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# A Psychometric Validation of the Sociomathematical Norm Scale for Senior High School Students in Mathematics Learning

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**Abstract:** Students in mathematics classes do not understand the importance of sociomathematical norms in learning mathematics. This causes sociomathematical norms not to be teachers' focus when learning mathematics. Besides, there is no standardized instrument for assessing this norm, so developing this instrument is necessary to measure socio-mathematical norms in learning mathematics. This study aims to create and verify the psychometric validity of the sociomathematical norm scale. This research used a survey method with 505 senior high school students from Jakarta and West Java as respondents. The results showed that 25 items had convergent validity, with a loading factor value of > 0.700, meaning they could be declared valid. Concurrent validity indicates that each sociomathematical norms indicator is valid as a whole. Discriminant validity shows that the average variance extracted value on the diagonal is higher than the other values, so each item is declared valid. It was concluded that each item of the sociomathematical norms instrument has accuracy in its measurement function. The reliability test shows that each sociomathematical norms item is declared reliable. The reliability value of the sociomathematical norm item is .99, and the person's reliability is .86. Thus, the instruments developed can measure sociomathematical norms in learning mathematics.

**Keywords:** *Developments scale, learning mathematics; psychometric validation, RASCH model, sociomathematical norms.*

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## Introduction

Learning mathematics is an activity that involves not only the process of thinking individually but also a collective action in social interaction (Dickes et al., 2020; Güven & Dede, 2017; McClain & Cobb, 2001; Yackel & Rasmussen, 2003). Social interaction in teaching and learning mathematics determines cognitive development through a group communication process that goes hand in hand (Widodo et al., 2019, 2023). Therefore, it is necessary to develop an in-depth study of the importance of social interaction norms in mathematics learning, known as sociomathematical norms (Maarif et al., 2022; Yackel & Cobb, 1996). Sociomathematical norms are normative understandings in the learning process of differences and the effectiveness of mathematical thinking to build mathematical knowledge (Denton, 2017; Lim et al., 2023). Other researchers reveal that sociomathematical norms are an attitude to explaining different answers to students' math problems (Code et al., 2016; Kang & Kim, 2016; Savuran & Akkoç, 2023). Sociomathematical norms will appear when there are differences in perceptions, ways, mindsets, arguments, expectations, and obligations that are in discussion. However, they can be neutralized through negotiations to share (Ozdemir Baki & Kilicoglu, 2023). This sharing process makes students effective in understanding math problems so that each student can take information from one another. The practical discussion will find a middle point in the differences in perceptions to understand a mathematical problem. Accuracy, efficiency, and motivation in solving mathematical problems can occur in learning (Arroyo et al., 2014).

In connection with the opinions of these experts, the sociomathematics norm is an activity that involves not only individual thought processes but also social interaction in the mathematics class. This norm implies the need for negotiation between students and exchanges with teachers. If there are differences in math answers and differences in mathematical explanations, they need an agreement so that the math problems faced by students are relatively easy to solve. Sociomathematical norms in learning mathematics are an essential part to be developed to discipline students in complying with the rules of the learning interaction process by respecting each other's opinions (Biza et al., 2015; Kang & Kim, 2016; Stephan, 2020; Widodo et al., 2020). Furthermore, sociomathematical norms can train cooperation between

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students in solving mathematical problems through sharing ideas (Fukawa-Connelly, 2012). In addition, with strong sociomathematical norms, students can explain, justify, and argue for solutions obtained in solving math problems (Francisco, 2013).

Sociomathematical norms result from forming self-confidence, attitude values, and individual arguments related to mathematics as a learning activity process (Apsari et al., 2020; Putri et al., 2015; Yun & Kim, 2015). In addition, sociomathematical norms can be developed through various mathematics learning activities that are interactive between individuals by emphasizing active collaboration (Levenson et al., 2009; Morrison et al., 2021).

Sociomathematical norms are mathematical activities in learning that is characterized by experience of mathematics, explanation of the mathematics, mathematical difference, mathematical communication, mathematical effectiveness, and mathematical insight (Heyd-Metzuyanim, 2015; Ningsih & Maarif, 2021; Widodo et al., 2020; Zembat & Yasa, 2015). In the process of learning mathematics, activity experience is needed. The intended mathematics experience is students' experience in understanding written mathematical ideas, which can then be explained systematically (Kang & Kim, 2016). Knowledge of mathematics can train students to construct beliefs about the arguments expressed when solving mathematical problems (Thompson, 2013; Zhou et al., 2021). Explaining the material being studied in mathematics learning activities is very much needed. That is necessary for developing sociomathematical norms, namely the explanation of mathematics (Matranga & Silverman, 2022). Description of mathematics is urgently required when learning activities are taking place to foster students' confidence in their understanding of the mathematical concepts they are learning (Maarif et al., 2020). Explanation of mathematics can provide inferences about descriptions of mathematical operations and provide a valid way of specifying a mathematical sentence needed in compiling ideas to a conclusion (Baker, 2009; Wylie & Chi, 2014).

There are often differences in thinking between students in learning mathematics. To bridge these differences in thinking, a method is needed to find common ground between the ideas expressed. Sociomathematical norms allow students to learn how to deal with differences in thinking in mathematical problems (Lim et al., 2023). We can view mathematical differences as a positive side for developing students' thinking so that the analysis of mathematical problems becomes more profound and comprehensive (Fukawa-Connelly, 2012). Mathematical differences can be analyzed by examining the similarities and differences in ideas from several alternative solutions, which are then compared to find the best solution (Zembat & Yasa, 2015).

Sociomathematical norms can be seen in how students develop mathematical communication of mathematical concepts both orally and in writing (Gearing & Hart, 2019; Kang & Kim, 2016). In learning mathematics, mathematical communication can be seen in how students express mathematical ideas, represent mathematical problems in images, discuss concepts coherently, and understand ideas in a language that is easy to understand (Lomibao et al., 2016). In addition, mathematical communication is also intended to see student explanations in acting to validate procedures or steps for solving mathematics systematically, both orally and in writing (Brendefur & Frykholm, 2000).

In learning mathematics, effective action is needed to understand and solve the mathematical problems being studied. For this reason, one of the values developed in the sociomathematical norm includes mathematical effectiveness (Ningsih & Maarif, 2021). The value of mathematics effectiveness will lead students to determine practical actions from several alternative solutions in solving a mathematical problem (Svensson & Wester, 2022). In previous research conducted by Ningsih and Maarif (2021) with class VII-A students at SMP 113 Jakarta learning mathematics in class, it was found that sociomathematical norms affect the learning outcomes of students learning mathematics. Students with high sociomathematical norms have good learning outcomes; if students have low sociomathematical norms, students also have expected learning outcomes. These results align with research conducted by Rahmah and Khusna (2023), which found a positive relationship between the ability to solve problems and the sociomathematical norms possessed by students. In other words, students with high problem-solving abilities have high sociomathematical norms, and students with low problem-solving abilities have standard sociomathematical norms.

When students encounter learning obstacles, practical steps are needed to solve problems with the right ideas (Maarif et al., 2019). This requires students to have the ability to think creatively in solving problems. The level of creativity students possess causes the arguments presented by students to vary, thus requiring negotiation so that the differences in opinions get a way out or a solution (Widodo et al., 2020). Although the results of this study are different from research conducted by Saskiya and Khusna (2023), which states that every individual who has high mathematical creative thinking abilities has high sociomathematical norms, every individual who has moderate mathematical creative thinking abilities also has sociomathematical norms. Students with low mathematical creative thinking abilities have soft aspects of sociomathematic norms.

Several different studies have focused on research on sociomathematical norms and how they are implemented in classroom learning by teachers and students (McClain & Cobb, 2001; Sánchez & García, 2014), identification of the elements forming sociomathematical norms (Maarif et al., 2022), observation of sociomathematical norm indicators (Widodo et al., 2020), and the relationship between sociomathematical norms on mathematical ability (Ningsih & Maarif, 2021; Rahmah & Khusna, 2023; Saskiya & Khusna, 2023). McClain and Cobb (2001), in their research to understand how mathematics teachers can proactively support their students' mathematics learning by documenting the role of a first-grade teacher in guiding the development of sociomathematical norms in their classrooms, found that it is essential for teachers to drive the emergence of social norms proactively—sociomathematical norms when teaching mathematics for understanding so that learning mathematics becomes more effective. Sánchez and Garcia (2014), who investigated whether or not there was a relationship between sociomathematical norms and mathematics at different academic levels, showed that sometimes there are cognitive conflicts when students work in small groups, the impact of which can lead to an incomplete understanding of mathematical concepts, for that conflict This cognitive function must be completed by students in their groups so that knowledge of concepts becomes better and learning mathematics becomes more effective. Both of these studies have used the sociomathematical norm instrument, but the level of validity of the instrument used has not been reported.

The results of research conducted by Ningsih and Maarif (2021), Rahmah and Khusna (2023), and Saskiya and Khusna (2023) have used instruments on sociomathematical norms to study sociomathematical norms based on their mathematical abilities such as critical and creative thinking skills. The instruments used in these three studies have used indicators of sociomathematical norms. Still, only the level of validity of these instruments has not been measured because they only use expert judgment in measuring the sociomathematical norms used. In contrast, the research conducted by Widodo et al. (2020) used a sociomathematical norm instrument which was developed from 4 aspects, namely (1) the experience of mathematics, (2) the explanation of the mathematics, (3) mathematical differences, (4) mathematical communication the indicators developed were analyzed using confirmatory analysis, and it was concluded that the four indicators are valid and fit

The researchers have provided some information that the importance of sociomathematical norms in learning mathematics needs to be developed in all elements (Güven & Dede, 2017; Stephan, 2020), as well as the hierarchical viewpoint related to research on sociomathematical norms. One crucial element to create is an instrument in the form of a questionnaire to measure sociomathematical norms in learning mathematics. An instrument used for research should be validated and standardized (Martin et al., 2022; Mohajan, 2017). as was done by Widodo et al. (2020), who developed an observation sheet to measure sociomathematical norms. However, research on developing sociomathematical norm questionnaires to obtain standardized and measurable questionnaire instruments has never been carried out. So, this study focused on creating an instrument as a standardized and quantifiable sociomathematics norm questionnaire. This is what distinguishes current research from research that several researchers have carried out, e.g., McClain and Cobb (2001), Sánchez and García (2014), Maarif et al. (2022), Ningsih and Maarif (2021), Rahmah and Khusna (2023), dan Saskiya and Khusna (2023).

In addition, the difference between this study and the research conducted by Widodo et al. (2020) lies in (1) the type of instrument being developed, which in the current research uses a questionnaire, while previous research is in the form of observation sheets, (2) the indicators used to develop sociomathematical norms, in the current research include elements of mathematical experience (MEx), explanation of mathematics (MMEp), the mathematical difference (MD), mathematical communication (MC), mathematical effectiveness (MEf), and mathematical insight (MI) (Kang & Kim, 2016; Yackel & Cobb, 1996). At the same time, previous research included elements of (1) the experience of mathematics, (2) the explanation of mathematics, (3) mathematical differences, and (4) mathematical communication. The last difference lies in the analysis used to test the development of the instrument. The current study used SmartPLS 4 and RASCH, whereas previous studies used Confirmatory Factor Analysis with LISRELL. For this reason, this study aimed to establish and verify the psychometric validity of the sociomathematics norm scale. This instrument can be used to strengthen the process of student competency in determining norms in learning mathematics. In addition, the instrument can be used as a reference for further research on developing sociomathematical norms in mathematics learning.

## Methodology

*Research Design*

This research develops an instrument of sociomathematical norm adapted from the aspects produced by Kang and Kim (2016), Widodo et al. (2020), and Yackel and Cobb (1996), including parts of MEx, MEp, MD, MC, MEf, and MI. The items developed were derived from these six (6) aspects. Before testing the validity and reliability using the survey method of senior high school students, the instrument was first translated in forward and back translation (English to Indonesian, then Indonesian to English) by linguists' expert and native speakers. This was done because the subjects used as trials used Indonesian as their mother language.

*Participant and Data Collection*

Participants in this study were senior high school students who voluntarily filled out the sociomathematical norm questionnaire. The questionnaire instrument was distributed via Google form, complete with a consent letter to participate as a respondent. This research involved 505 high school students spread across the provinces of DKI Jakarta (80.4%) and West Java (19.4%). This follows the minimum sampling requirement to validate the instrument with at least 150 to 200 respondents (Kim, 2023). Data was collected using a survey of 505 respondents who voluntarily filled out a questionnaire using the Google form platform from 20 December 2022 to 20 January 2023. All study participants were divided by gender and school level, which included grades X and XI, as shown in Table 1.

*Table 1. Participant Demographics*

| Respondent | | Frequency | Percent (%) |
|---|---|---|---|
| Gender | Male | 259 | 51.3 |
| | Female | 246 | 48.7 |
| | Total | 505 | 100 |
| Province | DKI Jakarta | 406 | 80.4 |
| | West Java | 99 | 19.6 |
| | Total | 505 | 100 |
| Grade | 10th | 350 | 69.3 |
| | 11th Science | 85 | 16.8 |
| | 11th Social Science | 70 | 13.9 |
| | Total | 505 | 100 |

*Instrument*

The sociomathematical norm instrument was developed and adapted by Kang and Kim (2016), Widodo et al. (2020), and Yackel and Cobb (1996). The steps for adjusting the sociomathematics norm instrument consist of five (5) stages. First, First, synthesize the indicators of sociomathematical norms reported by the three research teams. This stage is carried out to define the variables owned by sociomathematical norms. Second, it describes the variables the researchers agreed upon in more detailed indicators. Third, arrange items corresponding to the agreed variables to obtain a prototype instrument of sociomathematics norms. Fourth, try out sociomathematical norms instruments. Fifth, Analyzing the validity and reliability. From the analysis and synthesis results derived from the study report by Kang and Kim (2016), Widodo et al. (2020), and Yackel and Cobb (1996) obtained six (6) indicators or variables related to sociomathematical norms, which include indicator: MEx, MEp, MD, MC, MEf, and MI. MEx is defined as students being able to contribute to careful discussion activities in learning mathematics. MEp means that students can understand and explain ideas systematically in problem-solving.

Furthermore, MD can be interpreted as students being able to compare the similarities and differences of several alternative problem-solving solutions to get the best solution. The next indicator is MC, which defines students' ability to understand and express a statement using straightforward language. MEf can be interpreted as constructing the most effective alternative solutions and explaining them in plain language. The latter MI broadly refers to various sources of information and interaction in discussing mathematical problems.

The questionnaire consists of 28 items that refer to 6 predetermined indicators: MEx, MEp, MD, MC, MEf, and MI. Each item has four answer choices using a Likert scale. Items on an instrument of sociomathematical norms were developed by referring to the operational definitions of variables (indicators) set. Furthermore, the item items are validated by experts with academic positions as associate professors and doctoral degrees covering grammar, vocabulary, and content validity of the specified indicators and some input from experts as material for consideration for revising the developed instrument. The distribution of items based on each hand can be seen in Table 2.

*Table 2. Indicators and Coding (Total Items=28)*

| Indicators | Statement Item Numbers | Statement Item Codes | Sum of Items |
|---|---|---|---|
| Mathematical Experience (MEx) | 1,2,3,4,5,6 | MEx1, MEx2, MEx3, MEx4, MEx5, MEx6 | 6 |
| Mathematical Explanation (MEp) | 7,8,9,10 | MEp1, MEp2, MEp, MEp3, MEp4 | 4 |
| Mathematical Difference (MD) | 11,12,13,14 | MD1, MD2, MD3, MD4 | 4 |
| Mathematical Communication (MC) | 15,16,17,18,19,20 | MC1, MC2, MC3, MC4, MC5, MC6 | 6 |
| Mathematics Effectiveness (MEf) | 21,22,23,24 | MEf1, MEf2, MEf3, MEf4 | 4 |
| Mathematical Insight (MI) | 25,26,27,28 | MI1, MI2, MI3, MI4 | 4 |

*Statistical Data Analysis*

Statistical data analysis was performed using IBM SPSS Statistics 25, WINSTEPS Version 5.1.4.0, AMOS 22.0, and SmartPLS 4 software. Descriptive statistical analysis was performed to see an overview of the data's characteristics, including percentage, average and standard deviation. To analyze construct validity, convergent validity, discriminant, and concurrent validity. Furthermore, to test the reliability of sociomathematical norm instruments, RASH analysis, confirmatory factor analysis, and consistent internal analysis were used.

RASCH model analysis was performed using WINSTEPS Version 5.1.4.0 software. Much analysis of the RASCH model was carried out to analyze the construct validity of a questionnaire (Tabatabaee-Yazdi et al., 2018). An instrument is said to be valid if the research data that has been collected follows the model with constructs based on the covariance between items and the causes of item responses (Atmoko et al., 2022; Kim, 2023). RASCH model analysis was conducted on sociomathematical norm instruments to determine RASCH model analysis, construct validity, item difficulty parameters, separator index, and reliability index. Calculation of the mean square value (MNSQ) is performed to show the suitability of the model fit and determine an item according to the assumption of unidimensionality. Suppose the average infit MNSQ value is between 0.5 and 2.0 (Kandel et al., 2020; Matheny & Clanton, 2020; Muslihin et al., 2022), and the point-measure correlation value is more than .40 (Ghazali et al., 2019; Khamis et al., 2014; Kim, 2023). The instrument was considered a model assessed at the appropriate level and productive for measuring rating scales (Fan et al., 2022; Kim, 2023; Muniandy et al., 2023; Muslihin et al., 2022). To indicate the instrument item difficulty parameter, it can be shown that a higher logit value is interpreted as having an item difficulty level, and a low logic value indicates it is easier. The item response curve verifies the goodness of fit value of the category response with a Likert scale of 4. If the SI value is more than 2.0, then the unidimensionality of the item is appropriate, and RI is more than equal to 0.80, indicating internal scale consistency (Kim, 2023).

Confirmatory factor analysis was performed using IBM SPSS Statistics 25 and AMOS 22.0 software. Confirmatory factor analysis was carried out by constructing the equation model structure. Model fit was analyzed according to the criteria if $\chi 2/df \leq 3.0$, comparative fit index (CFI) ≥ 0.90, Tucker–Lewis's index (TLI) ≥ 0.90, incremental fit index (IFI) ≥ 0.90, adjusted fit index (AGFI) ≥ 0.80, and the root mean square error of approximation (RMSEA) ≤ 0.08 criteria are met, the model is considered suitable (Widodo et al., 2020).

Convergent validity analyses were conducted using SartPLS 4 software with criteria if the loading factor values of > 0.7 (Cheah et al., 2018; Purnomo et al., 2020; Webb et al., 2017; Wigert, 2013). Concurrent validity was carried out using SmartPLS with the Average Variance Extracted (AVE) criterion value > 0.5 (Cheah et al., 2018; Hermanda et al., 2019; Wong, 2013). Furthermore, the discriminant validity test is carried out by looking at the Fornell & Larcker Criterion value by assessing the Average Variance Extracted (AVE) value on the diagonal with higher values below (Ab Hamid et al., 2017; Karakus et al., 2021; Purwanto et al., 2021).

Analysis of the reliability of the sociomathematical norm instrument items was carried out using SmartPLS 4 software. To see the level of reliability, it was carried out using the RASCH model analysis. Reliability testing is carried out by looking at Cronbach's Alpha and Composite Reliability values with the criteria if the Cronbach's Alpha values are > 0.7 and Composite Reliability > 0.7, then the instrument items are said to be reliable (Kaur et al., 2012).

## Results

*Construct Validity Base on Rasch Model*

The results of the analysis of the RASCH model of the sociomathematical norm instrument involving 505 respondents are shown in Table 3.

*Table 3. Item Difficulty Measures and Statistical Fit Sociomathematical Norms Applied in the RASCH Model Analysis*

| Items Number | Items Statement | Items Code | Measure | Infit MNSQ | Outfit MNSQ | PT-Measure Corr. |
|---|---|---|---|---|---|---|
| 1 | I paid attention to the teacher while explaining the material | MEx1 | -1.54 | 0.74 | 0.73 | .51 |
| 2 | I can show enthusiasm when learning mathematics with an active attitude during learning | MEx2 | -0.45 | 0.79 | 0.78 | .57 |
| 3 | I can solve math problems correctly while learning | MEx3 | 0.25 | 0.86 | 0.86 | .59 |
| 4 | I never paid attention to the teacher while explaining the material | MEx4 | -1.03 | 1.46 | 1.46 | .35 |
| 5 | I am passive and do not show enthusiasm during learning | MEx5 | 0.08 | 1.36 | 1.39 | .47 |
| 6 | I could not solve math problems correctly during the lesson | MEx6 | 0.64 | 0.99 | 1.02 | .60 |
| 7 | I can understand ideas/arguments from solutions given by teachers of math problems | MEp1 | -0.48 | 0.72 | 0.70 | .58 |
| 8 | I accept ideas/arguments expressed by other students | MEp2 | -0.98 | 0.71 | 0.71 | .45 |

*Table 3. Continued*

| Items Number | Items Statement | Items Code | Measure | Infit MNSQ | Outfit MNSQ | PT-Measure Corr. |
|---|---|---|---|---|---|---|
| 9 | I have no difficulty expressing ideas/arguments to solve mathematical problems in a structured way | MEp3 | 0.71 | 0.76 | 0.77 | .57 |
| 10 | I have difficulty understanding the ideas/arguments given by the teacher or other students in solving math problems | MEp4 | 0.91 | 0.93 | 0.95 | .55 |
| 11 | I work on every problem given by the teacher using the solution myself | MD1 | 0.40 | 0.93 | 0.94 | .44 |
| 12 | I am happy when there are differences of opinion conveyed by other students in the class | MD2 | -0.55 | 0.95 | 0.97 | .58 |
| 13 | I am unable to accept the diversity of ideas/arguments from other students | MD3 | -0.39 | 1.04 | 1.03 | .41 |
| 14 | I am waiting for solutions from other students in working on the questions given by the teacher | MD4 | 1.16 | 1.09 | 1.13 | .48 |
| 15 | I can understand the material presented by the teacher with one explanation | MC1 | 0.87 | 1.10 | 1.14 | .47 |
| 16 | When the teacher asks me a question, I can respond or answer with the right answer | MC2 | 0.61 | 0.78 | 0.79 | .58 |
| 17 | I ask questions when I don't understand the material presented by the teacher | MC3 | -0.55 | 1.11 | 1.10 | .48 |
| 18 | I find it difficult to understand the material delivered by the teacher even though the explanation is repeated | MC4 | -0.85 | 1.27 | 1.35 | .18 |
| 19 | I am not able to give responses or answers appropriately when the teacher asks me questions | MC5 | 0.93 | 0.78 | 0.78 | .57 |
| 20 | I don't ask questions when I don't understand the material presented by the teacher | MC6 | 0.12 | 1.12 | 1.13 | .54 |
| 21 | can find an easier solution to solving math problems | MEf1 | 0.40 | 0.95 | 0.95 | .51 |
| 22 | I can explain the problem-solving solutions I find to other students appropriately | MEf2 | 0.39 | 0.79 | 0.77 | .56 |
| 23 | I am not able to explain the solution to the problem solving that I find to other students appropriately | MEf3 | 0.92 | 0.73 | 0.75 | .57 |
| 24 | I have no interest in finding solutions to math problems | MEf4 | 0.66 | 1.07 | 1.09 | .62 |
| 25 | I tried to find various solutions from different sources during the discussion | MI1 | -1.05 | 0.98 | 0.97 | .43 |
| 26 | I feel happy when learning mathematics applies the discussion system because I will get various solutions | MI2 | -1.00 | 1.19 | 1.17 | .43 |
| 27 | I help other students who have difficulty doing math problems | MI3 | 0.07 | 1.03 | 1.03 | .54 |
| 28 | I am not happy if my group mates do not accept my opinion | MI4 | 0.13 | 1.66 | 1.66 | .24 |

Note: MNSQ = Mean Squared; PT-Measure CORR. = Point-Measure Correlation

Table 3 shows that the MNSQ infit value for each item lies between 0.71 and 1.66 (with the criteria for an average MNSQ infit value being from 0.5 to 2.0), so 28 items are suitable for measuring the sociomathematical norm scale. Furthermore, Table 3 shows the correlation value of the 24 items, indicating more than 0.4, which means that the items can be used to measure the sociomathematical norm scale. At the same time, things with MEx4, MC4, and MI4 codes have a correlation value of less than .40. Nevertheless, the four items have MNSQ values following the criteria. So, overall, 28 items are considered to fulfil the model assessed at an appropriate and productive level for measuring the sociomathematical norm scale.

Furthermore, it shows each item's parameter difficulty by analyzing the logit value, as shown in Figure 1.

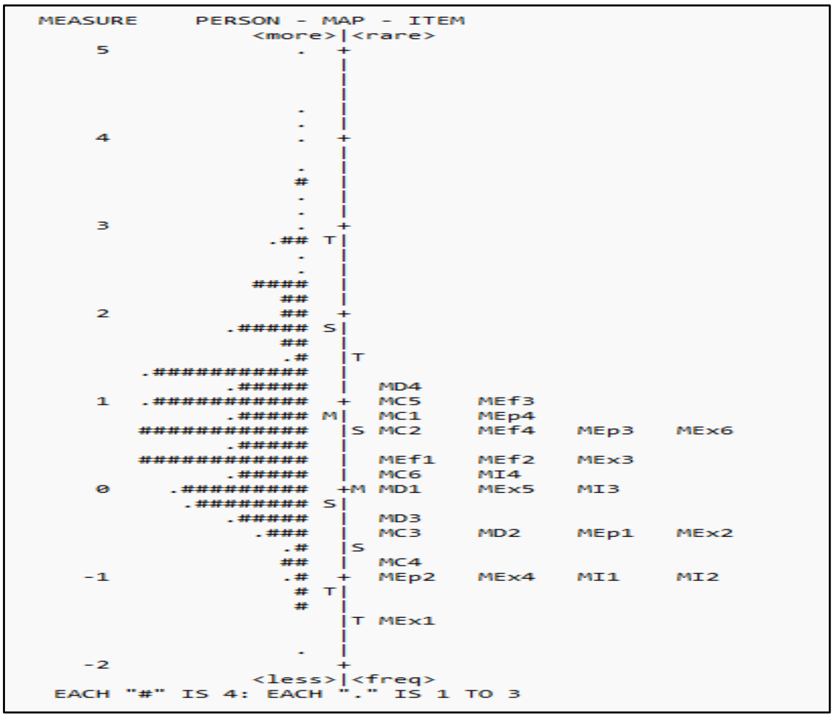


*Figure 1. Person Item Map Sociomathematical Norm*

Figure 1 shows the logit value of each item of the sociomathematical norm instrument. Items with code MEx1 with the editorial "I have paid attention to the teacher while explaining the material" are the lowest items, so they have a low difficulty level or are easy for respondents to answer. The item with the MD4 code with the editorial "I am waiting for solutions from other students in working on the questions given by the teacher" has the highest logit value, meaning that the respondent has difficulty being answered. Overall, Figure 1 shows the logit value of each item, which is equally distributed in terms of the problem.

To verify the goodness of fit value of the category response, it is shown through the item response curve, as shown in Figure 2.

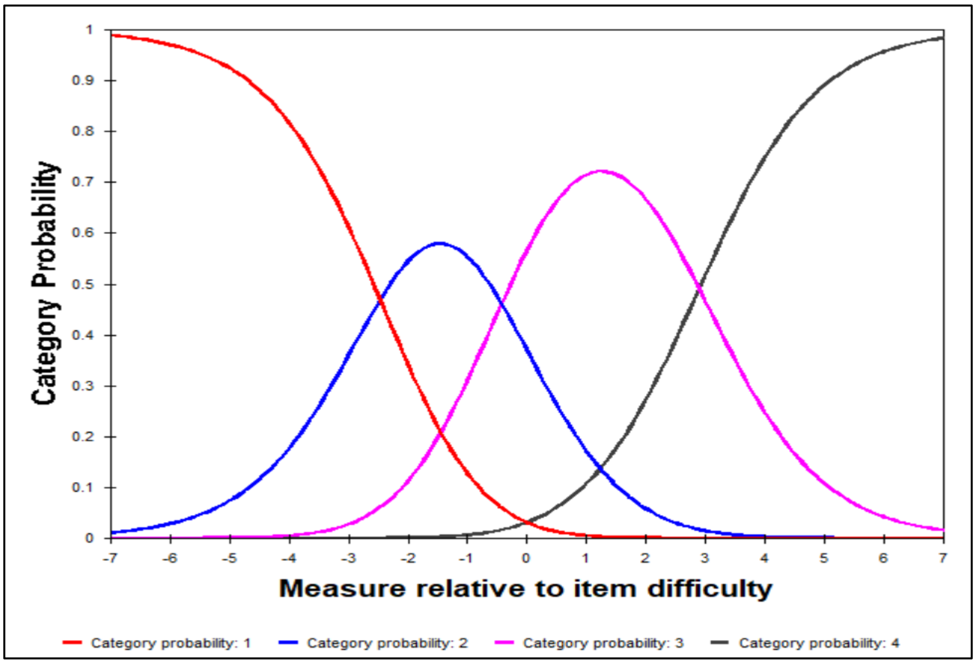


*Figure 2. Response Item Category Curve*

Figure 2 shows the sociomathematical norm curve's value, consisting of a Likert scale with four answers on the appropriate item response category curve. It can be seen that the rating scale looks different in each category, and there is an interaction between the scales, which indicates a relatively consistent interval scale.

*Confirmatory Factor Analysis*

The confirmation model for the sociomathematical norm factor can be seen in the following Figure 3. The results of the analysis of the norm sociomathematical factor confirmation model show $\chi 2/df = 0.971 \leq 3.0$, CFI = 0.935 ≥ 0.90, TLI = 0.912 ≥ 0.90, IFI = 0.905 ≥ 0.90, AGFI = 0.914 ≥ 0.80, and RMSEA) = 0.0036 ≤ 0,08. These results show that the model is at a suitable validation level.

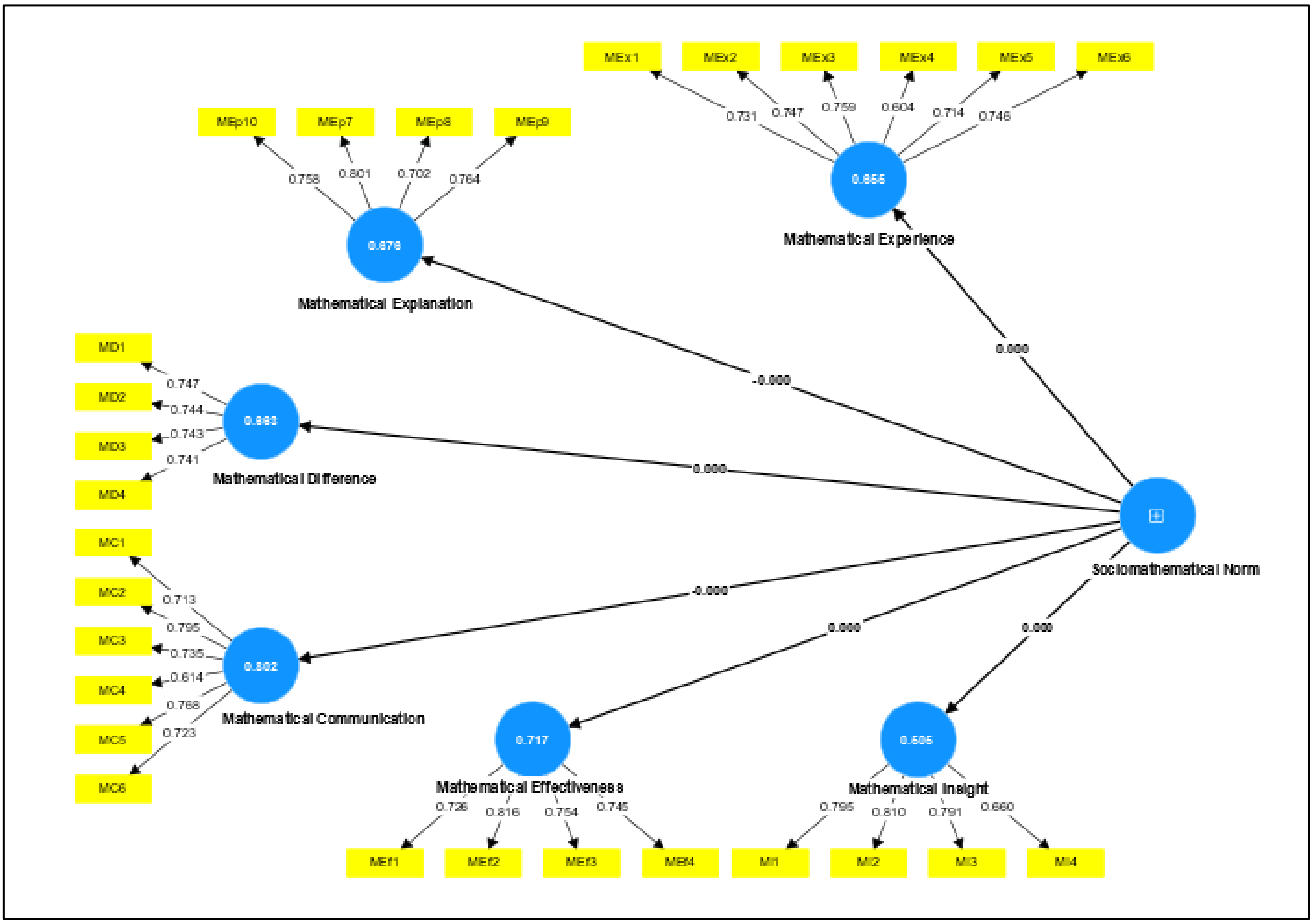


*Figure 3. The Confirmatory Factor Analysis of the Sociomathematical Norm Model With SmartPLS*

*Test of Validity: Convergent, Discriminant, and Concurrent*

Analysis of the convergent validity of the sociomathematical norm items is carried out by analyzing the factor loading of each item. Table 4 shows the results of the factor loading analysis for each item.

*Table 4. Results of Convergent Validity Analysis of Sociomathematical Norm Instruments*

| Numbers Item | Items Code | Outer Loading | Explanation | Numbers Item | Items Code | Outer Loading | Explanation |
|---|---|---|---|---|---|---|---|
| 1 | MEx1 | 0.731 | V | 15 | MC1 | 0.713 | V |
| 2 | MEx2 | 0.747 | V | 16 | MC2 | 0.795 | V |
| 3 | MEx3 | 0.759 | V | 17 | MC3 | 0.735 | V |
| 4 | MEx4 | 0.604 | NV | 18 | MC4 | 0.614 | NV |
| 5 | MEx5 | 0.714 | V | 19 | MC5 | 0.768 | V |
| 6 | MEx6 | 0.748 | V | 20 | MC6 | 0.723 | V |
| 7 | MEp1 | 0.758 | V | 21 | MEf1 | 0.720 | V |
| 8 | MEp2 | 0.801 | V | 22 | MEf2 | 0.816 | V |
| 9 | MEp3 | 0.702 | V | 23 | MEf3 | 0.754 | V |
| 10 | MEp4 | 0.764 | V | 24 | MEf4 | 0.745 | V |
| 11 | MD1 | 0.747 | V | 25 | MI1 | 0.795 | V |
| 12 | MD2 | 0.744 | V | 26 | MI2 | 0.810 | V |
| 13 | MD3 | 0.743 | V | 27 | MI3 | 0.791 | V |
| 14 | MD4 | 0.741 | V | 28 | MI4 | 0.660 | NV |

Note: V= Valid and NV=Not Valid

Table 4 shows that of the 28 items of the sociomathematical norm instrument, 25 items have a loading factor value > 0.700, which means they can be declared valid. The three items, which include MEx4, MC4, and MI4, have a factor loading value of < .700 even though each is more than .600, which means the three items are invalid. Furthermore, to show the validity for each item by showing AVE, as shown in Table 5.

*Table 5. Concurrent Validity Analysis with Average Variance Extracted (AVE)*

| Indicators | AVE | Rule of thumb | Explanation |
|---|---|---|---|
| MEx | .571 | > 0.500 | V |
| MEp | .573 | > 0.500 | V |
| MD | .553 | > 0.500 | V |
| MC | .574 | > 0.500 | V |
| MEf | .579 | > 0.500 | V |
| MI | .678 | > 0.500 | V |

Note: V=Valid

Table 5 shows the AVE value for each indicator of the sociomathematical norm > 0.500, meaning each indicator can be considered valid. Thus, the instrument is supported by each item that can measure each indicator. Furthermore, discriminant validity analysis is carried out to ensure that each concept from each latent model is different from the other variables. Validity testing is conducted to determine how precisely a measuring instrument performs its measurement function. The discriminant validity results using the Fornell & Larcker criterion values can be seen in Table 6.

*Table 6. Discriminant Validity: Fornell & Larcker Criterion*

| | MC | MD | MEf | MEx | MEp | MI |
|---|---|---|---|---|---|---|
| MC | .727 | | | | | |
| MD | .692 | .744 | | | | |
| MEf | .721 | .672 | .761 | | | |
| MEx | .642 | .560 | .603 | .719 | | |
| MEp | .675 | .611 | .664 | .640 | .757 | |
| MI | .581 | .559 | .558 | .444 | .461 | .767 |

Table 6 shows the Fornell & Larcker Criterion values on the diagonal with higher values below so that it can be concluded that each item of the sociomathematical norm instrument has accuracy in its measurement function. In addition, Table 7 shows the correlation between sociomathematical norm indicators showing a significant correlation.

*Table 7. Correlation Between Sociomathematical Norm Indicators*

| Correlation Between Indicators | r | p-value | Interpretation |
|---|---|---|---|
| MEx <=> MEp | .640 | <.000 | Sig. |
| MEx <=>MD | .560 | <.001 | Sig. |
| MEx <=>MC | .642 | <.000 | Sig. |
| MEx <=> MEf | .603 | <.000 | Sig. |
| MEx <=> MI | .444 | <.001 | Sig. |
| MEp <=> MD | .611 | <.001 | Sig. |
| MEp <=> MC | .675 | <.000 | Sig. |
| MEp <=> MEf | .684 | <.000 | Sig. |
| MEp <=> MI | .641 | <.000 | Sig. |
| MD <=> MC | .692 | <.000 | Sig. |
| MD <=> MEf | .627 | <.000 | Sig. |
| MD < => MI | .559 | <.001 | Sig. |
| MC <=> MEf | .721 | <.000 | Sig. |
| MC <=> MI | .581 | <.001 | Sig. |
| MEf <=> MI | .558 | <.001 | Sig. |

Note: Sig = Significant

Table 7 above shows that each sociomathematical norm indicator has a positive correlation. This shows that each indicator contributes positively to the sociomathematical norm. Thus, the developed indicators can be used to measure sociomathematical norms.

*Test of Reliability*

Instrument reliability testing was conducted by looking at Cronbach's alpha and composite reliability values. The results of reliability testing can be seen in Table 8.

*Table 8. Result of Reliability Test*

| Indicators | C$\alpha$ | CR | Rule of thumb | Explanation |
|---|---|---|---|---|
| MEx | .750 | .752 | > .700 | Rel. |
| MEp | .752 | .756 | > .700 | Rel. |
| MD | .731 | .731 | > .700 | Rel. |
| MC | .814 | .818 | > .700 | Rel. |
| MEf | .756 | .759 | > .700 | Rel. |
| MI | .764 | .765 | > .700 | Rel. |

Note: C$\alpha$ = Cronbach's alpha, CR = Composite reliability, Rel. = Reliabel

Table 8 shows that C$\alpha$ for each indicator is > .70, and the CR for each indicator is > .70. This can be interpreted that each item of sociomathematical norms is declared reliable. Furthermore, by analyzing the RASCH model, overall, the reliability of the sociomathematical norm instrument can be seen in Figure 4.

```
-------------------------------------------------------------------------------
| PERSON     493 INPUT     493 MEASURED              INFIT          OUTFIT    |
|          TOTAL      COUNT      MEASURE  REALSE    IMNSQ   ZSTD  OMNSQ   ZSTD|
| MEAN      79.0       28.0          .77     .37     1.00    -.4   1.00    -.4|
| P.SD       9.0         .0         1.03     .10      .78    2.3    .79    2.3|
| REAL RMSE    .38 TRUE SD     .96  SEPARATION  2.52  PERSON RELIABILITY  .86|
|-----------------------------------------------------------------------------|
| ITEM       28 INPUT     28 MEASURED              INFIT          OUTFIT      |
|          TOTAL      COUNT      MEASURE  REALSE    IMNSQ   ZSTD  OMNSQ   ZSTD|
| MEAN    1390.6      493.0          .00     .08     1.00    -.3   1.00    -.2|
| P.SD     117.3         .0          .73     .01      .23    3.4    .24    3.5|
| REAL RMSE    .08 TRUE SD     .72  SEPARATION  8.83  ITEM   RELIABILITY  .99|
-------------------------------------------------------------------------------
```

*Figure 4. Result of Reliability Test With RASCH Model Analysis*

Figure 4 shows the reliability value of the sociomathematical norm item of .99 and the person's reliability of .86. Thus, the sociomathematical norm instrument is identified as a scale with very high reliability.

## Discussion

This study aims to establish and verify psychometric validity on a sociomathematical norms scale. Following the phrase, Sociomathematical norms are social norms that exist in mathematics class (Widodo et al., 2019, 2023), so that this norm leads more to the process of mathematical thinking (Dickes et al., 2020; Gülburnu & Gürbüz, 2022). This norm is an activity that does not only involve individual thought processes but also social interactions in the mathematics class. This norm implies the need for negotiation if there are differences in mathematical answers and differences in mathematical explanations. In addition, sociomathematical norms in learning mathematics can discipline students to obey mathematical rules, follow the interactions of learning mathematics and respect each other's opinions (Biza et al., 2015; Kang & Kim, 2016; Stephan, 2020; Widodo et al., 2020). This is what underlies the need to develop a sociomathematical norms instrument. By acquiring or adapting a measuring tool for sociomathematical norms, it is hoped that it will make it easier to observe sociomathematical norms that exist in students in mathematics classes and make it easier for students to perceive themselves about social norms in learning mathematics.

The research that has been carried out seeks to develop and validate the sociomathematical norm instrument in the form of a questionnaire. The sociomathematical norm questionnaire was developed by adapting the indicators developed by Yackel and Cobb (1996) and Kang and Kim (2016), including Instruments Indicators MEx, MEp, MD, MC, MEf, and MI. This study's results align with previous research, which justifies the factor analysis of sociomathematical norm observation instruments (Widodo et al., 2020).

Research related to sociomathematical norms focuses more on analyzing sociomathematical norms in learning mathematics (Dickes et al., 2020; Fukawa-Connelly, 2012; Güven & Dede, 2017; Kang & Kim, 2016; Maarif et al., 2022; McClain & Cobb, 2001; Partanen & Kaasila, 2015; Putri et al., 2015; Sánchez & García, 2014; Widodo et al., 2019). Besides that, the analysis of sociomathematical norms on mathematical skills was also mainly carried out in previous studies (Ningsih & Maarif, 2021; Rahmah & Khusna, 2023; Saskiya & Khusna, 2023). It was found that only one study focused on developing a sociomathematical norms measurement, namely research conducted by Widodo et al. (2020). Previous measuring instrument studies used sociomathematical norms observation sheets, differentiating this research from current research. Besides that, in the study conducted by Widodo, the variables: experience of mathematics, explanation of the mathematics, mathematical differences, and mathematical communication were used to form sociomathematical norms, in contrast to the current research, which developed sociomathematical norms derived from Mathematical Experience (MEx), Mathematical Explanation (MEp), Mathematical Difference (MD), Mathematical Communication (MC), Mathematics Effectiveness (MEf), Mathematical Insight (MI).

The study results show that the item coded MEx1 with the editorial "I have paid attention to the teacher while explaining the material" is the lowest item. Hence, it has a low difficulty level, or in other words, it is easy for the respondent to answer. This condition can occur if one of the following conditions is met. First, items have meanings that have multiple linguistic interpretations or ambiguity. Ambiguity is the double meaning of a sentence uttered by someone so that it is doubtful (Bialystok & Shapero, 2005; Trueswell & Tanenhaus, 1994) or completely not understood by another person (Veale, 2014). Ambiguity can occur because the structure of phrases and sentences is inappropriate, and changes in the formation of words used in a sentence are not appropriate (Trueswell & Tanenhaus, 1994). This condition makes the subject confused because there is more than one sentence. The effect is that the student is confused in determining the appropriate answer to the subject's condition (Just & Carpenter, 2013; Slattery et al., 2013).

For this reason, in preparing the items of a research instrument, it is hoped that there will be no ambiguity. Second, all students' answers lead to one solution. This is in line with research conducted by Satrio (2008) that in social research involving questionnaires in the form of closed questions with answer choices provided, respondents are often "forced" to choose the answers provided because they do not have other answer choices. This forced condition results in the possibility that all students' responses refer to the same choice.

Item Code Mex1, the subject tends to answer according to the facts on the ground and the existing learning culture. This condition causes all students to give answers that lead to one solution. Context pays attention to the context of understanding different material. The context of paying attention does not necessarily mean that students understand. It's different if students understand. Students are more likely to pay attention to the material taught by the teacher in mathematics class. Students in the classroom learning process are always required to pay attention and understand the concept being conducted by the teacher so that when faced with these statements, students are easy to answer. These findings align with the previous study, which revealed teacher variations in teaching would attract students' attention and encourage students to provide quick responses in each mathematics lesson (Lan et al., 2009). In addition, the results of the previous study revealed that developing sociomathematical norms on aspects of mathematical experience shows that students' attention to most students can focus when the teacher is explaining math material in class (Ningsih & Maarif, 2021).

Items with the MD4 code with the editor "I am waiting for solutions from other students in working on the questions given by the teacher" have the highest logit value and mean that the respondent has difficulty answering the item. These conditions indicate that making decisions on statements to wait for solutions to problem solving from other people needs consideration. In learning mathematics, it is not uncommon for students to wait for confirmation of their classmates' ideas. This is in line with the results of previous research, which revealed that only 7% of the respondents could accept other friends' solutions while solving mathematical problems (Ningsih & Maarif, 2021). In line with this research, the different results show that in the process of mathematical representation, students experience a tendency to wait for the opinions of other participants to be compared with the results of the solutions that have been constructed (Renaldy & Maarif, 2022). Overall, Figure 1 shows the logit value of each item, which is equally distributed in terms of difficulty. These conditions indicate that the instrument is good at estimating the answers from respondents. This follows what previous researchers said: a measurement scale with an even difficulty level suggests that the instrument can differentiate solutions from respondents (Kim, 2023).

Furthermore, the concurrent validity test shows that of the 28 items of the sociomathematical norm instrument, 25 items are said to be valid. Three items include (1) I never paid attention to the teacher while explaining the material, which is contained in the indicator of MEx or Mathematical Experience; (2) I find it challenging to understand the material delivered by the teacher even though the explanation is repeated, which is contained in the indicator MC or Mathematical Communication, and (3) I am not happy if my group mates do not accept my opinion, which is contained in the indicator MC or Mathematical Insight has a loading factor value < .700. Even so, each factor loading value of more than 0.600 is valid. An instrument item can still be accepted if the loading factor is between .500 and .69 (Ghozali & Fuad, 2014).

Concurrent validity shows that each sociomathematical norm indicator is validated in the AVE analysis so that the instrument can measure sociomathematical norms. These results align with the previous research that validated sociomathematical norm indicators, including MEx, MEp, MD, and MC (Widodo et al., 2020). Furthermore, the discriminant validity results show the Fornell and Larcker Criterion values on the diagonal with higher values below, so it can be concluded that each item of the sociomathematical norm instrument has accuracy in its measurement function. Thus, the sociomathematical norm instrument that has been developed has been verified to have accuracy in its assessment. This aligns with research conducted by several previous studies (Kang & Kim, 2016; Ningsih & Maarif, 2021; Widodo et al., 2020).

The reliability test results showed that Cα for each indicator is > .70 and CR for each indicator is > .70. This can be interpreted that each item of the sociomathematical norms is declared reliable. Furthermore, the RASCH model analysis shows that Cα for item reliability is .99 and person reliability is .86. Thus, the sociomathematical norm instrument is identified as a very high-reliability scale, so it can be used to measure students' sociomathematical norms. This aligns with a previous study that confirmed sociomathematical norm indicators with reliable results (Widodo et al., 2020).

## Conclusion

This study developed a measure for sociomathematical norms in learning mathematics by testing its validity and reliability. The research results show that the instrument of sociomathematical norm has been obtained and comes from 6 variables: mathematical experience, mathematical explanation, mathematical difference, mathematical communication, mathematical effectiveness, and mathematical insight. This study provides findings that can be useful for the development of mathematics learning, especially sociomathematical norms, due to the compatibility of the analysis results using the model RASCH, Smart PLS, and AMOS. However, this study only involved students in two provinces, namely DKI Jakarta and West Java. Therefore, we hope that the findings of the sociomathematical norm instrument can be used and further developed to contribute to improving mathematics learning. In addition, knowledge of sociomathematical norms formed from these six variables can be used as an alternative to studying sociomathematical norms.

## Recommendations

This research produces a sociomathematical norms instrument that can improve mathematics learning in the classroom. The study results showed that the sociomathematical norms instrument consisted of 25 valid and reliable items. Based on the results of this study, we recommend teachers use the sociomathematical norms instrument to measure social abilities (student affective aspects) in learning and mathematics classrooms. In addition, this instrument can be used as an alternative to measuring sociomathematical norms for researchers in sociomathematical norms.

## Limitations

Several research limitations have been carried out in developing sociomathematical norm instruments. First, the research that has been done uses a sample of high school students, so it is limited in generalization. Therefore, in further study, we recommend validating the sociomathematical norm instrument with a more extensive and varied sample for all levels of education. Second, there are three sociomathematical norm items with a loading factor value of < .70, so these three items need to be re-analyzed regarding the editorial to be more easily understood by respondents. Third, the analysis of validity and reliability using the RASCH, Smart PLS, and Amos models that have been carried out still has weaknesses, so it is necessary to verify the reliability of the test-retest. Fourth, research on validating sociomathematical norm instruments has not examined comparisons between gender and educational levels. So that further analysis can be carried out to compare sociomathematical norms based on gender and status of education.

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### Conflict of Interest

The authors have no conflict of interest to declare.

### Authorship Contribution Statement

Maarif: Conceptualization, design, editing/reviewing, supervision, final approval. Soebagyo: Conceptualization, design, analysis/interpretation, writing. Pradipta: Editing/reviewing, supervision, final approval. Widodo: Editing/reviewing, critical revision of manuscript, supervision, final approval.

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