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Relationship between teachers' assessments of non-cognitive skills and cognitive skills in junior high school mathematics

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Abstract

The assessment of non-cognitive skills and the relationship between non-cognitive skills and cognitive skills have been studied using an interdisciplinary framework; however, this has not resulted in learning or teaching improvements. This study focused on teachers' observational assessment of non-cognitive skills specific to junior high school mathematics. Questionnaire surveys were used and a factor analysis was conducted. Three factors were identified to assess non-cognitive skills specific to junior high school mathematics based on teachers' observations: cooperation in mathematical problem-solving, spirit of inquiry in mathematical problem-solving, and composure in mathematical problem-solving. To analyze the relationship between each factor and the overall assessment of cognitive skills in junior high school mathematics, each factor's assessment was divided according to the stages of cognitive skills. A positive proportionality emerged between the assessment of the non-cognitive skills and cognitive skills. If these two assessments are treated independently, the findings suggest that teachers may have difficulty distinguishing between the assessments, both of which are specific to junior high school mathematics.

Keywords

assessment by teachers, Japanese mathematics education, junior high school mathematics, non-cognitive skills

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1. Introduction

In schools, teachers are tasked with assessing students' schoolwork and determining the results of their scholastic efforts, through a mix of relative and absolute criteria, depending on the assessments' purpose. In many cases, daily academic performance, that is, the academic skills acquired through schooling, is assessed by teachers based on their assessments of students' schoolwork. Academic performance is used as an indicator of the student's future success. It can be a key element in accessing higher education and employment (Strenze, 2007). Hence, teachers' assessment of students is important for the student in question, and to society as a whole. Therefore, it is necessary to develop assessment tools that are highly reliable and appropriate.

To develop skills that are important for individuals and society in an equitable way, it is important to develop both cognitive and non-cognitive skills and assess them appropriately. The assessment of cognitive skills has been emphasized and implemented according to the characteristics of the field and content, as shown in the tests and grades for each subject. In contrast, the social value of developing and assessing non-cognitive skills was only recognized after economics revealed the high correlation between non-cognitive skills and social well-being (Heckman & Rubinstein, 2001). In research about mathematics education, it is crucial to determine the intrinsic connection between non-cognitive skills and cognitive skills.

Mathematics education aims to equip students with an understanding of the properties and relationships among mathematical objects, such as numbers, figures, and functions, demonstrate logical explanations for these concepts, and show how they can be applied in daily life. Learning mathematics in school can be difficult owing to underdeveloped cognitive skills and non-cognitive elements, such as math anxiety (Bekdemir, 2010; Ho et al., 2000; Ma, 1999; Sparks, 2011; Woodard, 2004).

However, cognitive and non-cognitive skills have not been equitably assessed in mathematics education. Questions and criteria have been developed to assess the cognitive skills specific to mathematics education by establishing a set of correct answers for each school year and mathematics domain. Answering them demonstrates various aspects of mathematics skills and can be quantitatively measured. Moreover, mathematics scores are used as representative indicators of academic ability for employment purposes. Therefore, assessments of cognitive skills specific to mathematics education have high social credibility.

Meanwhile, many studies that examine the assessment of non-cognitive skills specific to mathematics education use students' self-assessments, such as the OECD's Programme for International Student Assessment (e.g., Lee, 2020). The accuracy of student self-assessment is limited and cannot be improved by more experience and regular feedback (Brown et al., 2015; Lew et al., 2010). On the other hand, non-cognitive skills may be implicitly assessed by others, such as classroom teachers, on a daily basis without using proper methods. To ensure that non-cognitive skill assessments are socially accepted and utilized for career decisions and other purposes, teachers should perform the assessment using scientific approaches similar to cognitive skills assessment.

Teachers specializing in mathematics in junior high schools often assess students' cognitive and non-cognitive skills during their classes. Specifically, in Japan, first-year junior high school students (aged 12–13 years) learn more advanced mathematics than they did in elementary school; therefore, they are expected to exhibit more pronounced mathematics-specific characteristics in their cognitive and non-cognitive skills. This study focuses on Teachers' Assessments of non-cognitive skills specific to junior high school mathematics.

This study aims to answer the following research questions:

1. How do teachers assess the non-cognitive skills specific to junior high school mathematics?
2. What are the characteristics of the relationship between teachers' assessments of non-cognitive skills and cognitive skills specific to junior high school mathematics?

2. Theoretical framework

2.1 Meaning of non-cognitive skills in this study

Non-cognitive skills refer to social and emotional skills that are essential for achieving goals, working with others, and managing emotions (OECD, 2015). These skills are developed through formal and informal learning experiences, and are the driving force that produces socioeconomic outcomes for individuals throughout their lives (OECD, 2015). Non-cognitive skills are *attributes of individuals that are not expected to be measured by IQ tests or achievement tests* (Kautz et al., 2014, p. 13) and are more malleable than cognitive skills in social activities. Society needs to implement concrete programs designed to improve non-cognitive skills, especially for children from disadvantaged backgrounds (Heckman & Rubinstein, 2001). Non-cognitive skills are not simply complements to cognitive skills. The development of non-cognitive skills and their mutually beneficial relationship with cognitive skills is crucial to support individual well-being and build a prosperous society. This study defines non-cognitive skills as social and emotional skills that are essential for the future of individuals and society, are difficult to measure using other ways besides tests, can be changed, for better or worse, through learning and teaching, and require educational support.

Various frameworks can be used to measure non-cognitive skills; each with a different purpose (e.g., grit; Duckworth et al., 2007) and social-emotional competence (Zhou & Ee, 2012). This study adopted the five-factor model of personality to exemplify non-cognitive skills (Costa & McCrae, 1992). Each factor has been scrutinized conceptually and explained recently as follows (Mammadov, 2022): *Openness* (a degree of intellectual curiosity, creativity, and preference for novelty and variety), *conscientiousness* (a tendency to show self-discipline, planning, and organization), *extraversion* (positive emotions, activity, sociability, and the tendency to seek stimulation in the company of others), *agreeableness* (a tendency to be prosocial and cooperative toward others rather than antagonistic), and *neuroticism* (a vulnerability to unpleasant emotions, such as anxiety, anger, and depression) (p. 223). These factors are commonly abbreviated as OCEAN.

The five-factor model has become prevalent in education research as studies using this method have demonstrated that higher levels of conscientiousness are related to higher learner performance and learning satisfaction (Smidt, 2015). Choi et al. (2022) found a statistically significant relationship between lesson study and extraversion and conscientiousness in teacher education. Adopting the five-factor model in this study supports these findings and may inspire future research owing to the model's similarities and differences.

2.2 Clarifying the relationship between the assessment of cognitive and non-cognitive skills specific to mathematics education

Non-cognitive skills research has identified concerns regarding the current education techniques, such as the excessive emphasis on cognition and traditional personal traits, lack of cross-cultural research, excessive focus on grade point averages, and how key learning elements are overlooked (Sanchez-Ruiz et al., 2016). These elements are overlooked when the focus is on non-cognitive skills specific to a subject area. If it is assumed that skills have both a subject-specific and a comprehensive aspect, then it follows that non-cognitive skills must be assessed in the context of a specific subject, similar to cognitive skills.

Studies have found that fear or anxiety related to mathematics has a negative effect on mathematical performance throughout an individual's schooling (Bekdemir, 2010; Ma, 1999; Zakaria & Nordin, 2008). In recent years, efforts have been made to focus on the relationship between mathematical cognitive skills and non-cognitive *elements* in an isolated manner within mathematics education research; however, there has not been a clear connection with advances in the study of non-cognitive skills in psychology or other related fields. For example, Özcan and Eren Gümüş (2019) found that metacognitive experiences directly affected mathematical problem-solving performance, and mathematical self-efficacy indirectly affected mathematical motivation and anxiety. Chatterji and Lin (2018) identified the impact of mathematics-related self-efficacy, self-concept, and anxiety on mathematics performance. At the same time, progress has been made in clarifying the relationship between the assessment of non-cognitive skills and cognitive skills without linking the assessment of non-cognitive skills to the peculiarities of mathematics education (Chen et al., 2018; Mammadov, 2016; Stajkovic et al., 2018; Zhang & Ziegler, 2018).

Thus, the focus has been on peculiar non-cognitive elements, with the exception of skills in mathematics education, such as math anxiety. In contrast, research outside of mathematics education has focused on generic non-cognitive skills that are not based on the characteristics of mathematics education. As a result, both findings in the existing literature remain uninterpretable and have not reached the point of reciprocity. To enhance the application of research findings to mathematics teaching and learning, it is crucial to assess non-cognitive skills specific to mathematics education, based on generic non-cognitive skills, such as the five-factor model (OCEAN), and establish their relationship with the assessment of cognitive skills that were developed according to mathematics education.

3. Methods

3.1 Context of the study: the state of the art for assessing non-cognitive skills in Japan

In Japan, the Government Guidelines for Education (Ministry of Education, Culture, Sports, Science and Technology [MEXT], 2019) set the following three pillars as the qualities and skills to be developed during an individual's education: the acquisition of "knowledge and skills" that are useful in daily life and work, the development of the "ability to think, judge, and express" to cope with unknown situations, and the cultivation of the "ability to pursue learning and human nature" to apply the learnings to life and society. Consequently, for each school year, these pillars have been defined in terms of each school subject. Among the three pillars, "knowledge and skills" and "the ability to think, judge, and express" correspond to cognitive skills, whereas "the ability to pursue learning and human nature" corresponds to non-cognitive skills. The goals of junior high school mathematics, which correspond to the last pillar, are as follows: "Cultivate an attitude of realizing the fun of mathematical activities and the good qualities of mathematics, and thinking tenaciously, as well as an attitude of trying to make use of mathematics in life and learning, and an attitude of looking back on the process of problem-solving and trying to evaluate and improve it" (MEXT, 2019, p. 65).

3.2 Survey items

The questionnaire items were developed by combining the five-factor model (OCEAN) with the non-cognitive skills' goals, as defined in the Japanese curriculum. The *ability to pursue learning and human nature* was assessed in terms of the *objectives of mathematics*. This objective was divided into three types (α, β, and γ) and combined with OCEAN of non-cognitive skills, which resulted in 15 classified types. This approach enabled the formulation of school mathematics-specific questions for non-cognitive skills relevant to the third objective of mathematics education and following a widely accepted theoretical foundation (OCEAN), without any omissions or exclusions.

α: Attitude of thinking tenaciously while realizing the fun of mathematical activities and the values of mathematics
β: Attitude of applying mathematics to life and learning
γ: Attitude of reflecting on, evaluating, and improving the problem-solving process

For each category, two items and two reversed items were developed by 12 Japanese researchers in mathematics education and one mathematics teacher, using questions derived from Murakami and

Murakami's (1997) personality test, which was based on the five-factor model (OCEAN). This questionnaire is widely used in Japan. This resulted in 60 question items that teachers could use to assess students' non-cognitive skills.

To create the questions, a team of researchers and experienced mathematics teachers identified student behaviors that teachers might recognize when teaching junior high school mathematics.

3.3 Participants and procedures

The participants were mathematics teachers in junior high schools. They had 2 to 31 years of experience and worked with mathematics education researchers on a daily basis to improve their teaching and the mathematical skills of their students. They worked in public junior high schools located in urban and suburban areas of Japan. In all the schools, the students are homogeneous. Ethical approval was obtained from each teacher to participate in this survey.

Teachers in Japan are responsible for assessing each student, each semester, on a 3-point Likert scale (High, Middle, or Low) regarding the third MEXT objective (the ability to pursue learning and human nature). According to MEXT, the grades A, B, and C are extremely satisfactory, satisfactory, and needs more effort, respectively.

Before the survey, the participating teachers were asked to select 15 first-year students while ensuring their anonymity, using the following conditions: Two to four students who received *High* in the assessment of *the ability to pursue learning and human nature*, seven to 11 students who received *Middle*, and two to four students who received *Low*. Teachers were then asked to assess their students twice, once at the beginning and once at the end of the school year.

The teachers were further asked to indicate each student's cognitive skills in terms of *knowledge and skills* and *thinking, judgment, and expression* on a 5-point Likert scale (1: Very low, 2: Low, 3: Medium, 4: High, and 5: Very high) (hereafter, referred to as *overall assessment of cognitive skills by teachers*). The teachers had prior experience of completing cognitive skills assessments using periodic achievement tests, hence, it was reasonable to expect that these assessments would remain stable. In addition, teachers were asked to use 60 questions to assess students' non-cognitive skills by selecting the most appropriate item on a 5-point Likert scale (1: Strongly agree, 2: Agree, 3: Neither agree nor disagree, 4: Disagree, and 5: Strongly disagree) based on their observation of each student's learning behaviors in daily lessons. The survey period and the number of participants are presented in Table 1. Teachers who declined the survey or submitted incomplete questionnaires were excluded, leading to the difference in the number of teachers between the two sessions.

3.4 Analysis

To answer the two research questions, the analysis was conducted in two phases: exploratory factor analysis, and the relationship between the factors and the assessment of cognitive skills.

3.4.1 Factor structure. Exploratory factor analysis was conducted for the first and second surveys, and the factor structure was determined. Although the factor structure was nearly the same in the two surveys, exploratory and confirmatory factor analyses were performed simultaneously to obtain

Table 1. Survey period and participants.

	Period	Number of teachers	Number of students
1st session	June–July, 2019	64	953
2nd session	February–March, 2020	59	873

the same factor structure in both surveys. The results were obtained as a three-factor structure. The bias of teacher ratings depending on individual teachers was examined; however, no significant differences were found among the teachers.

The analysis was conducted using the elementary raw data. SPSS version 28 and AMOS version 28 were used for the analysis. Exploratory factor analysis was performed using a stepwise method with Promax rotation. It was adjusted for question items as observation variables to increase statistical model validity.

If the factor structures were different in the two surveys, it was assumed that they were two-factor structures and that there were changes between the first and second sessions due to the learning advice. If there was a forward/backward item in the question, the backward item was analyzed by reversing the score. Regarding score distribution, there were no differences between teachers for any of the question items, therefore, the raw score was analyzed.

3.4.2 Relationship between factors and the assessment of cognitive skills. Assessments were based on the teacher's observation of each student's non-cognitive skills, and question items associated with each factor were scored on a 5-point Likert scale. This score was standardized and placed on the 5-point Likert scale of the overall assessment of cognitive skills by teachers. An analysis of variance was performed on the overall non-cognitive abilities of the students as assessed by the teachers, using the scores of each factor in the exploratory factor analysis. Five levels were used; therefore, multiple testing was performed, and the homogeneity of variance was examined using Levene's test, which was chosen because it is robust to outliers. In addition, as a 5-stage survey was conducted, multiple testing was used to avoid the accumulation of errors that would occur in a two-group comparison. In multiple testing, the method differs according to equal variances. Regarding the differences between the groups on the 5-point Likert scale of the overall assessment of cognitive skills by teachers, if Levene's test showed equal variance, the significance of all the differences between the groups was examined by multiple comparisons, using Tukey's HSD method (Jaccard & Wan, 1996). If the unequal variance was shown, the Games-Howell method was used to examine the differences between the groups (Jaccard & Wan, 1996).

4. Results

4.1 Relationships between three factors of non-cognitive skills and three aspects of the ability to pursue learning and human nature

The question items belonging to each factor had the characteristics of each aspect of *the ability to pursue learning and human nature* in the Japanese Government Guidelines for junior high school mathematics. According to this aspect, the question items in this model could be organized, as shown in Table 2.

4.2 Three factors related to the assessment of non-cognitive skills specific to junior high school mathematics

Exploratory factor analysis of the results of the first and second surveys revealed that the structure was composed of three factors and the question items were almost identical. Therefore, the study concluded that the factor structure of Teachers' Assessments of students' non-cognitive skills was the same in both survey results.

The question items associated with each factor were adjusted to increase content validity. Furthermore, data from both surveys was used to find the structure of the question items that best fit the statistical criteria (see the Section 3).

Table 2. Question items belonging to the three aspects of the ability to pursue learning and human nature.

Factors	Three aspects of *the ability to pursue learning and human nature*		
	α	β	γ
1 Cooperation in mathematical problem-solving	6*, 17, 19, 20*	28*, 37, 38*, 39, 40*	57, 58*
2 Spirit of inquiry in mathematical problem-solving	10*, 11, 12*, 14, 15, 16*	30*, 31, 32*, 33, 34*, 36*	43, 44*, 49, 50*, 52*, 53, 54*, 55
3 Composure in mathematical problem-solving	1, 2*, 7	21, 22*, 23, 24*	41, 42*, 45, 46*, 47

Note. An asterisk (*) indicates a reversed item.

Exploratory factor analysis was used to analyze the results of each survey, while confirmatory factor analysis was used to integrate the two surveys. To reinforce model content validity, questionnaire items, rather than the statistical sufficiency of each indicator, were retained as much as possible. Table 2 presents the indicators of confirmatory factor analysis.

The 20 items of the first factor referred to the different aspects of working together with the same goal in solving mathematical problems: Involving others (items 14, 15, 30, 33, 34, 36, 43, 44, and 52), collaborating (items 53, 54, and 55), and sharing (items 10, 11, 12, 16, 31, 32, 49, and 50). Therefore, this factor was named *Cooperation in mathematical problem-solving* (see Appendix A for details on the questionnaire items).

The 12 items of the second factor related to the orientation of the various aspects of inquiry required for mathematical problem-solving were: Outlook (7), scrutiny (1, 2, and 47), improvement (45 and 46), utilization (21 and 22), and discovery (23, 24, 41, and 42). Therefore, this factor was named *Spirit of inquiry in mathematical problem-solving* (see Appendix A).

The 11 items of the third factor related to the stability of various aspects of mental tension associated with solving mathematical problems were: Tenacity (6 and 28), calmness (17, 37, 38, 39, 40, 57, and 58), and concentration (19 and 20). Therefore, this factor was called *Composure in mathematical problem-solving* (see Appendix A).

4.3 Relationship between the assessment of non-cognitive skills and cognitive skills in junior high school mathematics

Regarding the assessment of cognitive skills, there was no difference in the ratio of the number of students at each stage of the 5-stage assessment. Therefore, the significance of the difference among groups in each stage was examined in terms of the relationship between cognitive skills and each factor.

The significance of intergroup differences in the relationship between the assessment of Factor 1, *Cooperation in mathematical problem-solving*, and the overall assessment of cognitive skills was examined, and significant differences were confirmed, except between groups of stages 3 (*Medium*) and 4 (*High*), in the overall assessment of cognitive skills (Appendix B; vertical axes in Figures 1 to 3 represent standardized factor scores and are given at 95% confidence intervals). This confirms that the groups in each stage are statistically distinguishable from each other, except for groups in stages 3 and 4.

The significance of intergroup differences in each stage in the relationship between the assessment of Factor 2, *Spirit of Inquiry in Mathematical Problem-solving*, and the overall assessment of cognitive skills was examined, and significant differences were confirmed among all the groups (Appendix C). This confirms that the groups in each stage are statistically distinguishable from each other.

When the significance of intergroup differences in each stage was examined for the relationship between the assessment of Factor 3, *Composure in mathematical problem-solving*, and the overall assessment of cognitive skills, significant differences were confirmed among all the groups (Appendix D). This confirms that the groups in each stage are statistically distinguishable from each other.

5. Discussion

5.1 Measurability of non-cognitive skills specific to junior high school mathematics by three-factor model

Table 2 identifies sets of question items belonging to α, β, and γ of *the ability to pursue learning and human nature*. Each set reflects the characteristics of each aspect. Therefore, by quantifying teachers'

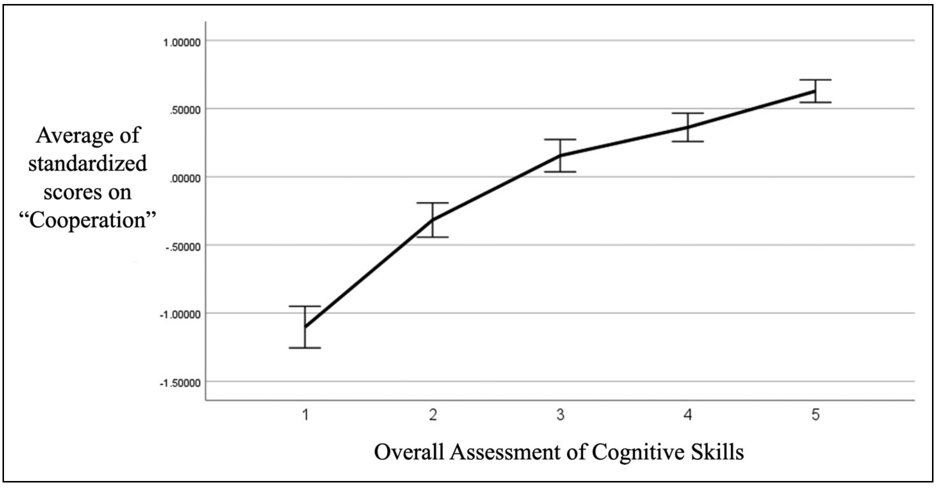

Figure 1. Relationship between the assessment of cooperation in mathematical problem-solving and the overall assessment of cognitive skills.

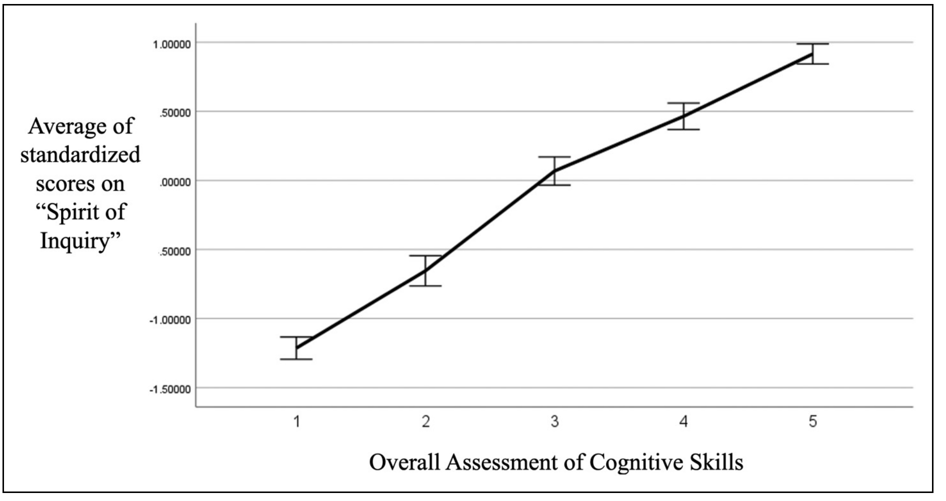

Figure 2. Relationship between the assessment of the spirit of inquiry in mathematical problem-solving and the overall assessment of cognitive skills.

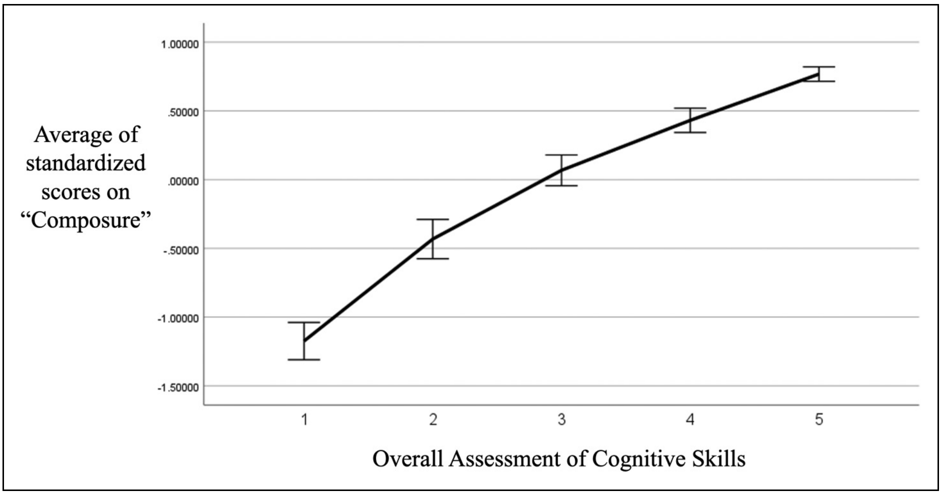

Figure 3. Relationship between the assessment of composure in mathematical problem-solving and the overall assessment of cognitive ability.

responses to question items on each aspect in line with the items/reversed items, these sets of question items can be used as an assessment model to measure *the ability to pursue learning and human nature* in the *objectives of mathematics* in the MEXT guidelines.

Generic assessment models and scales for non-cognitive skills have already been developed (e.g., GRIT-S; Duckworth & Quinn, 2009). The above assessment model is unique in that it serves as an assessment model based on teacher observations, and incorporates aspects characteristic of junior high school mathematics into question items. This makes it possible to assess non-cognitive skills following the characteristics of junior high school mathematics, allows for in-depth analysis and consideration of the relationship with cognitive skills assessments specific to school mathematics, and serves as a basis for developing both types of skills in a balanced manner in mathematics education.

5.2 Positive proportionality in handling the assessment of non-cognitive skills and the overall assessment of cognitive skills

When looking at the groups of non-cognitive skills assessment at each stage of the overall assessment of cognitive skills, there was no overlap among the groups for Factor 2 (*Spirit of inquiry in mathematical problem-solving*) or Factor 3 (*Composure in mathematical problem-solving*), and there were significant differences among them. For example, in Figure 2, there is no overlap among any of the groups during each stage of cognitive assessment in the distribution of scores on Factor 2. However, there was an overlap between the assessment groups of stages 3 (*Medium*) and 4 (*High*) in Factor 1 (*Cooperation in mathematical problem-solving*), and a significant difference among all other groups. Figure 1 shows an overlap in the distribution of scores for Factor 1 for students belonging to stages 3 and 4 of cognitive skills. Thus, the assessment of each factor of non-cognitive skills was divided according to the overall assessment of cognitive skills, and a positive proportionality emerged between the assessment of the non-cognitive skills and cognitive skills.

This relationship suggests predictability between teachers' assessments of cognitive and non-cognitive skills. Semeraro et al. (2020) found that, in terms of non-cognitive factors, the level of math anxiety was effective in predicting mathematics achievement after controlling for other measures, including self-esteem and the quality of the student-teacher relationship. Similarly, Lee

(2020) examined students' self-review and identified self-efficacy, self-concept, anxiety, and openness to problem-solving as non-cognitive traits that predicted cognitive skills in mathematics.

This study successfully visualized the positive proportionality between teachers' assessments of non-cognitive skills specific to junior high school mathematics and their assessment of cognitive skills for each of the factors of non-cognitive skills. This relation suggests that there may be some predictability between the two assessments. However, it is not clear from which side the effect is coming, considering only a correlation was found and not a causal relationship.

5.3 Difficulty for teachers in distinguishing between assessing cognitive and non-cognitive skills

Regarding the relationship between the assessment of cognitive and non-cognitive skills in junior high school mathematics, many students with low scores in the cognitive skills assessment may have low scores for non-cognitive skills. When assessments are specific to each domain of junior high school mathematics, the teacher's observational assessment mediates and the overall assessment of cognitive skills is weakened (Iwata et al., 2021).

Teachers are expected to assess cognitive and non-cognitive skills objectively, distinguishing between them, even when these assessments influence each other. In this case, even if there is a correlation between the two, given the independence of the assessments, there should be an overlap in the distribution of each set of non-cognitive skills assessments corresponding to each assessment.

However, the overlap of distributional areas was hardly confirmed in these results based on the end-of-year survey, and a clear positive proportionality between the two assessments was confirmed. This suggests that teachers may not be able to distinguish between the observational assessment of non-cognitive skills specific to junior high school mathematics and the overall assessment of cognitive skills.

There may be several reasons for this. Teachers may lack clear and independent assessment standards for non-cognitive skills. Even if they have such standards, they may struggle to assess students' learning behaviors according to each standard separately. For instance, consider a scenario where a student persists in solving a problem and eventually succeeds. In this case, teachers can focus on the cognitive skills needed to solve the problem; however, they may have difficulty capturing the process of perseverance as a manifestation of non-cognitive skills. Teachers may have implicitly linked the assessment of cognitive and non-cognitive skills. For instance, if teachers hold a preconceived belief that students' high or low test scores are solely due to their ability or inability to persevere, they may assess non-cognitive skills based on test scores.

5.4 Limitations and issues for future research

This study has three main limitations. First, it used exploratory factor analysis. However, the amount of data should be increased and a confirmatory factor analysis should be conducted to discuss a model. Second, when using the questionnaire items attributed to each factor as a measure of non-cognitive skills specific to junior high school mathematics, there are limitations in using the numerical values to rank-order the non-cognitive skills of individual children as no correlation or reproducibility with other scales was confirmed. Third, the survey conducted in this study identified a positive proportionality between the assessment of non-cognitive skills and cognitive skills among Japanese mathematics teachers, which may differ internationally; thus, international comparative research may reveal different results on the relationship between non-cognitive skills and cognitive skills assessments by teachers.

Future research should address the following issues. First, how the assessment of non-cognitive/cognitive skills for the same student happens and the correlation/causal relationship between the two overtime must be examined. Second, the factor structure of teachers' observational assessment of non-cognitive skills in each unit of arithmetic and mathematics (e.g., Algebra, Geometry, etc.) must be clarified. Third, the relationship between objective assessments of cognitive skills (academic achievement tests, etc.) and factors in the assessment of non-cognitive skills should be explored.

6. Conclusions

To address the first research question, "*How do teachers assess the non-cognitive skills specific to junior high school mathematics?,*" a questionnaire survey of teachers was conducted regarding the assessment of non-cognitive skills specific to junior high school mathematics based on the five characteristics of non-cognitive skills. The results showed that the teachers assessed the following three factors concerning non-cognitive skills specific to junior high school mathematics: *cooperation in mathematical problem-solving*, *spirit of inquiry in mathematical problem-solving*, and *composure in mathematical problem-solving*.

Regarding the second research question, "*What are the characteristics of the relationship between Teachers' Assessments of non-cognitive skills and cognitive skills both of which are specific to junior high school mathematics?,*" the study analyzed the relationship between Teachers' Assessments of non-cognitive skills specific to junior high school mathematics and their assessment of cognitive skills by using the factors of assessment of non-cognitive skills. The results showed several characteristics of the relationship. The assessment of each factor was divided according to the overall assessment stage of cognitive skills, and for both factors, a positive proportionality emerged between the assessment of the non-cognitive skills factors and the assessment of cognitive skills.

This study's results suggest that teachers might not be able to differentiate between the observational assessment of non-cognitive skills specific to junior high school mathematics and the overall assessment of cognitive skills, which must be addressed. To improve this situation, it is necessary to understand how teachers assess non-cognitive skills in the classroom and what kind of teacher education should be developed to improve their assessment abilities.

Additionally, the educational system needs to be improved. In the Japanese educational system, the development of non-cognitive skills is set as an educational goal on par with cognitive skills in the MEXT guidelines. However, as this study shows, Japanese teachers may not be able to distinguish between the two assessments. As international attention to the development of non-cognitive skills increases, the educational systems outside of Japan will likely set the development of non-cognitive skills as a goal along with cognitive skills. Therefore, the following points need to be considered: the non-cognitive skills specific to each subject in the educational system, how the skills should be assessed objectively, and how these assessments will shape students' futures.

The study suggests the possibility of developing a method that could combine the generic theoretical framework of non-cognitive skills with the concept of subject-specific non-cognitive skills to visualize the status of Teachers' Assessments of non-cognitive skills for a given subject. If this method is extended to school teaching, the current state of teachers' ability to assess non-cognitive subject-specific skills at each grade should improve. Hence, it is important to identify the problems in teacher education and develop measures to improve it.

Contributorship

Mikio Miyazaki carried out the research, drafted and revised the manuscript. Atsushi Yoshikawa performed the statistical analysis, and contributed to the revision. Taro Fujita provided important information on previous research and contributed to the revision.

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Appendix A

Question items that make up the factors and factor loadings.

Factor 1: Cooperation in mathematical problem-solving (20 items)	Factor loadings		
(54-γAR1) Not trying to cooperate with peers when creating new problems	0.910	−0.164	0.014
(33-βAF1) Trying to figure out with peers if mathematics can be used	0.907	−0.100	0.003
(30-βER1) Even when they know they can use mathematics, they do not want to tell their peers	0.853	0.112	−0.194
(55-γAF2) Trying to work with peers to find a better solution	0.842	0.034	−0.019
(34-βAR1) Not actively trying to get involved when thinking about how mathematics can be used together with peers	0.838	−0.040	0.051
(52-γER2) Not wanting to tell their peers what they did to solve the problem	0.823	0.141	−0.195
(12-αER2) Showing no interest in how peers are solving the problem	0.817	−0.059	0.103
(36-βAR2) Having trouble discussing with peers how to solve problems for which mathematics can be used	0.802	−0.128	0.109
(50-γER1) Not showing interest in the merits of their peers' solving methods	0.785	−0.073	0.165
(31-βEF2) Trying to solve mathematical problems using a peer's idea	0.743	0.037	0.002
(53-γAF1) Trying to think of new problems in cooperation with peers	0.733	0.261	−0.208
(49-γEF1) Actively trying to find merits in the solving methods of peers	0.724	0.124	0.009
(32-βER2) Not trying to use peers' ideas when solving mathematical problems	0.709	−0.107	0.191
(11-αEF2) Trying to understand the solutions of peers as much as possible	0.692	−0.121	0.256
(44-γOR2) Not being interested in a solution that differs from my own	0.661	0.051	0.159
(10-αER) Not caring if peers do not understand my solution method	0.609	0.197	−0.107
(15-αAF2) Discussing how to solve the problem until everyone is satisfied	0.583	0.370	−0.071
(43-γOF2) Being interested in a solution method different from my own	0.524	0.209	0.146
(16-αAR2) Not caring if the problem's solution does not make sense to some peers and just trying to convey it in simple words	0.480	0.227	0.052
(14-αAR1) Relying on others when trying to figure things out with peers	0.450	0.224	0.216

Factor 2: Spirit of inquiry in mathematical problem-solving (12 items)	Factor loadings		
(23-βOF2) Continuing to try to find a new problem by themself even after the problem has been solved	−0.034	1.003	−0.123
(41-γOF1) Continuing to try to find another solving method even after solving the problem	0.011	0.955	−0.075
(45-γCF1) Continuing to think about how to improve the solving method after solving the problem	−0.033	0.954	−0.032
(24-βOR2) Being satisfied once the problem is solved and not trying to find a new problem	−0.071	0.925	−0.021
(42-γOR1) Not trying to think of another solving method after solving a problem	0.015	0.883	−0.033
(47-γCF2) Trying to closely examine the problem's solution for errors	−0.001	0.762	0.135
(46-γCR1) Being satisfied after solving a problem and not interested in improving the solution	0.070	0.738	0.076
(21-βOF1) Actively trying to figure out if what has been learned in mathematics can be used in everyday life	0.149	0.675	0.063
(7-αCF2) Trying to solve the problem after having a clear overview	−0.026	0.663	0.231
(1-αOF1) Trying to produce a good solution method even if it may take longer	0.065	0.626	0.245
(2-αOR1) Trying not to spend a lot of time thinking about a good solution method	0.137	0.531	0.240
(22-βOR1) Not trying to relate what they learned in mathematics to everyday life	0.185	0.527	0.196

Factor 3: Composure in mathematical problem-solving (11 items)	Factor loadings		
(20-αNR2) Being unable to tackle problems calmly because of trivial concerns	−0.057	−0.091	0.938
(38-βNR1) Getting frustrated and demotivated when they are not able to use what they have already learned when solving a mathematical problem	−0.127	−0.013	0.917
(58-γNR1) Getting frustrated or demotivated when someone points out a mistake in the solution method	0.019	−0.144	0.911
(19-αNF2) Being able to concentrate on problems without distraction	−0.019	0.157	0.775
(39-βNF2) Trying to work calmly in situations where mathematics is used	0.098	0.057	0.754
(40-βNR2) Getting in a bad mood and demotivated in situations where mathematics is used	0.098	−0.035	0.743
(37-βNF1) Trying to remain calm when solving mathematical problems, even when not using what they have already learned	0.034	0.144	0.733
(17-αNF1) Trying to take time to think calmly without panicking when there is a problem that cannot be solved	−0.035	0.281	0.687
(57-γNF1) Being able to calmly handle the situation when a mistake in the solution is pointed out	0.146	0.007	0.671
(6-αCR1) Giving up if not being able to solve a problem after a little thought	0.012	0.318	0.613
(28-βCR2) Stopping halfway when not being able to use what has been learned in mathematics in daily life situations	0.006	0.394	0.519

Appendix B

Cooperation in mathematical problem-solving.

		Difference of mean value (I-J)	Standard error	Significance probability	95% confidence interval	
					Lower limit	Upper limit
1	2	−0.785	0.100	0.000	−1.060	−0.511
	3	−1.257	0.098	0.000	−1.526	−0.989
	4	−1.464	0.094	0.000	−1.722	−1.208
	5	−1.730	0.088	0.000	−1.972	−1.489
2	1	0.785	0.100	0.000	0.511	1.060
	3	−0.471	0.088	0.000	−0.712	−0.232
	4	−0.679	0.083	0.000	−0.906	−0.453
	5	−0.945	0.076	0.000	−1.155	−0.736
3	1	1.257	0.098	0.000	0.989	1.526
	2	0.471	0.088	0.000	0.232	0.712
	4	−0.207	0.080	0.073	−0.427	0.012
	5	−0.473	0.073	0.000	−0.675	−0.272
4	1	1.464	0.094	0.000	1.208	1.722
	2	0.679	0.083	0.000	0.453	0.906
	3	0.207	0.080	0.073	−0.012	0.427
	5	−0.265	0.067	0.001	−0.450	−0.081
5	1	1.730	0.088	0.000	1.489	1.972
	2	0.945	0.076	0.000	0.736	1.155
	3	0.473	0.073	0.000	0.272	0.675
	4	0.265	0.067	0.001	0.081	0.450

Note. "Difference of mean value (I-J)" was significantly different in all cases except "3–4 (−0.207)" and "4–3 (0.207)."

Appendix C

Spirit of inquiry in mathematical problem-solving.

		Difference of mean value (I-J)	Standard error	Significance probability	95% confidence interval	
					Lower limit	Upper limit
1	2	−0.5592	0.069	0.000	−0.748	−0.371
	3	−1.282	0.066	0.000	−1.463	−1.101
	4	−1.678	0.063	0.000	−1.852	−1.504
	5	−2.130	0.055	0.000	−2.281	−1.979
2	1	0.559	0.069	0.000	0.371	0.748
	3	−0.722	0.076	0.000	−0.930	−0.515
	4	−1.118	0.073	0.000	−1.321	−0.917
	5	−1.570	0.066	0.000	−1.753	−1.388
3	1	1.282	0.066	0.000	1.101	1.463
	2	0.722	0.076	0.000	0.515	0.930
	4	−0.396	0.071	0.000	−0.591	−0.202
	5	−0.847	0.064	0.000	−1.022	−0.674

(continued)

(continued)

		Difference of mean value (I-J)	Standard error	Significance probability	95% confidence interval	
					Lower limit	Upper limit
4	1	1.678	0.063	0.000	1.504	1.852
	2	1.118	0.073	0.000	0.917	1.321
	3	0.396	0.071	0.000	0.202	0.591
	5	−0.451	0.061	0.000	−0.619	−0.285
5	1	2.130	0.055	0.000	1.979	2.281
	2	1.570	0.066	0.000	1.388	1.753
	3	0.847	0.064	0.000	0.674	1.022
	4	0.451	0.061	0.000	0.285	0.619

Note. "Difference of mean value (I-J)" was significantly different in all cases.

Appendix D

Composure in mathematical problem-solving.

		Difference of mean value (I-J)	Standard error	Significance probability	95% confidence interval	
					Lower limit	Upper limit
1	2	−0.742	0.100	0.000	−1.016	−0.468
	3	−1.242	0.089	0.000	−1.487	−0.998
	4	−1.605	0.082	0.000	−1.831	−1.381
	5	−1.942	0.074	0.000	−2.145	−1.740
2	1	0.742	0.100	0.000	0.468	1.016
	3	−0.500	0.092	0.000	−0.752	−0.248
	4	−0.863	0.085	0.000	−1.098	−0.629
	5	−1.200	0.077	0.000	−1.413	−0.987
3	1	1.242	0.089	0.000	0.998	1.487
	2	0.500	0.092	0.000	0.248	0.752
	4	−0.363	0.072	0.000	−0.562	−0.165
	5	−0.700	0.063	0.000	−0.872	−0.528
4	1	1.605	0.082	0.000	1.381	1.831
	2	0.863	0.085	0.000	0.629	1.098
	3	0.363	0.072	0.000	0.165	0.562
	5	−0.336	0.052	0.000	−0.480	−0.193
5	1	1.942	0.074	0.000	1.740	2.145
	2	1.200	0.077	0.000	0.987	1.413
	3	0.700	0.063	0.000	0.528	0.872
	4	0.336	0.052	0.000	0.193	0.480

Note. "Difference of mean value (I-J)" was significantly different in all cases.