity and ingenuity. Once textbooks are completed, publishers apply for government examination.

2.Examination

Only textbooks that have passed an examination conducted by the Minister of Education, Culture, Sports, Science and Technology (hereinafter referred to as "the Minister") may be used in school curriculums. After the publisher of a textbook applies for examination, the textbook concerned is studied by textbook experts of the Ministry of Education, Culture, Sports, Science and Technology (MEXT). It is also referred to the Textbook Approval and Research Council, which is an advisory body to the Minister. The Minister examines the concerned textbook on the basis of the findings of the report submitted by the Council. The textbook examination standards form the basis upon which textbooks are screened to determine their suitability for inclusion in the school curriculum.

3.Adoption

In most cases, more than one approved textbook is available for each category (subject-based textbook classification unit, for example, "Elementary School Japanese Language (1st through 6th grade)," "Junior High School Social Studies (geography-related)," or "Senior High School Mathematics I"). Thus, each Board of Education must make a decision as to which textbook should be used for the schools. In the case of public schools (excluding national schools), the authority to select and adopt textbooks rests with the competent Board of Education at the local level. In the case of national and private schools, it is the principal who is authorized to select the textbook to be used at those schools. A report outlining the requisite number of textbooks adopted is submitted to the Minister.

4.Publishing

On the basis of the information submitted in the reports on the requisite number of textbooks, the Minister issues instructions to the publishers indicating which textbooks are to be published and the number of textbooks to be published. Based on the said instructions, publishers produce textbooks and supply them to schools through distributors. Students receive the textbooks from their schools.

5.Free Supply of Textbooks

The Government of Japan bears the cost of textbooks for all students at national, public, and private compulsory-level schools (elementary schools, junior high schools, and the first three years of integrated high schools and elementary and junior high divisions of schools for the blind, the deaf, and the disabled).

In essence, in Japan, textbooks are developed on the basis of the curriculum standards of education. Curriculum standards are determined by the course of study and the school education law. Therefore, although publishers may vary, the contents of the textbooks are the same. Accordingly, it is meaningful to conduct research on statistical literacy using textbooks. In previous research on textbooks, there are examples citing the domains of graphs and tables. For example, Kubo et al. analyzed the problems in arithmetic textbooks and identified many problems expressed by using tables, formulas, graphs, and figures, whereas they found very few problems related to social phenomena [7].However, the reality is that there are not enough studies conducted on issues that are identified from the number of problems in textbooks without being restricted to any specific statistical literacy and clarifying their causes.

The purpose of this research is thus explained. As reported in [1], Japanese students have high levels of ability in reading table and graph values as tasks related to statistical literacy but have low levels of reading comprehension and critical thinking abilities [1]. Therefore, the purpose of this study was to quantitatively analyze the number of issues related to statistical literacy in elementary school arithmetic textbooks and junior high school and high school mathematics textbooks to clarify the cause of these issues.

3 Method of Study

3.1 Definition of statistical literacy

The definition of statistical literacy employed in this study is the same as that used in [1]. The definition of statistical literacy assumed here is derived from that which was posited by Watson et al. of definition [8]. The model for statistical literacy defined by Watson et al. consists of three tiers (i.e., Watson's tiers. See Table 2).

Table 2: Watson's tiers

Tier 1: A basic understanding of statistical terminology.
Tier 2: Understanding of statistical language and concepts when they are embedded in the context of wider social discussion.
Tier 3: A questioning attitude one can assume when applying more sophisticated concepts to contradict claims made without proper statistical foundation.

3.2 Objects of research

The textbooks used in the present study were produced by two top companies. Company A and Company B's books are designated as "Textbook Group A" and "Textbook Group B," respectively. The junior high school mathematics textbooks were from the same publishing company that published the elementary school arithmetic textbooks. In addition, while the publication year of the elementary school arithmetic textbooks is 2010, the publication year of the junior high school and high school mathematics textbooks is 2011. However, the mathematics textbooks of high schools are denoted as mathematics I and mathematics II.

3.3 Items of investigation

3.3.1 Course of Study

In order to be able to receive a certain level of education irrespective of which area in the country one is receiving it, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) has established standards for formulating the course of study (curriculum) in each school based on the School Education Law [9]. This is referred to as the"Course of Study."

3.3.2 Items pertaining to the stages of Watson's tiers

Items related to statistics (hereafter, statistical items) were extracted from the mathematics [10],[11],[12] elementary, junior high, and high school Course of Study (Table 3, Table 4, and Table 5). Thereafter, we summarized the items related to Watson's Tier 1 from the statistical items and expressed the summarized items using symbols (Table 3, Table 4, and Table 5). Watson's Tier 1 consists of items that form the basic foundation of statistical literacy. However, in mathematics II, statistics-related items were not found.

Table 3: Course of Study for Japanese Elementary School: Mathematics ※1 Grade ※2 Symbol

※1	The statistics domain of the Course of Study	※2	Item about Tier 1
2	**Simple Tables and Graphs** To help pupils organize and classify numbers and quantities in everyday life, represent them by using simple tables and graphs, and interpret these representations.	Da Ta Gr	To sort and organize data. Represent the data by simple tables and interpret those data. Represent the data by simple graphs and interpret those data.

3	**Tables and bar graphs** To help pupils organize and classify data, represent them clearly by using tables and graphs, and interpret these representations. a. To get to know how to interpret and draw bar graphs.	Da Ta Gr	To sort and organize data. Represent the data by simple two-dimensional tables and interpret those data. Represent the data by bar graphs and interpret those data.
4	**Two quantities that vary simultaneously** To help pupils represent and explore the relationships between two numbers/quantities as they vary simultaneously. a. To represent how the numbers/quantities vary on a broken-line graph and to interpret the features of their variation. **Collecting, sorting, and organizing data** To help pupils gather and organize data according to their purposes, represent them clearly by using tables and graphs, and explore features of data. a. To explore features of the data by organizing the data from two perspectives. b. To get to know how to interpret and draw broken-line graphs.	Qu Da Ta Gr	Understand the relations between two quantities. Sort and organize data. Represent the data by tables with two perspectives and interpret those data. Represent the data by broken-line graphs, and interpret those data.
5	**Percentage** To help pupils understand percentage. Pie charts and percentage bar graphs To help pupils gather and organize data according to their purposes, represent them by using pie graphs and band graphs, and investigate features of data.	Ra Da Gr	Understand percentage and ratio. Collect data according to one's objectives and sort the data. Represent the data with pie charts and percentage bar graphs and interpret those data.
6	**Analyzing data** To help pupils determine the average of data and the distribution of data and to explore and represent the data statistically. a. To get to know the average of data. b. To get to know the tables and graphs that represent frequency distribution. **Possible outcomes** To help pupils analyze all the possible outcomes systematically for actual events.	Sa Sa Po	Understand the meaning of an average. Understand the meaning of a frequency distribution chart To investigate possible outcomes by organizing data.

Table 4: Course of Study for Japanese Junior High School: Mathematics ※1 Grade ※2 Symbol

※1	The statistics domain of the Course of Study	※2	Item about Tier 1
1	**Making Use of Data** To be able to collect data according to a purpose, arrange it into tables and graphs by using a computer and other means, and then read trends in the data by focusing on its representative values and its variations. a. To understand the necessity and meaning of the histogram and representative values. b. To grasp and explain trends in the data by using histograms and 4 representative values.	Da Gr Ta Re	Collect data according to one's objectives and sort the data. Represent graphs according to one's objectives from data, and interpret those data. Represent tables according to one's objectives from data and interpret those data. Understand the meaning of applying histograms and representative values.
2	**Making Use of Data** Through activities such as the observation of and experimentation on uncertain phenomena, to understand probability, and to be able consider and represent by using probability. a. To understand the necessity and meaning of probability and find the probability of an uncertain event in simple cases. b. To grasp and explain uncertain phenomena by using probability.	Pr	Understand the meaning of probability.
3	**Making Use of Data** Through selecting samples out of a population and exploring its trends by using a computer and other means so as to be able to understand that it is possible to read trends in the population. a. To understand the necessity and meaning of a sample survey. b. To carry out sample surveys in simple cases and grasp and explain trends in the population.	Sa Sa	Understand the necessity and meaning of a sample survey. To carry out sample surveys in simple cases and grasp and explain trends in the population.

Table 5: Course of Study for High School: Mathematics ※1 Grade ※2 Symbol

※1	The statistics domain of the Course of Study	※2	Item about Tier 1
1	**Analysis of data** To be able to understand the fundamental ideas of statistics and also be able to use them to organize and analyze data and understand trends. a. Understand the meaning of data distribution, quartile deviation, breakup, and standard deviation and be able to use these to understand and explain trends in data. b. Understand the meaning of data scatter diagrams and the meaning of correlation coefficients and be able to use these to understand and explain the correlation between two sets of data.	Da Re	To sort and organize data. Understand the representative values.

If we summarize the items related to Watson's Tier 1 from the above, we get Table 6. However, it was considered that summarizing items related to Watson's Tier 2 and Watson's Tier 3 from the statistical items is difficult as Watson's Tier 2 and Watson's Tier 3 do not consist of items occurring independently of each other. Therefore, Watson's Tier 2 was represented using the symbol □, and Watson's Tier 3 was represented using the symbol■.

Table 6: Items pertaining to the stages of Watson's tiers

	Item	Symbol
	Sort and organize data.	Da
	Represent the data by graphs, and interpret those data.	Gr
	Represent the data in tables, and interpret those data.	Ta
	Understand the quantitative relationships.	Qu
Tier 1	Understand percentage and ratio.	Ra
	Understand the meaning of representative values.	Re
	Organize possible outcomes.	Po
	Understand the meaning of probability.	Pr
	Understand the sample survey.	Sa
Tier 2		□
Tier 3		■

3.4 Survey method

3.4.1 Procedure

There were 21 elementary school arithmetic textbooks, including the prequels and sequels of all grades. Textbook Group A consisted of 11 books and Textbook Group B consisted of 10 books. Conversely, there were 6 junior high school mathematics textbooks when all the grades were included. In this case, Textbook Group A and Textbook Group B each had 2 books. There were 4 high school mathematics textbooks. In this case, Textbook Group A and B each had one textbook of mathematics I and mathematics II.

The problems extracted from the elementary school arithmetic textbooks were examples, exercises, and review questions. In this study, we analyzed problems according to the following procedures:

Procedure 1: We extracted problems related to statistical literacy from the elementary school arithmetic textbooks based on the statistical items of the Course of Study for Japanese Elementary School: Mathematics (Table 3).

Procedure 2: We selected the ability required to solve problems related to statistical literacy from the items pertaining to Watson’s tiers (Table 6) and categorized each item..

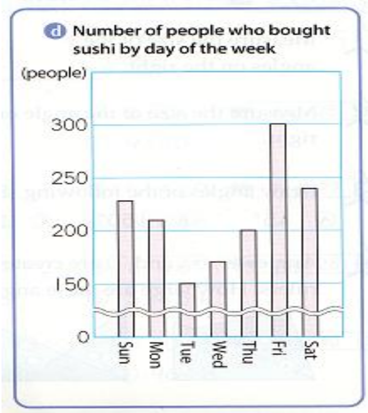
Procedure 3: The number of problems related to statistical literacy extracted through Procedure 1 was represented using a table and graph to analyze the characteristics of questions related to statistical literacy in elementary school arithmetic textbooks. Next, the number of items pertaining to Watson’s tiers categorized through Procedure 2 was represented using a table and graph to analyze the characteristics of items pertaining to statistical literacy in elementary school textbooks.

Our survey methods for the junior high school and high school mathematics textbooks were the same as those for the elementary school arithmetic textbooks.

3.4.2 Survey example

By drawing on the following examples, we described the procedure of categorizing the questions according to Watson's tiers using the problems in the textbooks. An example where Watson's tiers correspond to Tier 1 and Tier 3 is depicted in Figure 3 [12].

Mirai collected the information in the graph below at a nearby sushi restaurant.



Look at the documents above and answer the following questions.

Question1 : What day of the week was sushi sold most?

Question2 : Tsubasa looked at the graph and said:

Judging from the height of the bar graph, it looks like the number of people who bought sushi on Friday was about twice as many as the number who bought sushi on Thursday.

Is he right?

Answer by writing “correct” or “not correct.”

Explain the reason for your choice by using words and math sentences.

Excerpt of a portion of the problem from
KEIRINKAN Fun with MATH 4A for Elementary School, p. 130

Figure 3: Selected examples of items related to Watson’s hierarchy

Figure 3 is an excerpt of the problem from the elementary school fourth grade arithmetic textbook. The questions related to the problems were categorized on the basis of Watson's tiers. The results were as follows. Question 1 concerns interpreting the day of the week that sushi was sold the most from the bar graph. From this, Watson's tiers in Question 1 become Tier 1. Next, the items of Tier 1 become items for interpreting those data from the graph. Therefore, the items of Tier 1 can be represented by [Gr]. Question 2 is a problem in which part of the scale of the bar graph has been omitted so that the differences among the numbers of people eating sushi are visually misleading. Here, it is necessary for students to notice that the number of people who bought sushi on Friday is not twice the number of people who bought sushi on Thursday. Therefore, Question 2 will be categorized into the following two items. In the first case, in the context of Watson's tier, it is Tier 1. Then, the item in Tier 1 is the item to interpret those data from the graph, which can be represented by [Gr]. The second item is Tier 3 in Watson's tiers. This requires interpreting data from the graph critically so that it can be represented by [■]. Therefore, the survey result of Question 2 can be represented by [Gr] and [■].

4 Findings and analysis

4.1 A comparison of the total number of problems and the number of target problems

First, in this study, we investigated the total number of problems included in the elementary school arithmetic textbooks and junior high school mathematics textbooks. Then, we selected problems related to statistical literacy from the total number of problems on the basis of the procedure followed. In this case, selected problems were called target problems. In Table 7, the total number of problems and the number of target problems in the elementary school arithmetic textbooks are reflected. The total number of problems and the number of target problems in junior high school mathematic textbooks are also shown in Table 7. Based on this, regarding the number of target problems in elementary school arithmetic textbooks displayed in Table 7, Textbook Group B had 103 more than Textbook Group A. Therefore, there were differences in the number of target problems depending on the arithmetic textbook publisher. Conversely, regarding the number of target questions in elementary school arithmetic textbooks, Textbook A had 21 fewer than Textbook B. From this, it was observed that there was no significant difference in the number of target questions among the elementary school arithmetic textbooks of all the publishers.

Table 7: Number of problems and questions in mathematics textbooks of elementary school

Text Book	Problem	Grade1	Grade2	Grade3	Grade4	Grade5	Grade6	Grand total
A	Total	201	405	498	566	482	371	2523
	Target	1	4	19	34	75	40	173
B	Total	272	602	660	641	627	575	3377
	Target	4	13	33	58	93	75	276
Text Book	**Question**	**Grade1**	**Grade2**	**Grade3**	**Grade4**	**Grade5**	**Grade6**	**Grand total**
A	Total	478	1201	1409	1735	1182	968	6973
	Target	6	12	50	83	151	98	400
B	Total	800	1285	1879	1565	1412	1177	8118
	Target	5	17	45	94	147	113	421

Conversely, regarding the number of target problems in junior high school mathematics textbooks displayed in Table 8, Textbook Group B had 15 fewer than Textbook Group A. Therefore, there were no major differences in the number of target problems included by the mathematics textbook publishers for junior high school.

Regarding the number of target problems in high school mathematics textbooks, Textbook B had 4 less than Textbook A. From this, it was observed that there was no significant difference in the number of target problems in high school mathematics textbooks of all the publishers. Conversely, Textbook A had 15 fewer target questions in high school mathematics textbooks than did Textbook B.

Table 8: Number of problems and questions in mathematics textbooks of junior high school and high School

Text Book	Problem	Junior high school Grade7	Grade8	Grade9	Grand total	High school Grade8	Grade9	Grand total
A	Total	682	494	625	1801	297	474	771
	Target	58	48	34	140	24	2	26
B	Total	620	436	528	1584	315	408	723
	Target	48	54	23	125	30	0	30
Text Book	Question	Grade7	Grade8	Grade9	Grand total	Grade8	Grade9	Grand total
A	Total	1374	892	1275	3541	602	826	1428
	Target	85	64	46	195	38	4	42
B	Total	1481	788	1074	3343	683	724	1407
	Target	64	87	29	180	57	0	57

Note: Grade 8 is Mathematics Ⅰ, Grade 9 is Mathematics Ⅱ

The bar graph in Figure 4 represents the ratio of the number of target problems with respect to the total number of problems in each school year. Consequently, based on Figure 4, the ratio of the number of target problems increased from first grade up to fifth grade.

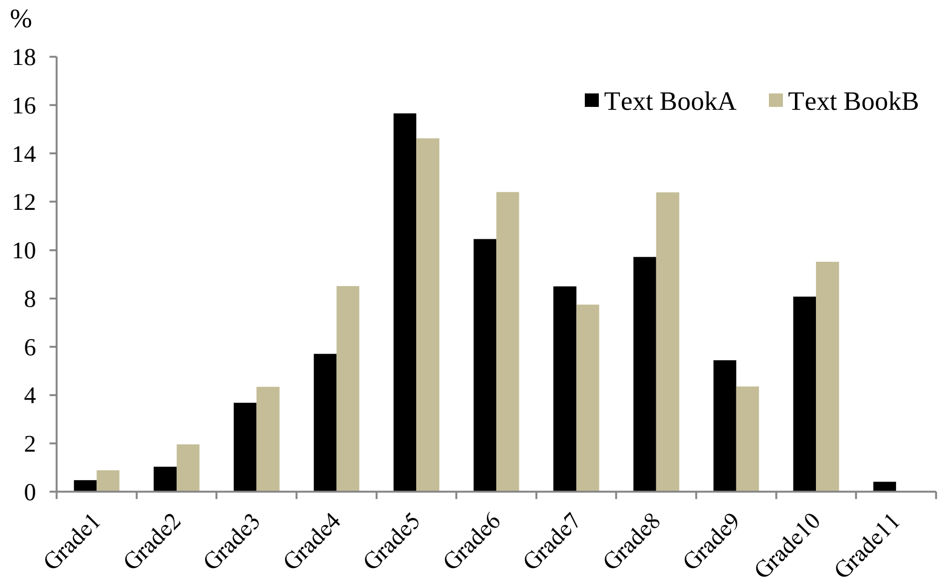


Figure 4: The ratio of the number of target problems with respect to the total number of problems

In addition, there was a decrease from the fifth grade of elementary school to the third grade of junior high school. It became clear that many problems related to statistical literacy were included in the elementary school fifth grade textbook.
Further, many problems related to statistical literacy were not included in the textbooks used in the third grade of junior high school.

However, one of the factors for the high percentage in junior high grade 2 and senior high grade 1 mathematics textbooks could be the increase in problems due to the utilization of materials in junior high school (probability) and the analysis (creation of scatter diagrams and correlation coefficients) of data in high school mathematics textbook 1.

4.2 Comparison of each items of Watson's tiers

In Table 9, the items related to Watson's tiers based on target problems in Table 2 are reflected. The numbers in parentheses in Table 9 show the ratio of the number of each item to the total number of items. From Table 9, Textbook Group B with regard to elementary school arithmetic textbooks had 29 more items than Textbook Group A. Textbook Group B with regard to junior high school mathematics textbooks had 21 fewer items than Textbook Group A. Regarding the total number of items for high school, Textbook B had 18 items more than Textbook A. From this, with the exception of high school, there was no large difference in the total number of items in terms of Watson's tiers depending on the textbook publisher. In addition, there were more than 100 items of [Ta] and [Gr]. The highest numbers of these items were found in the items of the elementary school arithmetic textbooks. In two elementary school arithmetic textbook publishers, the maximum value of items [Ta] was 25%. The items of [Gr] were 20% or more. Conversely, the item in [■] was less than 2%. Furthermore, items in [Da] and [Gr] were less than 5%.

Table 9: Comparison of each item of Watson's tiers for the target problems

Symbol	Elementary school Textbook Group A	Elementary school Textbook Group B	Junior high school Textbook Group A	Junior high school Textbook Group B	High school Textbook Group A	High school Textbook Group B
Da	25(4.9)	23(4.3)	1(0.4)	5(1.9)	0(0.0)	3(4.2)
Ta	135(26.6)	155(28.9)	42(15.0)	44(17.1)	26(48.1)	14(19.4)
Gr	118(23.3)	108(20.1)	19(6.8)	19(7.4)	4(7.4)	0(0.0)
Qu	39(7.7)	45(8.4)	11(3.9)	2(0.8)	0(0.0)	0(0.0)
Ra	83(16.4)	73(13.6)	17(6.1)	14(5.4)	0(0.0)	4(5.6)
Po	25(4.9)	29(5.4)	13(4.7)	10(3.9)	0(0.0)	0(0.0)
Re	23(4.5)	25(4.7)	60(21.5)	57(22.1)	23(42.6)	42(58.3)
Pr	0(0.0)	0(0.0)	41(14.7)	62(24.0)	0(0.0)	0(0.0)
Sa	0(0.0)	0(0.0)	15(5.4)	15(5.8)	0(0.0)	0(0.0)
□	50(9.9)	68(12.7)	53(19.0)	29(11.2)	1(1.9)	7(9.7)
■	9(1.8)	10(1.9)	7(2.5)	1(0.4)	0(0.0)	2(2.8)
Grand total	507(100)	536(100)	279(100)	258(100)	54(100)	72(100)

For two junior high school mathematics textbooks publishers, the maximum value item [Re] was 20%. Item [Ta] was 15% or more. On the other hand, item [■] was less than 3%. Items [Da], [Qu], and [Po] were less than 5%. The ratio of items in the elementary school arithmetic textbooks, the ratios of items [■], [Re], and [Da], were significantly lower than the ratios of items [Ta] and [Gr]. The ratios of items in the junior high school textbook, the ones regarding [■], [Da], [Qu], and [Po], were significantly lower than the ratios of items [Re] and [Ta]. In particular, the ratio of item [■] was the lowest in the elementary school arithmetic textbooks and junior high school mathematics textbooks. Regarding the percentage of items related to Watson's tiers in high school textbooks, the total number of items of the symbols [Ta] and [Re] accounted for 83%. Problems related to symbol [Ta] and [Re] were published in “Data Analysis” in Mathematics 1. Furthermore, symbols [Gu], [Ra], and [□] had significantly decreased when compared with elementary and junior high school, and symbol [■] was less than 2% for elementary, junior, and senior high school.

5 Summary and Future tasks

Maki et al. revealed that in the PISA and TIMSS surveys, the percentage of correct answers to problems related to items [□] and [■] tends to be low[1]. In order to investigate the cause, we quantitatively analyzed the data by classifying issues related to Watson’s stages from mathematics textbooks in Japan's elementary schools and junior high schools.

Results showed there were fewer issues related to items [□] and [■] in mathematics textbooks used in Japan’s elementary schools and junior high schools. When compared with those of elementary and junior high schools, high school mathematics textbooks tend to have an increased number of problems asking for averages. Opportunities for senior high grade 1 students to solve problems on average also increases, and the acquisition of knowledge required to understand averages can be expected. Conversely, as problems on percentages and critical thinking tended to decrease when compared with elementary and junior high schools, opportunities for senior high grade 1 students to solve problems on percentages decrease; this suggests a progressive decline in critical thinking abilities and the ability to understand percentages.

In other words, decreased reading comprehension and critical thinking abilities among Japanese students is perhaps due to there being fewer opportunities to solve problems targeting reading comprehension and critical thinking abilities.

In brief, results showed that there are few opportunities to experience diverse practical applications involving reading comprehension of statistical data in arithmetic and mathematics classes. Therefore, we believe that increasing opportunities to read and understand statistical data outside of arithmetic and mathematics classes would contribute to solving this deficiency.

For example, the social studies textbooks for grade 5 contain many tables and graphs showing automobile production volume and so on. Therefore, improvements in reading comprehension and critical thinking ability of children can be expected by repeatedly reading and examining the tables and graphs for short periods at the beginning of the lesson in social studies classes. Thus, from the results obtained in this study, curriculum management to link the subjects of arithmetic and mathematics with other subjects is desirable for improving the reading comprehension and critical thinking ability of children and students.

A task for the future will be to implement classes that link the subjects of arithmetic and mathematics with the subject of social studies and verify the results. Moreover, in the future, by comparing Japanese textbooks and foreign textbooks, we will examine the statistical literacy of domestic and foreign students.

References

[1] S. Maki and T. Horita, “Japanese Students' Actual Conditions of Statistical Literacy on the TIMSS, PISA and National Assessment Test.” Education Information Research, vol. 31, no. 3, 2015, pp. 13-22.

[2] Y. Oguchi, K. Aoyama, and Y, Fujii, “A survey on the reading of the graph of the third grade of junior high school students.” Journal of Japan Society of Mathematical Education, vol. 94, no.7, 2012, pp. 2-10

[3] National Institute for Educational Policy Research, “Programme for International Student Assessment. Summary of international research results in 2015,” Dec. 2016; https://www.nier.go.jp/kokusai/pisa/pdf/2015/03_result.pdf. (2017/09/29 accessed).

[4] Organisation for Economic Co-operation and Development, “A Profile of Student Performance in Mathematics”, Figure 2.13a, p. 82; http://www.oecd.org/edu/school/programmeforinternationalstudentassessmentpisa/33917867.pdf. (2017/9/29 accessed).

[5] Organisation for Economic Co-operation and Development, “Can you solve the problem of PISA?,” National Institute for Educational Policy Research, Akashi Shoten, p. 344.

[6] Ministry of Foreign Affairs of Japan, “How a Textbook Becomes Part of a School Curriculum,”; http://www.mofa.go.jp/mofaj/area/taisen/kentei.html.(2017/9/29 accessed).

[7] Y. Kubo and E. Nagasaki, “Comparison of Elementary school, junior high school and high school mathematics textbooks on connection between mathematics and society,” Mathematical education thesis presentation meeting, vol.35, pp. 115-120.

[8] J. Watson and B. Moritz, “Developing Concepts of Sampling,” Journal for Research in Mathematics Education, 2000, vol. 31, no.1, pp. 44-70.

[9] Ministry of education, “What is the Course of Study? ”; http://www.mext.go.jp/a_menu/shotou/new-cs/idea/1304372.htm .(2018/1/9 accessed).

[10] CRICED,University of Tsukuba, “Elementary School Teaching Guide for the Japanese Course of Study: Mathematics (Grade 1-6) with the English translation on the opposite page,” M. Isoda et al.,eds., Jan. 2010.

[11] CRICED,University of Tsukuba, “Junior High School Teaching Guide for the Japanese Course of Study: Mathematics (Grade 7-9) with the English translation on the opposite page,” M. Isoda et al.,eds., Jan. 2010.

[12].S.Shimizu et al., “Fun with MATH 4A for Elementary School” Shinko Shuppansha KEIRINKAN, Apr. 2012, p. 130.