Korean Students’ Responses to Non-Cognitive Variables Compared to Japanese and Singaporean Students Based on TIMSS Data

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Abstract

This study analyzed the responses of Korean students to interest, confidence, value, and instructional clarity in science and mathematics. To achieve this, the raw data of the recent student survey of TIMSS were analyzed. A one-way ANOVA was performed, and a post hoc test was performed. Additionally, a cohort analysis was performed to determine the changes when the fourth-grade students reached the eighth grade. The study results are as follows. First, interest and confidence were higher in the fourth grade than in the eighth grade. Second, in most cases, the average response of Singaporean students was the most positive, but in terms of interest and confidence in science in the fourth grade, the Japanese response average was generally the highest. Third, the average scores of Korean students on wanting to have a job related to their subject and knowing what teachers expect from them were low in both science and mathematics.

Keywords

Mathematics – science – interest – confidence – value – instructional clarity
1 Introduction

Mathematics and science are fundamental to understanding the world in which we live. With the ongoing Fourth Industrial Revolution – where communication is integrated with automation and smart technology – the ability to understand and utilize mathematics and science in particular is becoming increasingly important. Unfortunately, rapid social changes, such as the coronavirus disease pandemic, have raised concerns about the current school education and its ability to foster mathematics- and science-related capabilities (OECD, 2020). Educational practitioners worldwide are continuously seeking solutions to improve academic performance in these subjects. South Korea has also emphasized innovation in teaching and learning (Ministry of Science and ICT – Korea, 2021). However, in schools, students find these subjects relatively difficult compared with other subjects, and this has resulted in fewer students choosing science- and engineering-based careers.

Mathematics and science are essential for students aspiring to enter diverse fields, such as economics, science, technology, and engineering. They are also used in international academic achievement level assessments, such as the Trends in International Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA), which collects data on non-cognitive domains related to student achievement and provides information on how these relate to students’ academic achievement. The results are linked to the national educational contexts, such as social norms, value, and attitudes toward education (Mullis et al., 2020), making such assessments possible.

Thus, studies related to the TIMSS have analyzed the effects of various non-cognitive variables on cognitive achievement in mathematics and science based on the results of international academic achievement tests (Lay & Rajoo, 2020). These studies have also compared male and female achievement in these subjects (Luo et al., 2014). However, major non-cognitive variables, such as motivation, beliefs, and attitudes are not only considered major predictors of cognitive achievement and career choices, but also significantly affect personal growth (Wigfield et al., 1998). The information represented by these variables in the educational context is very significant in terms of the sustainability of the academic curriculum and careers. Nevertheless, although numerous studies have been conducted on non-cognitive areas in mathematics and science (e.g., Alexander et al., 2012; Mata et al., 2012), it is difficult to find studies that compare the non-cognitive features in these subjects. Consequently, many unanswered questions remain related to the characteristics of non-cognitive areas.
Recently, in Korea, levels of interest and confidence have been substantially lower than cognitive achievement in international academic performance. Considering that science and mathematics are core subjects that will be required to lead the intelligent information society of the future, low achievement levels in these academic areas in Korea have now emerged into public consciousness as issues that must be resolved to effectively restructure future educational practices (Ministry of Science and ICT – Korea, 2021). Therefore, this study analyzed the characteristics of South Korean students by selecting non-cognitive factors that are known or expected to be closely related to achievement in mathematics and science. Additionally, Japan and Singapore were selected as countries for comparative analysis.

TIMSS provides information that can compare education in each country in addition to cognitive achievement among participating countries. Japan and Singapore are countries that have shown excellent achievement in both science and mathematics, and both countries have recently revised their curricula. Japan has a similar educational environment to Korea, including the 6:3:3 school system, and is a powerhouse in basic science that has produced many Nobel Prize winners. Japan's curriculum was recently revised, with the new curriculum starting to be applied from 2020 (Ministry of Education, Culture, Sports, Science, and Technology – Japan, 2018). Singapore, similar to Korea, is a country with high enthusiasm for education and fierce competition for entrance exams. A competency-based curriculum was introduced in the late 1990s (Tan et al., 2017), and recently a new curriculum revision was implemented in line with the OECD 2030 (Ministry of Education – Singapore, 2020). Due to these similarities in curriculum focus and educational contexts, in this study, non-cognitive variables closely related to achievement in science and mathematics were selected and the responses of Korean students to these variables were analyzed by comparing them with those of Japanese and Singaporean students.

2 Theoretical Background

2.1 Non-Cognitive Variables: Interest, Confidence, Value, and Instructional Clarity

Improving students' attitudes toward learning is a major curricular goal for many countries, and an abundance of research has documented the relationship between student achievement and student attitudes (Mullis & Martin, 2017). Research on student attitudes is related to non-cognitive areas, and
attitudes toward mathematics and science commonly dealt with in the TIMSS comprise interest, confidence, and value (utility for the future). These are generally recognized as definitive domain variables (Mullis et al., 2020). Previous studies have found that positive attitudes, including beliefs, motivational tendencies, self-efficacy, and value toward mathematics and science can affect students' willingness to learn and perform (Mata et al., 2012). A positive attitude toward these subjects also increases both their importance and student learning (Mullis et al., 2020). The main non-cognitive variables that influence students' attitudes require a review of their interests, confidence, and value.

2.1.1 Interest
First, related to interests, learning motivations based on interest and pleasure are self-determining and intrinsic (Krapp & Prenzel, 2011). They influence student engagement, learning habits, and performance and are dependent on class activities and parents' motivation (Gottfried et al., 2009). Moreover, students with a high interest in mathematics or science show higher cognitive achievement than those who do not. Interest in mathematics is strongly correlated with learning achievement, and there is a positive relationship between students' enjoyment of mathematics and achievement in the same (Mullis et al., 2020).

2.1.2 Confidence
Second, confidence can be conceptualized as self-concept and self-efficacy (Bong & Clark, 1999). Self-concept reflects the current belief in one's ability generated within a particular domain, while self-efficacy reflects an individual's future-oriented belief in their ability to perform a particular action or achieve a particular outcome successfully (Bong & Skaalvik, 2003). In other words, self-efficacy relates to belief in one's ability to construct and successfully implement a course of action necessary to achieve a goal (Bandura et al., 1999). In the TIMSS, confidence in mathematics and science measures students' subject-specific self-concepts. Over the years, assessment results have consistently demonstrated a strong correlation between students' academic self-concept and cognitive achievement (Mullis et al., 2020). Self-efficacy is related not only to students' academic achievement, but also to career orientation and choice (Nugent et al., 2015). Teachers have also noted that students' lack of confidence needs to be resolved before assuming that growing interest in mathematics and science increases student participation (Sheldrake, 2016). Additionally, it has also been recognized that self-efficacy in these subjects is higher in male students than in female students (Louis & Mistele, 2012). A
marked difference also exists between male and female students in their confidence about understanding scientific information, discussing scientific issues, and explaining phenomena scientifically (OECD, 2016a).

2.1.3 (Perceived) Value
Third, value refers to the perceived or real benefits, rewards, and gains an individual recognizes as related to a task or activity and increases the likelihood of the individual participating in it (Eggen & Kauchak, 2010). Such expectations and perceived value of success are considered important factors for learning and academic achievement. Value are a key component of the OECD Learning Compass 2030, along with knowledge, skills, and attitudes, factors that help learners fulfill their potential (OECD, 2019). Value represent principles and beliefs that affect student choices, judgments, and behaviors on the path toward individual, social, and environmental welfare (OECD, 2020). Value are highly correlated with academic achievement. While mathematics is important in most occupational fields, as jobs in the future will certainly rely more heavily on quantitative reasoning skills (Lay & Rajoo, 2020), students’ perceptions of the value of mathematics and careers in it are declining (Mullis et al., 2020). Comparatively, most students have been shown to agree that studying science in school is valuable and positively perceive its academic and professional importance (Mullis et al., 2020). Students interested in science are more likely to pursue technical and scientific occupations. Therefore, information on whether students will choose careers related to science can be inferred from students’ perceptions of their value. The questions that make up the value of mathematics and science will provide specific information on the utility, importance, utilization plan, future career path, and thoughts on parents’ value in mathematics and science.

2.1.4 Instructional Clarity
Additionally, instructional clarity is one of the main factors that influence students’ learning. Instructional clarity refers to an instructor’s ability to clearly communicate math- and science-based content to help students understand and build knowledge (Chesebro & McCroskey, 1998). It has a significant impact on upper-grade student achievement (Snyder, 1991) and can be a powerful tool used by teachers to narrow classroom activities so that students can focus better. In the course of teaching and learning, instructional clarity allows students to recognize learning as a self-directed task, thus shifting the responsibility for learning from teachers to students (Ovbiagbonhia et al., 2019). The TIMSS views the ability to provide clear instruction as a key quality in teachers and examines students’ perceptions of effective instructional practices (Mullis et al.,
Instructional clarity requires clear presentation and appropriate structuring of concepts by teachers (Snyder, 1991). Teachers should also consider levels of student development, use appropriate examples, illustrations, and demonstrative materials to clarify explanations and learning objectives, and present summaries and exercises at the end (Borich, 2003). As such, instructional clarity helps students fully understand the content of the class, resulting in successful teaching, which in turn positively affects student achievement. Instructional clarity differs from interest, confidence, and value but is closely related to the way students experience class.

2.2 Educational Characteristics of Japan and Singapore

2.2.1 Japan

Japan has produced winners of Nobel Prizes in Physics, Chemistry, Physiology, and Medicine, and is the country with results in both mathematics and science that are most similar to Korea in TIMSS and PISA. In addition, Japan is a country with a similar educational environment to Korea. Japan follows the same 6-3-3 school system as Korea, and Korea’s subject system is also similar to that of Japan. The Japanese curriculum is revised about every 10 years, and the current curriculum, the New Learning Guidance, was announced in March 2017. The new curriculum was first applied in middle schools starting in 2021, and in high schools in 2022 (Ministry of Education, Culture, Sports, Science, and Technology – Japan, 2018).

Similar to Korea, Japan has tried to overcome the problems caused by education centered on entrance exams. To this end, a holistic education policy called Yutori education was implemented in 2002. This policy advocated education that avoided competition and emphasized creativity and autonomy. However, because of this policy, the decline in students’ academic ability and low achievement in PISA emerged as problems. Accordingly, in 2011, Japan gave up Yutori education and turned to education for strengthening academic abilities. Until 2012, Korea’s achievement results were relatively better on the PISA assessments than Japan, but on the PISA 2015 assessments, Japan ranked first in both science and mathematics among OECD member countries in Asia.

2.2.2 Singapore

More recently, Singapore has ranked first in both mathematics and science in international comparative studies such as TIMSS 2019 and PISA 2018. Many countries have shown interest in Singapore’s education system, as it consistently achieves the best results in international comparative evaluations such as TIMSS and PISA. Singapore has a high public enthusiasm for education, similar to Korea, but unlike Korea’s standardization policy which abolished
middle school entrance exams, Singaporean students must compete in middle school entrance exams and Singapore students are ranked using high-stakes assessments in elementary school. Singaporean students must take level tests whenever there is a change in school level, for example, in the sixth grade there is a graduation test and the placement for middle school is based on the results of student performance on this exam. Singapore and Korea share other similarities that may impact on education, including having both suffered a long colonial period and both countries have experienced rapid industrialization since the 1970s and now have become economically developed countries.

Since 2010, Singapore has established an education vision and implemented curriculum and education policies for developing competencies in the 21st century (Tan et al., 2017). Singapore's competency-based science education has reflected the international trend, following the revision of the secondary school curriculum in 2012, the elementary school curriculum in 2013, and a new revision of the secondary school curriculum in 2020 (Ministry of Education – Singapore, 2013, 2020). Additionally, it has aimed for the holistic development of students by emphasizing value and attitudes along with knowledge and skills in the curriculum.

2.3 Research Questions
Japan and Singapore were selected for comparison because these Asian countries showed excellent results in the TIMSS, were geographically close to South Korea, and had similar educational environments. Given these various similarities in approach to education and relatively similar student performance outcomes on international assessment measures in mathematics and science, it can be beneficial to conduct comparisons of students’ outcomes on various assessments in relation to different non-cognitive variables to better understand how students in each country compare in these areas. This study analyzed the characteristics of Korean students’ perceptions of interest, confidence, value, and instructional clarity, which are major non-cognitive variables for achievement in mathematics and science and compared Korean students’ perceptions with students from Singapore and Japan to better understand how these non-cognitive variables may influence on student performance in math and science. This study aimed to identify:

1. What is the difference between Korean students’ responses to interest, confidence, value, and instructional clarity in science and mathematics compared with Japanese and Singaporean students?
2. When fourth graders and eighth graders are compared, are there any differences in interest, confidence, and instructional clarity in science and mathematics?
3 Methods

This study compared the characteristics of South Korea with regard to the major non-cognitive factors related to teaching and learning science and mathematics by analyzing the TIMSS data of recent cycles. Teaching and learning variables commonly asked about in the student survey of science and mathematics of TIMSS were selected, and Korean students’ perceptions of each variable were compared with those of Japan and Singapore.

3.1 Data Set Used for Study
The raw data for this study were collected from the student questionnaires in the TIMSS 2019 International Database (Fishbein et al., 2021) and TIMSS 2015 International Database (Foy, 2017). Table 1 shows the TIMSS participants in South Korea, Japan, and Singapore.

3.2 Variables and Instrument
The TIMSS has been measuring student attitudes toward science and mathematics achievement since 1995. The TIMSS 2015 and TIMSS 2019 measured students’ attitudes through several scales, including interest, confidence, value, and instruction clarity (Mullis & Martin, 2017). These include common questions depending on the target grade and others that apply only to specific grades. There were 18 questions in the fourth grade and 26 questions in the eighth grade, and each question included sub-questions according to the context. In this study, among the teaching and learning variables expected to be significantly related to student cognitive achievement in the TIMSS student

| Table 1 | Study sample |
|---------|--------------|
| **Country** | **Grade** | **TIMSS 2015** | **TIMSS 2019** |
| | | **Number of schools** | **Number of students** | **Number of schools** | **Number of students** |
| Korea | Fourth | 149 | 4,669 | 151 | 3,893 |
| | Eighth | 150 | 5,309 | 168 | 3,861 |
| Japan | Fourth | 148 | 4,383 | 147 | 4,196 |
| | Eighth | 147 | 4,745 | 142 | 4,446 |
| Singapore | Fourth | 179 | 6,517 | 187 | 5,986 |
| | Eighth | 167 | 6,116 | 153 | 4,853 |
questionnaires, the questions commonly asked in mathematics and science were selected. Survey questionnaires on interest, confidence, and value, which are variables related to student attitudes and cognitive achievement in science and mathematics subjects, were used to gather data. The questionnaire items of the TIMSS 2015 and TIMSS 2019 student surveys were slightly different, and the specific questionnaire items are shown in Table 2.

The reliability of the questionnaire for interest, confidence, value, and instructional clarity in science and mathematics was 0.81 to 0.95 in South Korea, 0.77 to 0.94 in Japan, and 0.75 to 0.94 in Singapore.

**Table 2** Composition of questions by subject and cycle

| Category | Item (4-point Likert Scale) | Science | Mathematics |
|----------|-----------------------------|---------|-------------|
|          |                             | 2015    | 2019        | 2015    | 2019        |
| Interest |                             | 4th     | 8th         | 4th     | 8th         | 4th     | 8th         | 4th     | 8th         |
| 1.       | I enjoy learning science/   | ○ ○ ○ ○ | ○ ○ ○ ○     | ○ ○ ○ ○ | ○ ○ ○ ○     |
|          | mathematics.                |         |             |         |             |         |             |         |             |
| 2.       | I wish I did not have to    | ○ ○ ○ ○ | ○ ○ ○ ○     | ○ ○ ○ ○ | ○ ○ ○ ○     |
|          | study science/mathematics.  |         |             |         |             |         |             |         |             |
| 3.       | Science/mathematics are     | ○ ○ ○ ○ | ○ ○ ○ ○     | ○ ○ ○ ○ | ○ ○ ○ ○     |
|          | boring.                     |         |             |         |             |         |             |         |             |
| 4.       | I learn many interesting    | ○ ○ ○ ○ | ○ ○ ○ ○     | ○ ○ ○ ○ | ○ ○ ○ ○     |
|          | things in science/          |         |             |         |             |         |             |         |             |
|          | mathematics.                |         |             |         |             |         |             |         |             |
| 5.       | I like science/mathematics. | ○ ○ ○ ○ | ○ ○ ○ ○     | ○ ○ ○ ○ | ○ ○ ○ ○     |
| 6.       | Science/mathematics are     | ○ ○ ○ ○ | ○ ○ ○ ○     | ○ ○ ○ ○ | ○ ○ ○ ○     |
|          | two of my favorite subjects.|         |             |         |             |         |             |         |             |
| 7.       | I like to solve math        | ○ ○ ○ ○ | ○ ○ ○ ○     | ○ ○ ○ ○ | ○ ○ ○ ○     |
|          | problems/I like to conduct  |         |             |         |             |         |             |         |             |
|          | science experiments.        |         |             |         |             |         |             |         |             |
| 8.       | I look forward to math      | ○ ○ ○ ○ | ○ ○ ○ ○     | ○ ○ ○ ○ | ○ ○ ○ ○     |
|          | class/I look forward to     |         |             |         |             |         |             |         |             |
|          | learning science in school. |         |             |         |             |         |             |         |             |
| 9.       | I like any schoolwork that  | × × × × | ○ ○ ○ ○     | ○ ○ ○ ○ | ○ ○ ○ ○     |
|          | involves numbers.           |         |             |         |             |         |             |         |             |
| 10.      | Science teaches me how     | ○ ○ ○ ○ | ○ × × ×      | ○ × × × | ○ × × ×     |
|          | things in the world work.   |         |             |         |             |         |             |         |             |
| Category | Item (4-point Likert Scale)                                                                 | Science | Mathematics |
|----------|-------------------------------------------------------------------------------------------|---------|-------------|
|          |                                                                                          | 2015    | 2019        | 2015    | 2019    | 2015    | 2019    | 2015    | 2019    |
|          |                                                                                          | 4th     | 8th         | 4th     | 8th         | 4th     | 8th         | 4th     | 8th         |
| Confidence | 11. I usually do well in science/mathematics.                                            | o       | o           | o       | o           | o       | o           | o       | o           |
|          | 12. Science/mathematics are more difficult for me than for many of my classmates.        | o       | o           | o       | o           | o       | o           | o       | o           |
|          | 13. Science/mathematics is not one of my strengths.                                       | o       | o           | o       | o           | o       | o           | o       | o           |
|          | 14. I learn things quickly in science/mathematics.                                        | o       | o           | o       | o           | o       | o           | o       | o           |
|          | 15. My teacher tells me I am good at science/mathematics.                                 | o       | o           | o       | o           | o       | o           | o       | o           |
|          | 16. Science/mathematics are harder for me than any other subject.                         | o       | o           | o       | o           | o       | o           | o       | o           |
|          | 17. Science/mathematics make me confused.                                                 | o       | o           | o       | o           | o       | o           | o       | o           |
|          | 18. I am good at working out difficult science/mathematics problems.                      | x       | o           | x       | o           | o       | o           | o       | o           |
|          | 19. Mathematics makes me nervous.                                                         | x       | x           | x       | x           | o       | o           | o       | o           |
| Value    | 20. I think learning science/mathematics will help me in my daily life.                   | x       | o           | x       | o           | x       | o           | x       | o           |
|          | 21. I need science/mathematics to learn other school subjects.                            | x       | o           | x       | o           | x       | o           | x       | o           |
|          | 22. I need to do well in science/mathematics to get into the university of my choice.    | x       | o           | x       | o           | x       | o           | x       | o           |
| Category | Item (4-point Likert Scale) | Science 2015 | Science 2019 | Mathematics 2015 | Mathematics 2019 |
|----------|-----------------------------|--------------|--------------|------------------|------------------|
|          |                             | 4th 8th      | 4th 8th      | 4th 8th          | 4th 8th          |
| 23.      | I need to do well in science/mathematics to get the job I want. | × ○ | × ○ | × ○ | × ○ |
| 24.      | I would like a job that involves using science/mathematics. | × ○ | × ○ | × ○ | × ○ |
| 25.      | It is important to learn about science/mathematics to get ahead in the world. | × ○ | × ○ | × ○ | × ○ |
| 26.      | Learning science/mathematics will give me more job opportunities when I am an adult. | × ○ | × ○ | × ○ | × ○ |
| 27.      | My parents think that it is important that I do well in science/mathematics. | × ○ | × ○ | × ○ | × ○ |
| 28.      | It is important to do well in science/mathematics. | × ○ | × ○ | × ○ | × ○ |
| Instructional Clarity | 29. I know what my teacher expects me to do. | ○ ○ ○ ○ ○ ○ ○ ○ |
|          | 30. My teacher is easy to understand. | ○ ○ ○ ○ ○ ○ ○ ○ |
|          | 31. My teacher has a clear answer to my questions. | ○ ○ ○ ○ ○ ○ ○ ○ |
|          | 32. My teacher is good at explaining science/mathematics. | ○ ○ ○ ○ ○ ○ ○ ○ |
|          | 33. My teacher does a variety of things to help us learn. | ○ ○ ○ ○ ○ ○ ○ ○ |
|          | 34. I am interested in what my teacher says. | ○ ○ × × ○ ○ × × |


3.3 Data Analysis

First, a one-way ANOVA was performed on the overall mean of TIMSS 2015 and TIMSS 2019 for variables of interest, confidence, value, and instructional clarity in science and mathematics. This was performed to identify the average response trends of Korean students to non-cognitive variables in two cycles and to compare them between subjects. Additionally, for in-depth analysis, a one-way ANOVA was conducted for each item, focusing on common questions in TIMSS 2019 in science and mathematics. This was conducted to examine the characteristics of Korean students revealed in the specific item analysis. When the main effect was significant in the one-way ANOVA, a post-hoc test (Scheffe) was performed to confirm the specific differences between countries.

Second, a cohort analysis was performed to determine whether there was any change between the responses of Korean fourth graders and eighth graders. Since the TIMSS study provides a cohort between two cycles with a difference of 4 years, cohort analysis is possible (Mullis et al., 2017). The fourth

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Table 2: Composition of questions by subject and cycle (cont.)

| Category | Item (4-point Likert Scale)                                                                 | Science | Mathematics |
|----------|------------------------------------------------------------------------------------------|---------|-------------|
|          |                                                                                         | 2015    | 2019        |
|          |                                                                                         | 4th     | 8th         | 2015 | 8th         | 2019 | 8th |
| 35.      | My teacher gives me interesting things to do.                                            | ○ ○     | × ×         | ○ ○  | × ×         |
| 36.      | My teacher lets me show what I have learned.                                             | ○ ○     | × ×         | ○ ○  | × ×         |
| 37.      | My teacher tells me how to do better when I make mistakes.                               | ○ ○     | × ×         | ○ ○  | × ×         |
| 38.      | My teacher listens to what I have to say.                                                | ○ ○     | × ×         | ○ ○  | × ×         |
| 39.      | My teacher links new lessons to what I already know.                                     | × ○     | × ○         | × ○  | × ○         |
| 40.      | My teacher explains a topic again when we don't understand.                             | × ×     | × ×         | × ×  | × ×         |

Note: ○: included, ×: not included

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graders of the TIMSS 2015 became eighth graders in the TIMSS 2019, and a cohort group was formed, with a cohort analysis of students’ interest, confidence, and instruction clarity in science and mathematics being possible. The TIMSS 2015 and TIMSS 2019 did not have the same composition of survey questions for each variable; in the cohort analysis, referring to the previous TIMSS studies (Meinck & Brese, 2019), all items corresponding to each variable were included in the overall mean comparison, and a t-test was performed. In addition, while performing cohort analysis, a t-test was also performed on the overall average of male and female students to see if there was a difference.

For comparison between countries, the results for South Korea, Japan, and Singapore were compared by applying the weights provided by the TIMSS. Survey response data were coded on a 4-point Likert scale, and responses to negative questions were reverse-coded. The content and coding standards of the Likert scale for positive and negative questions according to the context of the survey questions were as follows:

- Positive items: 1 = disagree a lot, 2 = disagree a little, 3 = agree a little, 4 = agree a lot
- Negative items: 1 = agree a lot, 2 = agree a little, 3 = disagree a little, 4 = disagree a lot

4 Results

To determine the overall trend by variable in the TIMSS 2015 and TIMSS 2019, a one-way ANOVA was performed to determine the overall average score by variable and the difference by country. Tables 3 and 4 present the results for interest, confidence, value, and instructional clarity in science and mathematics. Table 3 shows the results of the fourth grade, and Table 4 shows the results of the eighth grade.

Table 3 shows that fourth graders’ overall average scores for interest and confidence in science and mathematics were similar in TIMSS 2015 and TIMSS 2019. In all three countries, the average score of interest and confidence in science was higher than that in mathematics. In terms of interest and confidence in science, Japan was overall very positive. Interest and confidence in science were high in Japan and interest was statistically significantly more positive than in Korea and Singapore in 2019. Confidence was statistically significantly higher in Japan than in Korea and Singapore in both cycles. Interest in science had the lowest score in Korea, but confidence in science had the lowest score in Singapore. In terms of interest and confidence in mathematics, Singapore
Table 3: Mean score difference in non-cognitive variables in the fourth grade

| Variables       | Subject | Year | Mean (SD)  | F      | p   | Post-hoc test |
|-----------------|---------|------|------------|--------|-----|---------------|
|                 |         |      | KOR (JPN)  |        |     |               |
| Interest        | Sci     | 2015 | 3.24 (0.65) | 3.39 (0.63) | 3.41 (0.65) | 6,956.19 | 0.00 | SG > JP > KR |
|                 |         | 2019 | 3.17 (0.67) | 3.38 (0.61) | 3.34 (0.65) | 19,485.65 | 0.00 | JP > SG > KR |
| Math            | 2015    |      | 2.77 (0.74) | 2.91 (0.75) | 3.09 (0.78) | 7,811.31 | 0.00 | SG > JP > KR |
|                 | 2019    |      | 2.73 (0.80) | 2.96 (0.73) | 3.07 (0.78) | 9,040.59 | 0.00 | SG > JP > KR |
| Confidence      | Sci     | 2015 | 2.92 (0.60) | 3.02 (0.59) | 2.89 (0.74) | 7,769.88 | 0.00 | JP > KR > SG |
|                 |         | 2019 | 2.90 (0.59) | 3.08 (0.57) | 2.84 (0.71) | 4,820.06 | 0.00 | JP > KR > SG |
| Math            | 2015    |      | 2.68 (0.56) | 2.56 (0.56) | 2.71 (0.60) | 4,868.30 | 0.00 | SG > KR > JP |
|                 | 2019    |      | 2.68 (0.56) | 2.60 (0.55) | 2.75 (0.61) | 29,993.55 | 0.00 | SG > KR > JP |
| Instructional  Clarity | Sci     | 2015 | 3.09 (0.62) | 3.00 (0.65) | 3.40 (0.59) | 7,578.38 | 0.00 | SG > KR > JP |
|                 |         | 2019 | 3.21 (0.57) | 3.21 (0.60) | 3.47 (0.58) | 8,156.12 | 0.00 | SG > KR, SG > JP |
| Math            | 2015    |      | 3.06 (0.57) | 3.02 (0.59) | 3.39 (0.54) | 9,704.25 | 0.00 | SG > KR > JP |
|                 | 2019    |      | 3.25 (0.51) | 3.23 (0.55) | 3.51 (0.52) | 6,635.10 | 0.00 | SG > KR, SG > JP |

Note: SD, standard deviation. KOR = South Korea; JPN = Japan; SPG = Singapore.

was very positive, in the order of interest: Singapore > Japan > Korea, and in confidence, Singapore > Korea > Japan. In the case of instructional clarity, there was an increase in the average scores of the TIMSS 2019, although there are limitations in interpreting and comparing these scores to the TIMSS 2015 because the number of questions differed between the surveys.

Table 4 shows that eighth graders’ overall average scores for interest, confidence, value, and instructional clarity in science and mathematics were similar in TIMSS 2015 and TIMSS 2019. Singapore was found to be statistically significantly more positive than Korea and Japan in all variables in eighth-grade science and mathematics. Compared with Table 3, the average score of all variables decreased compared with the fourth grade in all three countries. In the fourth grade, Japanese scores in science were often high, but this tendency disappeared in the eighth grade. In Table 3, the average scores of interest and confidence in science in all three countries were higher than those in mathematics. In the eighth grade, only interest in science was higher than in mathematics. Confidence in science decreased significantly compared with the fourth graders, and in Korea, the average score of confidence in science was
Table 4  Mean score difference in non-cognitive variables in the eighth grade

| Variables | Subject | Year | Mean (SD) | F      | p      | Post-hoc test |
|-----------|---------|------|-----------|--------|--------|---------------|
|           |         |      | KOR       | JPN    | SPG    |               |
| Interest  | Sci     | 2015 | 2.55 (0.70)| 2.72 (0.70)| 3.20 (0.66)| 24,936.54   | 0.00 | SG > JP > KR |
|           |         | 2019 | 2.58 (0.71)| 2.76 (0.69)| 3.19 (0.64)| 19,485.65   | 0.00 | SG > JP > KR |
| Math      |         | 2015 | 2.36 (0.74)| 2.39 (0.74)| 2.82 (0.79)| 8,493.96    | 0.00 | SG > JP > KR |
|           |         | 2019 | 2.32 (0.74)| 2.43 (0.74)| 2.79 (0.78)| 9,040.50    | 0.00 | SG > JP > KR |
| Confidence| Sci     | 2015 | 2.32 (0.67)| 2.30 (0.64)| 2.70 (0.70)| 8,321.93    | 0.00 | SG > KR > JP |
|           |         | 2019 | 2.40 (0.70)| 2.35 (0.64)| 2.67 (0.71)| 4,820.06    | 0.00 | SG > KR > JP |
| Math      |         | 2015 | 2.48 (0.59)| 2.23 (0.56)| 2.58 (0.62)| 42,302.61   | 0.00 | SG > KR > JP |
|           |         | 2019 | 2.48 (0.59)| 2.24 (0.56)| 2.57 (0.64)| 29,993.55   | 0.00 | SG > KR > JP |
| Value     | Sci     | 2015 | 2.70 (0.67)| 2.56 (0.65)| 3.23 (0.58)| 29,548.36   | 0.00 | SG > KR > JP |
|           |         | 2019 | 2.74 (0.70)| 2.65 (0.66)| 3.26 (0.61)| 17,519.60   | 0.00 | SG > KR > JP |
| Math      |         | 2015 | 2.82 (0.59)| 2.77 (0.58)| 3.20 (0.53)| 12,814.98   | 0.00 | SG > KR > JP |
|           |         | 2019 | 2.76 (0.65)| 2.81 (0.59)| 3.20 (0.55)| 9,203.68    | 0.00 | SG > JP > KR |
| Instructional Clarity | Sci | 2015 | 2.60 (0.67)| 2.63 (0.66)| 3.18 (0.60)| 16,764.47   | 0.00 | SG > JP > KR |
|           |         | 2019 | 2.84 (0.66)| 2.82 (0.66)| 3.26 (0.62)| 8,156.12    | 0.00 | SG > KR > JP |
| Math      |         | 2015 | 2.82 (0.59)| 2.77 (0.58)| 3.20 (0.53)| 15,488.74   | 0.00 | SG > KR > JP |
|           |         | 2019 | 2.76 (0.65)| 2.81 (0.59)| 3.20 (0.55)| 6,635.10    | 0.00 | SG > JP > KR |

Note: SD, standard deviation. KOR = South Korea; JPN = Japan; SPG = Singapore.

lower than that in mathematics. As for the value of the subjects, Singaporean students scored similarly in science and mathematics, but in Korea and Japan, mathematics scores were higher than science.

As for instructional clarity, scores improved in science as scores increased in 2019 in the fourth grade, but mathematics did not have a common feature among the three countries. Characteristically, Korea showed low interest in science and mathematics.

Related to interest in learning science and mathematics, Tables 5 and 6 show the results for students' responses to the question “How much do you agree with these statements about learning science/mathematics?”

Table 5 shows that fourth-grade students showed a higher interest in science than in mathematics. In Table 3, just as the fourth graders’ interest in science was statistically significantly positive in Japan, in terms of individual questions,
Japan’s response was the most positive and was similar to Singapore’s. In Korea, the average scores of “6. Mathematics is one of my favorite subjects,” “7. I like to solve Mathematics,” and “8. I look forward to mathematics class” were particularly low. Additionally, Korean students showed a large difference in the average score of responses between the science and mathematics in questions, “7. I like to solve mathematics problems/I like to conduct science experiments” and “8. I look forward to learning science in school.” In Questions 7 and 8, the score for mathematics was lower than that of Japan and Singapore, so the difference in scores in science subjects increased. In other words, Korean fourth

| Subject | Mean (SD) | F      | p     | Post-hoc test     |
|---------|-----------|--------|-------|-------------------|
|         | KOR       | JPN    | SPG   |                   |
| 1 Sci   | 3.19 (.82) | 3.48 (.71) | 3.34 (.81) | 24,513.02 | 0.00 | JP > SG > KR |
| Math    | 2.89 (.91) | 3.05 (.85) | 3.25 (.87) | 7,349.07  | 0.00 | SG > JP > KR |
| 2† Sci  | 3.22 (.80) | 3.54 (.69) | 3.18 (1.00) | 32,168.27 | 0.00 | JP > KR > SG |
| Math    | 3.02 (.93) | 3.39 (.78) | 3.12 (1.04) | 31,491.85 | 0.00 | JP > SG > KR |
| 3† Sci  | 3.20 (.82) | 3.54 (.70) | 3.23 (0.96) | 33,529.58 | 0.00 | JP > SG > KR |
| Math    | 2.88 (.94) | 3.27 (.82) | 3.10 (0.99) | 30,339.17 | 0.00 | JP > SG > KR |
| 4 Sci   | 3.31 (.76) | 3.47 (.74) | 3.56 (0.72) | 7,689.36  | 0.00 | SG > JP > KR |
| Math    | 2.99 (.85) | 3.05 (.85) | 3.36 (0.83) | 3,705.49  | 0.00 | SG > JP > KR |
| 5 Sci   | 3.09 (.90) | 3.35 (.84) | 3.29 (0.88) | 13,683.63 | 0.00 | JP > SG > KR |
| Math    | 2.73 (1.01) | 2.92 (.98) | 3.18 (0.95) | 8,097.77  | 0.00 | SG > JP > KR |
| 6 Sci   | 2.81 (.98) | 3.29 (0.98) | 3.19 (0.91) | 44,395.50 | 0.00 | JP > SG > KR |
| Math    | 2.62 (.95) | 2.76 (0.90) | 2.94 (1.12) | 3,854.30  | 0.00 | SG > JP > KR |
| 7 Sci   | 3.22 (.77) | 3.06 (0.87) | 3.50 (0.75) | 9,946.35  | 0.00 | SG > KR > JP |
| Math    | 2.61 (0.99) | 2.92 (.94) | 2.85 (1.02) | 15,222.76 | 0.00 | JP > SG > KR |
| 8 Sci   | 3.53 (.69) | 3.66 (0.63) | 3.70 (0.64) | 6,778.84  | 0.00 | SG > JP > KR |
| Math    | 2.31 (.94) | 2.67 (0.93) | 2.95 (0.97) | 25,868.55 | 0.00 | SG > JP > KR |

Note: SD: Standard Deviation, †: Reverse scored, KOR: South Korea, JPN: Japan, SPG: Singapore.
TABLE 6  Mean score difference in interest in the TIMSS 2019 in the eighth grade

| Subject | Mean (SD) | F          | p     | Post-hoc test |
|---------|-----------|------------|-------|---------------|
|         | KOR       | JPN        | SPG   |               |
| Sci     | 2.55 (0.88) | 2.87 (0.85) | 3.26 (0.76) | 27,693.76 | 0.00 | SG > JP > KR |
| Math    | 2.52 (0.90) | 2.62 (0.90) | 3.09 (0.89) | 36,353.45 | 0.00 | SG > JP > KR |
| Sci     | 2.48 (0.90) | 2.81 (0.87) | 3.00 (0.95) | 23,370.04 | 0.00 | SG > JP > KR |
| Math    | 2.31 (0.94) | 2.76 (0.92) | 2.75 (1.06) | 20,059.55 | 0.00 | JP > KR, SG > KR |
| Sci     | 2.54 (0.87) | 2.91 (0.81) | 3.04 (0.88) | 32,253.27 | 0.00 | SG > JP > KR |
| Math    | 2.44 (0.87) | 2.75 (0.85) | 2.72 (0.95) | 9,498.25  | 0.00 | JP > SG > KR |
| Sci     | 2.86 (0.84) | 2.84 (0.83) | 3.45 (0.68) | 10,155.46 | 0.00 | SG > KR > JP |
| Math    | 2.59 (0.86) | 2.48 (0.84) | 3.03 (0.83) | 6,558.47  | 0.00 | SG > KR > JP |
| Sci     | 2.48 (0.91) | 2.66 (0.92) | 3.19 (0.83) | 13,601.60 | 0.00 | SG > JP > KR |
| Math    | 2.36 (0.93) | 2.39 (0.97) | 2.94 (0.95) | 4,643.37  | 0.00 | SG > JP > KR |
| Sci     | 2.36 (0.95) | 2.52 (0.96) | 2.99 (0.97) | 30,891.24 | 0.00 | SG > JP > KR |
| Math    | 2.18 (0.88) | 2.13 (0.81) | 2.53 (0.90) | 4,409.55  | 0.00 | SG > JP > KR |
| Sci     | 2.87 (0.88) | 3.07 (0.87) | 3.32 (0.81) | 27,214.34 | 0.00 | SG > JP > KR |
| Math    | 2.31 (0.92) | 2.39 (0.93) | 2.76 (0.97) | 19,588.59 | 0.00 | SG > JP > KR |
| Sci     | 2.19 (0.87) | 2.52 (0.89) | 3.05 (0.86) | 10,413.02 | 0.00 | SG > JP > KR |
| Math    | 1.94 (0.80) | 2.18 (0.85) | 2.63 (0.94) | 4,348.66  | 0.00 | SG > JP > KR |

Note: SD: Standard Deviation, †: Reverse scored, KOR: South Korea, JPN: Japan, SPG: Singapore.

Graders responded that they liked science class more than mathematics class, and they preferred conducting science experiments to solving math problems. Table 6 shows the results of individual questions of interest in the subjects in the eighth grade.

In Table 6, the average score of the eighth-grade students’ responses to all questions constituting their interest in the subjects was lower than that of the fourth-grade students in Table 5. Furthermore, the differences in the eighth graders’ average scores between Korea and Singapore were much greater than.
those between Korea and Japan. Korea had the lowest average scores by both the fourth and eighth graders to the response “8. I look forward to mathematics class.” Not only were these the scores lowest among all other item scores within the country but also in all three countries. In science, even though there was a decrease in the average scores for the items among the eighth graders, the average scores for the statement “7. I like to conduct science experiments” among the eighth graders across all three countries did not significantly decrease. Related to confidence, Tables 7 and 8 present the results for students’ responses to the question, “How much do you agree with these statements about science/mathematics?”

### Table 7  Mean score difference in confidence in the TIMSS 2019 in the fourth grade

| Subject | Mean (SD) | F     | p     | Post-hoc test |
|---------|-----------|-------|-------|---------------|
|         | KOR       | JPN   | SPG   |               |
| 11 Sci  | 2.84 (0.80)| 2.78 (0.80)| 2.99 (0.86)| 1,886.06 | 0.00 | SG > KR > JP |
| Math    | 2.82 (0.84)| 2.62 (0.85)| 3.05 (0.92)| 12,500.89 | 0.00 | SG > KR > JP |
| 12† Sci | 3.21 (0.73)| 3.22 (0.83)| 2.79 (1.02)| 5,351.85 | 0.00 | JP > KR > SG |
| Math    | 3.12 (0.83)| 2.78 (0.94)| 2.73 (1.06)| 22,161.46 | 0.00 | KR > JP > SG |
| 13† Sci | 2.66 (0.83)| 3.37 (0.83)| 2.89 (1.03)| 112,360.28 | 0.00 | JP > SG > KR |
| Math    | 2.61 (0.87)| 2.84 (1.07)| 2.86 (1.09)| 8,291.23  | 0.00 | SG > JP > KR |
| 14 Sci  | 2.83 (0.85)| 2.96 (0.87)| 2.99 (0.91)| 3,251.60  | 0.00 | SG > JP > KR |
| Math    | 2.86 (0.86)| 2.72 (0.88)| 2.96 (0.96)| 4,910.93  | 0.00 | SG > KR > JP |
| 15 Sci  | 2.27 (0.82)| 2.31 (0.86)| 2.53 (0.98)| 1,754.54  | 0.00 | SG > JP > KR |
| Math    | 2.35 (0.83)| 2.31 (0.88)| 2.56 (1.00)| 1,724.68  | 0.00 | SG > KR > JP |
| 16† Sci | 3.26 (0.78)| 3.35 (0.81)| 2.87 (1.07)| 7,736.55  | 0.00 | JP > KR > SG |
| Math    | 2.89 (0.99)| 2.85 (1.01)| 2.87 (1.12)| 182.46    | 0.00 | KR > SG > JP |
| 17† Sci | 3.24 (0.84)| 3.63 (0.66)| 2.88 (1.05)| 57,754.57 | 0.00 | JP > KR > SG |
| Math    | 2.80 (0.98)| 3.30 (0.87)| 2.75 (1.09)| 51,563.68 | 0.00 | JP > KR > SG |

Note: SD: Standard Deviation, †: Reverse scored, KOR: South Korea, JPN: Japan, SPG: Singapore.
In Table 7, the average scores of fourth-grade students’ responses on confidence in these subjects were similar to science and mathematics scores in Korea and Singapore. In Japan, there were items with similar scores in science and mathematics, but there were many cases where students scored higher in confidence in science than in mathematics. Korea had higher response scores for questions “12. Mathematics is more difficult for me than for many of my classmates” and “16. Mathematics is harder for me than any other subject” than Japan and Singapore. And Korea had lower response scores for questions “13. Science/mathematics is not one of my strengths” and “14. I learn things quickly in science” compared to Japan and Singapore. “15. My teacher tells me I am good at science/mathematics” was very low in all three countries.

### Table 8: Mean score difference in confidence in the TIMSS 2019 in the eighth grade

| Subject | Mean (SD) | F     | P     | Scheffe         |
|---------|-----------|-------|-------|-----------------|
|         | KOR       | JPN   | SPG   |                 |
| 11 Sci  | 2.37 (0.87)| 2.17 (0.79) | 2.84 (0.90) | 19,321.92 | 0.00 | SG > KR > JP |
| Math    | 2.50 (0.92)| 2.11 (0.84) | 2.71 (1.00) | 37,667.56 | 0.00 | SG > KR > JP |
| 12† Sci | 2.73 (0.85)| 2.61 (0.87) | 2.72 (0.91) | 2,842.36 | 0.00 | KR > JP, KR > SG |
| Math    | 2.87 (0.88)| 2.49 (0.91) | 2.62 (0.97) | 28,123.87 | 0.00 | KR > SP > JP |
| 13† Sci | 2.40 (0.89)| 2.43 (0.95) | 2.59 (1.01) | 741.53 | 0.00 | SG > JP > KR |
| Math    | 2.38 (0.85)| 2.21 (1.04) | 2.48 (1.11) | 5,517.84 | 0.00 | SG > KR > JP |
| 14 Sci  | 2.40 (0.84)| 2.29 (0.78) | 2.79 (0.86) | 9,313.07 | 0.00 | SG > KR > JP |
| Math    | 2.57 (0.84)| 2.34 (0.81) | 2.72 (0.92) | 14,727.43 | 0.00 | SG > KR > JP |
| 15 Sci  | 2.15 (0.84)| 1.96 (0.80) | 2.59 (0.89) | 18,736.64 | 0.00 | SG > KR > JP |
| Math    | 2.32 (0.87)| 1.88 (0.80) | 2.32 (0.93) | 27,434.84 | 0.00 | SG > KR > JP |
| 16† Sci | 2.83 (0.82)| 3.08 (0.78) | 2.83 (0.94) | 213.06 | 0.00 | JP > KR > SP |
| Math    | 2.56 (0.97)| 2.42 (1.02) | 2.75 (1.07) | 26,671.78 | 0.00 | JP > KR > SP |
| 17† Sci | 2.57 (0.91)| 2.59 (0.92) | 2.83 (0.94) | 1,381.84 | 0.00 | SG > JP > KR |
| Math    | 2.36 (0.92)| 2.67 (1.01) | 2.43 (1.01) | 45,723.98 | 0.00 | JP > KR > SP |

Note: SD: Standard Deviation; †: Reverse scored; KOR: South Korea; JPN: Japan; SPG: Singapore.
Table 8 shows the average scores of eighth-grade students’ confidence in the subjects, which were lower than those of fourth graders (Table 7). Similar to the fourth grade, “15. My teacher said that I am good at science/mathematics” was the lowest in all three countries. Korea had a higher response score for “12. Science and mathematics are more difficult for me than for many of my classmates” and a lower response score for questions “13. Science is not one of my strength” and “17. Science makes me confused” compared to Japan and Singapore. To recognize the value of science and mathematics, the results for students’ responses to the question “How much do you agree with these statements about science/mathematics?” are presented in Table 9.

Table 9 shows the response scores of students from the three countries to the items constituting the value section, and Singapore showed the highest for all items. Within each country, the average score for the statement “24. I would like a job that involves using science/mathematics” was the lowest. Many items showed a large difference in the value scores between science and mathematics. In the case of Korea, science was higher than mathematics in “20. I think learning science/mathematics will help me in my daily life,” 24, and “25. It is important to learn about science/mathematics to get ahead in the world.” For “21. I need science/mathematics to learn other school subjects,” “22. I need to do well in science/mathematics to get into the university of my choice,” “23. I need to do well in science/mathematics to get the job I want,” and “27. My parents think that it is important that I do well in science/mathematics,” the mathematics score was higher than the science score.

For most questions concerning science, responses were more positive in Korea than in Japan. Korea was much more positive than Japan in 25, “26. Learning science will give me more job opportunities when I am an adult,” and 27. Japan scored significantly higher than Korea in 20 and “28. It is important to do well in science/mathematics.” Additionally, Korea showed a significant difference in scores from Singapore in terms of career selection using science and mathematics and the importance of science and mathematics to parents. For instructional clarity, Table 10 presents the results for students’ responses to the question, “How much do you agree with these statements about your science/mathematics lessons?”

Table 10 shows the students’ response scores to the questions constituting instructional clarity. All three countries showed similar scores in science and mathematics in each question. In both the fourth and eighth grades, Singaporean students showed the highest response scores for all questions, but the difference in scores between countries was not large. In particular, “29. I know what the teacher expects of me” was very low in Korea and Japan in both grades. In Japan, a score of 29 was extremely low in the eighth grade.
Next, a cohort analysis was conducted focusing on the overall average for interest, confidence, and instructional clarity in science and mathematics, as shown in Table 11. Through cohort comparison, when fourth-grade students reached the eighth grade, the change in the response to subject interest, confidence, and instructional clarity was confirmed. Since cohort analysis

| Subject | Mean (SD) | F       | p       | Post-hoc test |
|---------|-----------|---------|---------|---------------|
|         | KOR       | JPN     | SPG     |               |
| 20      | Sci       | 2.89 (0.85) | 2.76 (0.86) | 3.37 (0.71) | 11,817.78 | 0.00 | SG > KR > JP |
|         | Math      | 2.56 (0.91) | 2.91 (0.84) | 3.15 (0.84) | 28,816.22 | 0.00 | SG > JPN > KR |
| 21      | Sci       | 2.68 (0.86) | 2.45 (0.85) | 2.96 (0.87) | 16,062.39 | 0.00 | SG > KR > JP |
|         | Math      | 2.82 (0.81) | 2.80 (0.81) | 3.00 (0.82) | 1,090.86  | 0.00 | SG > KR > JP |
| 22      | Sci       | 2.85 (0.88) | 2.81 (0.91) | 3.28 (0.80) | 5,209.42  | 0.00 | SG > KR > JP |
|         | Math      | 3.10 (0.84) | 3.04 (0.87) | 3.30 (0.78) | 2,291.04  | 0.00 | SG > KR > JP |
| 23      | Sci       | 2.75 (0.92) | 2.69 (0.94) | 3.18 (0.86) | 5,681.84  | 0.00 | SG > KR > JP |
|         | Math      | 2.93 (0.91) | 2.91 (0.88) | 3.20 (0.83) | 1,896.15  | 0.00 | SG > KR > JP |
| 24      | Sci       | 2.21 (0.93) | 2.11 (0.90) | 2.91 (0.97) | 15,057.05 | 0.00 | SG > KR > JP |
|         | Math      | 1.95 (0.88) | 2.01 (0.85) | 2.46 (0.97) | 6,470.65  | 0.00 | SG > JPN > KR |
| 25      | Sci       | 2.90 (0.89) | 2.57 (0.88) | 3.36 (0.74) | 32,867.64 | 0.00 | SG > KR > JP |
|         | Math      | 2.62 (0.90) | 2.74 (0.87) | 3.21 (0.78) | 8,780.05  | 0.00 | SG > JPN > KR |
| 26      | Sci       | 2.90 (0.87) | 2.64 (0.89) | 3.35 (0.76) | 22,672.28 | 0.00 | SG > KR > JP |
|         | Math      | 2.96 (0.87) | 2.91 (0.83) | 3.38 (0.79) | 6,162.93  | 0.00 | SG > KR > JP |
| 27      | Sci       | 2.60 (0.89) | 2.55 (0.92) | 3.39 (0.72) | 16,194.98 | 0.00 | SG > KR > JP |
|         | Math      | 2.93 (0.89) | 2.65 (0.91) | 3.54 (0.66) | 30,459.47 | 0.00 | SG > KR > JP |
| 28      | Sci       | 2.90 (0.86) | 3.22 (0.79) | 3.51 (0.66) | 29,921.46 | 0.00 | SG > JPN > KR |
|         | Math      | 3.00 (0.88) | 3.33 (0.75) | 3.56 (0.64) | 30,670.81 | 0.00 | SG > JPN > KR |

Note: SD, standard deviation. KOR = South Korea; JPN = Japan; SPG = Singapore.
Table 10: Mean score difference in instructional clarity in the TIMSS 2019

| Grade | Subject | Mean (SD) | F       | p     | Post-hoc test |
|-------|---------|-----------|---------|-------|---------------|
|       |         | KOR       | JPN     | SPG   |               |
| 29    | 4       | Sci 2.43 (0.88) | 2.44 (0.89) | 3.39 (0.76) | 22,629.30 | 0.00 | SG > JP > KR |
|       |         | Math 2.41 (0.88) | 2.47 (0.89) | 3.43 (0.70) | 24,764.83 | 0.00 | SG > JP > KR |
| 8     |       | Sci 2.46 (0.84) | 2.17 (0.81) | 3.25 (0.70) | 47,092.96 | 0.00 | SG > KR > JP |
|       |         | Math 2.45 (0.83) | 2.18 (0.81) | 3.32 (0.68) | 48,562.06 | 0.00 | SG > KR > JP |
| 30    | 4       | Sci 3.34 (0.72) | 3.38 (0.74) | 3.40 (0.77) | 510.19    | 0.00 | SG > JP > KR |
|       |         | Math 3.36 (0.71) | 3.36 (0.73) | 3.40 (0.76) | 60.69     | 0.00 | SG > JP > KR |
| 8     |       | Sci 2.71 (0.86) | 2.88 (0.85) | 3.20 (0.80) | 9,955.79  | 0.00 | SG > JP > KR |
|       |         | Math 2.83 (0.82) | 2.94 (0.81) | 3.17 (0.83) | 4,805.73  | 0.00 | SG > JP > KR |
| 31    | 4       | Sci 3.26 (0.74) | 3.28 (0.77) | 3.49 (0.73) | 1,611.67  | 0.00 | SG > JP > KR |
|       |         | Math 3.29 (0.70) | 3.31 (0.71) | 3.48 (0.72) | 1,406.98  | 0.00 | SG > JP > KR |
| 8     |       | Sci 2.93 (0.78) | 2.93 (0.81) | 3.27 (0.78) | 3,393.13  | 0.00 | SG > JP > KR |
|       |         | Math 3.00 (0.75) | 3.05 (0.76) | 3.25 (0.79) | 2,253.00  | 0.00 | SG > JP > KR |
| 32    | 4       | Sci 3.48 (0.63) | 3.43 (0.71) | 3.59 (0.69) | 1,810.10  | 0.00 | SG > KR > JP |
|       |         | Math 3.53 (0.59) | 3.40 (0.69) | 3.61 (0.66) | 6,791.42  | 0.00 | SG > KR > JP |
| 8     |       | Sci 3.01 (0.77) | 2.93 (0.84) | 3.34 (0.76) | 5,373.00  | 0.00 | SG > KR > JP |
|       |         | Math 3.06 (0.74) | 2.99 (0.82) | 3.31 (0.79) | 3,831.23  | 0.00 | SG > KR > JP |
| 33    | 4       | Sci 3.35 (0.70) | 3.40 (0.72) | 3.52 (0.73) | 1,310.68  | 0.00 | SG > JP > KR |
|       |         | Math 3.41 (0.66) | 3.44 (0.66) | 3.56 (0.69) | 1,045.18  | 0.00 | SG > JP > KR |
| 8     |       | Sci 2.86 (0.80) | 3.01 (0.78) | 3.25 (0.78) | 7,650.70  | 0.00 | SG > JP > KR |
|       |         | Math 2.93 (0.78) | 3.08 (0.74) | 3.17 (0.83) | 6,404.13  | 0.00 | SG > JP > KR |

Note: SD: standard deviation. KOR = South Korea; JPN = Japan; SPG = Singapore

requires results from both Grades 4 and 8, no cohort analysis was performed on value, which was investigated only in Grade 8.

Table 11 shows that in all three countries, average scores for interest, confidence, and instructional clarity decreased in both science and mathematics when fourth graders reached the eighth grade. In particular, interest and confidence in subjects fell sharply in Korea and Japan. Compared with Korea and Japan, the decreases in average scores for interest, confidence, and
| Variable                | 19 8th | 15 4th | t     |
|------------------------|--------|--------|-------|
|                        | Mean (SD) |     |       |
| Interest               |         |       |       |
| Sci                    |         |       |       |
| KR                     | 2.58 (0.71) | 3.24 (0.65) | 455.71** |
| JP                     | 2.76 (0.69) | 3.39 (0.63) | 699.67** |
| SG                     | 3.19 (0.64) | 3.41 (0.65) | 46.61**  |
| Math                   |         |       |       |
| KR                     | 2.32 (0.74) | 2.77 (0.74) | 285.15** |
| JP                     | 2.43 (0.74) | 2.91 (0.75) | 470.27** |
| SG                     | 2.79 (0.78) | 3.09 (0.78) | 53.49**  |
| Confidence             |         |       |       |
| Sci                    |         |       |       |
| KR                     | 2.40 (0.70) | 2.92 (0.60) | 374.91** |
| JP                     | 2.35 (0.64) | 3.02 (0.59) | 801.79** |
| SG                     | 2.67 (0.71) | 2.89 (0.74) | 43.06**  |
| Math                   |         |       |       |
| KR                     | 2.48 (0.59) | 2.68 (0.56) | 163.30** |
| JP                     | 2.24 (0.56) | 2.56 (0.56) | 415.32** |
| SG                     | 2.57 (0.64) | 2.71 (0.60) | 31.67**  |
| Instructional Clarity  |         |       |       |
| Sci                    |         |       |       |
| KR                     | 2.84 (0.66) | 3.09 (0.62) | 179.67** |
| JP                     | 2.82 (0.66) | 3.00 (0.65) | 192.43** |
| SG                     | 3.26 (0.62) | 3.40 (0.59) | 32.09**  |
| Math                   |         |       |       |
| KR                     | 2.90 (0.62) | 3.06 (0.57) | 124.85** |
| JP                     | 2.87 (0.62) | 3.02 (0.59) | 181.30** |
| SG                     | 3.24 (0.61) | 3.39 (0.54) | 35.43**  |

sd: Standard Deviation, **p < 0.01
Note: (1) “19 8th” mean Grade 8 result in 2019. (2) “15 4th” means Grade 4 result in 2015
### Table 1 1 Cohort analysis results for non-cognitive variables

| Variable       | Total | Male | Female |
|----------------|-------|------|--------|
|                | Mean (SD) | t    | Mean (SD) | t     | Mean (SD) | t     |
|                | 19th | 15th |       | 19th | 15th |       | 19th | 15th |       |
| **Interest Sci** | 2.58 (0.71) | 3.24 (0.65) | 317.46** | 2.62 (0.66) | 3.22 (0.64) | 331.65** |
| **JP**         | 2.76 (0.69) | 3.39 (0.63) | 699.67** | 2.90 (0.69) | 3.45 (0.61) | 432.10** |
| **SG**         | 3.19 (0.64) | 3.41 (0.65) | 46.61**  | 3.25 (0.64) | 3.45 (0.66) | 317.46** |
| **Math KR**    | 2.32 (0.74) | 2.77 (0.74) | 285.15** | 2.41 (0.77) | 2.84 (0.77) | 218.47** |
| **JP**         | 2.43 (0.74) | 2.91 (0.75) | 470.27** | 2.55 (0.76) | 2.96 (0.77) | 331.65** |
| **SG**         | 2.79 (0.78) | 3.09 (0.78) | 53.40**  | 2.85 (0.78) | 3.14 (0.79) | 317.46** |
| **Confidence Sci** | 2.40 (0.70) | 2.92 (0.60) | 374.91** | 2.47 (0.72) | 2.97 (0.62) | 317.46** |
| **JP**         | 2.35 (0.64) | 3.02 (0.59) | 801.79** | 2.90 (0.76) | 2.96 (0.77) | 331.65** |
| **SG**         | 2.67 (0.71) | 2.89 (0.74) | 43.06**  | 3.25 (0.69) | 3.09 (0.65) | 317.46** |
| **Instructional Clarity Sci** | 2.84 (0.66) | 3.09 (0.62) | 179.67** | 2.83 (0.67) | 3.00 (0.59) | 317.46** |
| **JP**         | 2.82 (0.66) | 3.00 (0.65) | 192.43** | 2.90 (0.76) | 2.96 (0.77) | 331.65** |
| **SG**         | 3.26 (0.62) | 3.40 (0.59) | 32.09**  | 3.24 (0.64) | 3.38 (0.56) | 317.46** |

SD: Standard Deviation, **p < 0.01

Note: (1) "19 8th" mean Grade 8 result in 2019. (2) "15 4th" means Grade 4 result in 2015.
instructional clarity in both science and mathematics among the eighth graders in Singapore were relatively smaller. Also, in all three countries, male students’ average scores for interest and confidence in science and mathematics were higher than female students’ scores. Gender differences in instructional clarity were small compared with other variables. In Korea, the average scores of female students’ responses to interest and confidence in science and mathematics were low. Although not presented as a table, when looking at the difference in perception between male and female students for all individual questions, male students’ perceptions were more positive than female students in terms of interest, confidence, and value, similar to the trend in the overall average. In all three countries, the average scores of male students’ responses to “24. I would like a job that involves using science/mathematics” were much higher than those of female students.

5 Conclusions and Discussion

This study analyzed non-cognitive variables of science and mathematics using recent TIMSS data and derived implications for Korean science education based on this. To analyze the response trends of Korean students, Japan and Singapore were selected as comparative countries. The study results were as follows.

5.1 Students’ Interest and Confidence in Science and Mathematics

First, the scores for interest, confidence, value, and instructional clarity in science and mathematics of Korean, Japanese, and Singaporean students were similar in TIMSS 2015 and TIMSS 2019. In most cases, Singapore’s response score was the most positive among the three countries, but in the fourth grade, Japan’s response score was high in interest and confidence in science. When the fourth-grade students of TIMSS 2015 reached the eighth grade, their interest and confidence in the subject decreased. The scores of interest and confidence in subjects were higher in science than in mathematics in both fourth and eighth grades in all countries. Non-cognitive dispositions, such as interest, confidence, value, and instructional clarity tended to decrease with student progression through grade levels. This is supported by various studies that have reported how changes in interest and confidence in mathematics and science tend to be increasingly negative with added years of schooling (Mullis et al., 2020). To improve low achievement in the definitive domains of science and mathematics, Korea is implementing various educational policies, such as a comprehensive plan for mathematics and science and programs for gifted
science students in high schools and science-focused schools for ordinary students interested in science (Ministry of Education – Korea, 2020). However, even with these diverse policies, interest in learning science and mathematics remains low and needs to be promoted.

Confidence is a powerful predictor of cognitive achievement (Mullis et al., 2020). Low self-confidence leads to high anxiety, which can negatively affect achievement even if students put significant effort into learning (Morony et al., 2013). In science, Japanese students showed more positive overall perceptions than Korean students. Japanese students, affiliated with a country that has produced many Nobel laureates in science, responded positively to most of the questions regarding confidence in the subject, including “Science is not one of my strengths.” Luo et al. (2014) argued that due to the nature of Confucian culture, Asian students seem to have low confidence because of the culture that lowers them. While Korea, Japan, and Singapore ranked low regarding confidence in mathematics and science, compared with other participating countries in the TIMSS (Mullis et al., 2020), their relative ranking differed depending on the subject and the questions asked. This is most likely related to the differing emphasis on mathematics and science in major educational policies and curricula in all three countries. Confidence is a factor that enables students to continue their studies and can be linked to academic performance, so the low responses to the item “My teacher tells me I am good at science” in Korea need to be shared with teachers, and positive feedback from teachers must be elicited.

5.2 **Students Perceived Value of Mathematics and Science**

Second, the response scores of Korean students were higher in perceived value for science class and conducting science experiments than in mathematics. Perceived value for mathematics class and solving math problems showed lower scores. Science was given a higher score than mathematics possibly because it is seen as useful in everyday life and is necessary for understanding the world. However, the response score was higher for mathematics than for science possibly because students feel that mathematics is necessary for learning other subjects, going to a good university, and getting a good job. However, response that mathematics class is perceived as valuable was very low. What is worrisome is that the number of respondents who wanted to have a job related to science and mathematics was very low. The low expectations of value for math class are probably because most math classes are primarily about solving problems to get good grades. This means that, despite continued curriculum revisions, mathematics learning is seen as neither enjoyable nor applicable for the future.
Unfortunately, in Asian countries, mathematics learning is mostly focused on identifying the content of the problem. The ability to solve problems in real-life situations is not adequately practiced (Wu, 2011). This differs from the generally positive perceptions toward learning science because, in Korea’s elementary schools, the science curriculum comprises exploration activities that make science learning enjoyable and practical (Kim, 2020). In Korea, the delivery of curriculum content has become important from middle school onward. At higher grades, experimental practice is not compulsory but is at the discretion of the teachers. A positive response to “I like to conduct science experiments” for eighth-grade science demonstrates that students enjoy science experiments. However, not many such lessons are being conducted in Korean schools (Kim & Kim, 2021). This naturally reduces the interest in learning science. Korea recognizes mathematics as a tool to engage with other subjects, academic learning, college admissions, and favorable jobs. However, perceptions such as “I would like a job that involves using science/mathematics” were found to be markedly negative in both South Korea and Japan. Students consider mathematics and science to be generally important but personally less important. They select STEM-related subjects for securing admissions to preferred universities, getting good jobs, and earning high wages, while recognizing that careers in these fields are challenging (Bøe et al., 2011).

Such perceptions also affect students’ expectations of success in science subjects, which generally fall below those of other subjects in school. The avoidance of mathematics- and science-related jobs is a phenomenon seen in various countries that have also been promoting national science and engineering talent-nurturing policies to cope with the rejection of science and engineering jobs (Ministry of Science and ICT – Korea, 2021), prioritizing science, technology, engineering, arts, and mathematics (STEAM) education to increase interest in learning mathematics and science and drive career choices (Ministry of Education – Korea, 2020). However, careers in science and mathematics appear to be less attractive to South Korean students than other occupations, which may also be attributed to parental perceptions.

To overcome these perceptions, South Korea requires curricula or educational programs that improve the perceived value of mathematics and science not only for students but also for their parents. Singapore, by comparison, shows an extremely positive perception of the value of mathematics and science. This may be related to the overall composition of Singapore’s curriculum and the fact that more hours are provided to mathematics and science in Singapore than in South Korea (OECD, 2016b). Singapore, since 2012, has added value and ethics and attitudes domains in its curriculum (Ministry of Education – Singapore, 2013). Value and attitudes enable the development of scientific attitudes and build curiosity regarding their surroundings. The
curriculum content is also designed to introduce students to science, technology, society, and the environment and issues and controversies in social sciences. This revised curriculum may have led to positive perceptions of value in mathematics and science among Singaporean students.

5.3 Instructional Clarity for Mathematics and Science

Third, in terms of instructional clarity, Korean students showed very low scores on the question about knowing the expectations of their teachers in both science and mathematics. Teachers need to identify instructional strategies that can accommodate learning difficulties and encourage learning efficacy. However, this method does not appear to be used well in eighth grade science and mathematics classes in Korea. These results suggest that the establishment of learning objectives and the use of various teaching methods appropriate for different topics are essential evaluation items for teachers (Kim et al., 2013). As such, teachers in Korea are expected to clearly share with students the learning objectives which must be achieved in the class and teachers’ expectations and use various teaching methods to help students understand, especially in middle and high schools. Since instructional clarity is one of the most influential variables affecting students’ learning and achievement (Hattie, 2018), efforts to improve teaching practices must be prioritized in all educational reforms.

5.4 Influence of Gender on Non-Cognitive Factors

Fourth, as fourth-grade students move through the grades to eighth grade, they show a greater decline in interest in science and confidence than in mathematics, and the decline is greater for female students than for males. This can manifest itself as a difficulty in science learning for students in eighth grade. The experience of science inquiry decreases compared to elementary school in higher school levels, which may negatively affect interest and understanding of science. Therefore, it can be helpful to prepare classes so that students can experience science learning centered on student-centered inquiry activities. Regarding science and mathematics, the difference in achievement between male and female students is due to differences in the approach to learning and problem-solving strategies, rather than cognitive differences (Cascella et al., 2021). As such, it is necessary to compose learning content and devise teaching and learning activities while keeping in mind the characteristics of male and female students’ approaches to mathematics and science. Although the gender gap in perceived value is small, students interested in mathematics and science are more likely to pursue careers related to science and mathematics. Results from all three countries show that differences exist in the perceptions of men and women, and their response to “I would like a job that involves using science/mathematics” indicates that male students still have a significantly
positive perception compared with female students regarding careers in mathematics and science. In large-scale evaluations such as the TIMSS, a high percentage of top-ranking students in mathematics and science are male (Baye & Monseur, 2016). In fact, the male-female gender gap in careers in science and engineering fields continues to remain large despite continuous efforts to decrease the gap over the past decade. According to Women in Science, Engineering, and Technology (WISE, 2019), there were far fewer women than men working in science and engineering occupations, with women accounting for 20.7% of new hires and 26.2% of incumbents.

5.5 Implications for Korean Science and Mathematics Education

Finally, although Korean students scored relatively low on interest and confidence, their overall scores were positive (Mullis et al., 2020). Therefore, rather than the overall score for each variable, it is possible to provide a solution for improving academic achievement by identifying the items that are particularly low in each country. Recently, there has been widespread discussion in South Korea and Japan regarding the development of a curriculum that reflects the value of mathematics and science (Ministry of Education – Korea, 2021; Yamanaka & Suzuki, 2020). Improving the perceived value of mathematics and science could transform external rewards, build intrinsic motivation, and strengthen cognitive achievement (Michaelides et al., 2019). Learning practices that are influenced by intrinsic motivation can improve achievement standards, attitudes, and value and change students’ perceptions of careers in mathematics and science.

This study analyzed the characteristics of Korean students’ perceptions of major non-cognitive factors through a comparison with their counterparts from two other countries. Although South Korea exhibits excellent cognitive abilities in the TIMSS, various follow-up studies are needed to understand the factors that decrease performance scores. It is also necessary to investigate practices generating higher response rates in Japan and Singapore to improve teaching and learning methods in Korea.

Abbreviations

| Abbreviation | Description |
|--------------|-------------|
| PISA         | Programme for International Student Assessment |
| STEAM        | Science, Technology, Engineering, Arts, and Mathematics |
| STEM         | Science, Technology, Engineering, and Mathematics |
| TIMSS        | Trends in International Mathematics and Science Study |
| WISE          | Women in Science, Engineering, and Technology |
Ethical Considerations

The data reported in this study does not require human subjects' approval.

About the Author

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