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Development of the Pre-Service Teachers' Mathematics Identity Instrument (P-STMI)

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ABSTRACT

Background: The urgency of knowledge of mathematical identity is one of the reasons for the increasing numbers of research on mathematical identity. Knowing pre-service mathematics teachers' mathematical identity becomes essential and needs to be done using valid mathematical identity instruments. Mathematical identity instruments can reveal one's mathematical identity, contributing to learning and teaching mathematics. However, mathematical identity instruments have not been widely developed, especially for pre-service mathematics teachers. **Objectives**: This research aims to develop valid and reliable mathematical identity instruments for pre-service mathematics teachers. **Design**: This research used scale-development research using the DeVellis' model. **Setting and Participants**: 196 pre-service mathematics teachers from 7 universities in Indonesia were involved in piloting the test. **Data collection and analysis**: The questionnaire instrument was distributed via google form and analysed for content validity, construct validity, and reliability. The data analysis used the Exploratory Factor Analysis (EFA) method to test the construct validity. **Results**: The Pre-Service Teachers' Mathematics Identity Instrument (P-STMI) contains 18 closed questions with five components. In addition, the instrument meets the criteria for content validity with a range between 0.79-1.00, meets construct validity, and the overall reliability value is 0.91. **Conclusions**: The P-STMI satisfies content validity, construct validity, and reliability. Therefore, the P-STMI is valid and reliable and can be used to see the mathematical identity of pre-service mathematics teachers.

Keywords: Mathematical Identity; Scale Development; Instrument Validation; Pre-service mathematics Teacher; Questionnaire.

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Desenvolvimento do Instrumento de Identidade Matemática dos Professores em Formação

RESUMO

Contexto: A urgência do conhecimento da identidade matemática é uma das razões para o aumento do número de pesquisas sobre identidade matemática. Conhecer a identidade matemática dos professores de matemática em formação torna-se essencial e precisa ser feito por meio de instrumentos de identidade matemática válidos. Os instrumentos de identidade matemática podem revelar a identidade matemática de uma pessoa, contribuindo para a aprendizagem e o ensino da matemática. No entanto, os instrumentos de identidade matemática não foram amplamente desenvolvidos, especialmente para professores de matemática em formação. **Objetivos**: Esta pesquisa tem como objetivo desenvolver instrumentos de identidade matemática válidos e confiáveis para professores de matemática em formação. **Design**: Esta pesquisa usou pesquisa de desenvolvimento de escala usando o modelo DeVellis. **Cenário e participantes**: 196 professores de matemática pré-serviço de 7 universidades na Indonésia estiveram envolvidos no teste piloto. **Coleta e análise de dados**: O instrumento do questionário foi distribuído via formulário google e analisado quanto à validade de conteúdo, validade de construto e confiabilidade. A análise dos dados utilizou o método de Análise Fatorial Exploratória (AFE) para testar a validade de construtos. **Resultados**: O Instrumento de Identidade Matemática dos Professores em Formação (P-STMI) é composto por 18 questões fechadas com cinco componentes. Além disso, o instrumento atende aos critérios de validade de conteúdo com intervalo entre 0,79-1,00, atende à validade de construto e o valor de confiabilidade geral é de 0,91. **Conclusões**: O P-STMI satisfaz a validade de conteúdo, validade de construto e confiabilidade. Portanto, o P-STMI é válido e confiável e pode ser usado para ver a identidade matemática de professores de matemática em formação.

Palavras-chave: Identidade Matemática; Desenvolvimento de Escala; Validação de Instrumentos; Professor de matemática em formação; Questionário.

INTRODUCTION

The significance of academic identity in determining a student's academic achievement and perseverance has long been recognized (Marsh, 1990, 1993; Marsh et al., 1988). Sfard & Prusak (2005a) defined identity as a collection of reified, significant and endorsable narratives about a person. Researchers have recently demonstrated the importance of content-specific identities (e.g., mathematics identity, science identity, engineering identity) in understanding academic performance (Carlone & Johnson, 2007; Cass et al., 2011; Chemers et al., 2011; Godwin et al., 2013; Hazari et al., 2010; Stets & Burke, 2000; Syed et al., 2011). Of the various research topics on identity, mathematical identity has become one of the growing research topics in the mathematics education field.

Identity research in mathematics education has seen an explosion of studies in the past two decades (Darragh, 2016; Radovic et al., 2018). Mathematical identity is an essential topic in mathematics education research because one's mathematical identity contributes to one's success in mathematics (Akwaji-Anderson, 2019). Like other latent constructs (e.g., conceptual knowledge, self-efficacy), mathematics identity is constructed in an individual's mind rather than directly observable (Cribbs et al., 2021). The term mathematical identity relates to how someone sees themselves as a mathematician or learner, the knowledge, skills, habits, attitudes, beliefs, and relationships students need to develop as successful mathematicians (Aguirre et al., 2013; Anderson, 2007; Grootenboer & Zevenbergen, 2007). Therefore, mathematical identity can be a concept that can comprehensively describe how a person sees himself in mathematics.

According to Grootenboer (2020), the idea of identity is complicated and controversial, but in general, the term identity can be defined as how people label and perceive themselves. A person's mathematical identity encompasses how he thinks about mathematics (*head*), how he feels about mathematics (*heart*), and what he performs (*hand*). A person's mathematical identity does not negate the relevance of mathematical knowledge; instead, it views mathematics education as a means of empowering students to 'move on' mathematically and apply mathematics in various situations. "Students with healthy mathematical identities usually achieve better results in mathematics courses, will engage more wholeheartedly in their mathematical learning, are more likely to continue with their mathematical studies, and will more readily participate in mathematical experiences," Grootenboer & Marshman (2015) wrote. Therefore, a mathematical identity can be used to glimpse how a person relates to mathematics as a whole.

A person's mathematical identity is vital to know, especially for those who do have interactions with mathematics in doing their work, for example, pre-service mathematics teachers. The mathematical identity of pre-service mathematics teachers needs to be known because their mathematical identity will be related to how a person learns and teaches mathematics. Information related to the mathematical identity of pre-service mathematics teachers can be used as a basis for policymaking or determining learning strategies carried out at the lecture level to achieve the goal of forming professional mathematics teacher candidates. In this regard, pre-service mathematics teachers ideally have a positive mathematical identity. It is because the identity of mathematics cannot be separated from the identity of a teacher in learning and teaching mathematics (in this case, pre-service mathematics teachers are prospective mathematics teachers) (Brown & McNamara, 2011; Hodgen & Askew, 2007; Jones et al., 2000). Although pre-service mathematics teachers ideally have a positive mathematical identity, many still have mathematics anxiety (Juniati & Budayasa, 2020). Math anxiety has a negative impact on performance; the more anxious a student is about math, the worse their results are (Juniati & Budayasa, 2022). When pre-service mathematics teachers experience mathematics anxiety and have a negative mathematical identity, the teaching strategy tends to be potentially dull. Furthermore, a person's method, strategy, or technique of teaching mathematics is related to their mathematical identity. Therefore, it is necessary to know the mathematical identity of pre-service mathematics teachers who are ideally prospective mathematics teachers.

So far, research on mathematical identity tends to use a qualitative approach and prioritize narratives. In a survey of mathematics identity studies, 45 of the 47 publications examined reported on eight or fewer students; most studies (76%) used interview data to understand identities in mathematics education (Graven & Heyd-Metzuyanim, 2019). Although qualitative research provides in-depth information about a person's mathematical identity, quantitative research also needs to be carried out to get an overview of the mathematical identity of pre-service mathematics teachers. Furthermore, the use of instruments in quantitative research is an essential matter for the benefit of data acquisition. Unfortunately, mathematical identity instruments used for quantitative research are still limited. As we refer to it in this study, there are few instruments for measuring mathematical identity (Kaspersen & Ytterhaug, 2020). For example, a previously designed questionnaire (Kaspersen et al., 2017; Kaspersen & Ytterhaug, 2020) examines STEM and lower secondary school students' math identities. From the research results, there is still no instrument developed to measure the mathematical identity of pre-service mathematics teachers. Therefore, research instruments to measure mathematical identity, especially those intended for pre-service mathematics teachers, need to be developed to complement the existing mathematical identity research instruments. Furthermore, in this study's mathematical identity research instrument, the researcher provides statement items that ask how pre-service teachers' mathematical identity is when learning mathematics and teaching mathematics.

The development of research instruments to measure the mathematical identity of pre-service mathematics teachers needs to be done because it can be used as a tool to find out how the mathematical identity of pre-service mathematics teachers in general is. General information about the mathematical identity of pre-service mathematics teachers is needed for further policymaking by stakeholders. In addition, by knowing general information about the mathematical identity of pre-service mathematics teachers, it is hoped that educators can design more optimal learning strategies.

THEORETICAL BACKGROUND

Mathematical Identity Component

Researchers in mathematics education can investigate the relationship between a person's self-perception and perseverance in mathematics by constructing a mathematical identity. Mathematical identity research, in particular, can help us better grasp the larger context of mathematics education and what it means to be a math learner (Lester, 2007). Concerning mathematical identity, Cobb (2004) states that the construction of mathematical identity is still not clearly explained. There is currently no consensus on what constitutes mathematical identity. Darragh (2016) identifies and criticizes the various and sometimes contradictory versions and the lack of a clear definition in several studies. The ambiguity produced by multiple definitions is accepted as a given in Lutovac & Kaasila's (2018) overview; nonetheless, following Sfard & Prusak (2005a), they insist that research present at least a workable definition. According to Eaton et al. (2019), mathematical identity refers to an individual's multi-faceted relationship with mathematics, including knowledge, experiences, and perspectives. Several studies have been conducted relating to identity construction in conjunction with mathematics using explanatory frameworks (Holland & Lave, 2001; Sfard & Prusak, 2005b).

Several previous works on mathematical identity that used a quantitative approach were limited in scope and presented various techniques for operationalizing the construct (Ingels et al., 2011; Mangu et al., 2015). The High School Longitudinal Study, for example, used two questions to operationalize mathematics and scientific identity, both of which were purely concerned with recognition (Ingels et al., 2011). On the other hand, other research has stressed the importance of other aspects while investigating identity (Carlone & Johnson, 2007; Hazari et al., 2010). When Carlone & Johnson (2007) investigated science identity formation for women of colour as they transitioned through undergraduate and graduate courses and into science-related employment, they found that recognition, competence, and performance were critical elements. This work was used by Hazari et al. (2010) to create a framework for physics identity that included interest as consideration for freshman-level undergraduate students. The study also discovered that particular high school physics experiences, such as "focusing on conceptual understanding, making real-world connections, countering stereotypes that physics is a one-dimensional pursuit that requires giving up other desires, getting students to take on active expert roles..., and encouraging students" Hazari et al. (2010), predicted students' physics identities.

Mathematical identity cannot be separated from mathematics learning. Considering the identity of mathematics in learning becomes important because mathematical identity is related to perseverance and one's involvement in mathematics (Boaler & Greeno, 2000; Hazari et al., 2010). Martin (2000) elaborates on the definition of mathematical identity as follows:

> Mathematics identity refers to the dispositions and deeply held beliefs that individuals develop about their ability to participate and perform effectively in mathematical contexts and to use mathematics to change the conditions of their lives. A mathematics identity encompasses a person's self-understanding and how others see him or her in the context of doing mathematics. (pp. 136–137).

According to Cribbs et al. (2015), mathematical identity is linked to an individual's self-perception of mathematics, including components of interest, recognition, competence, and performance. A person's desire or curiosity to think and learn mathematics is characterized as interest. Recognition is defined as how one's perception of others' views of him/her relates to mathematics. In contrast, A person's opinions about their capacity to understand and demonstrate work results in mathematics are characterized as competence/performance (Cribbs et al., 2021).

In contrast to Cribbs et al. (2015), the components of mathematical identity expressed by Solomon (2009) consist of beliefs about oneself as a math learner, beliefs about the nature of mathematics, perceptions of oneself as potential participants in mathematics, and involvement in mathematics. The components used by Solomon (2009) have similarities to the components used by Martin (2000), which is about belief about the nature of mathematics. Thus, the mathematical identity component used in this study refers to the component used by Cribbs et al. (2015) by adding one aspect of Solomon's component (2009), which is about belief about the nature of mathematics. This component is added because a person's belief about the nature of mathematics has a role in his mathematical abilities (Presmeg, 2002).

Interest

The first component to be explored is of interest. Hidi & Renninger (2006) defined interest as a learner's tendency to engage and reengage with certain discipline content (e.g., mathematics, science) over time, as well as the psychological state that goes along with it. Regarding the definition of the term interest, Cribbs et al. (2015), who previously researched mathematics identity, argued that interest is a person's desire or curiosity to think and learn mathematics. Köller et al. (2001) found that interest is critical of one's academic choice. Someone interested in their educated choice can make a more significant contribution and effort than someone not interested in the major they are taking. Student interest in mathematics and its relationship to motivation (Frenzel et al. 2010; Schiefele 1991; Singh et al. 2002), career choice (Lent et al. 1991, 2008; Su et al. 2009), and identity (Mangu et al. 2015) has been studied extensively. Furthermore, several studies have proposed that interests influence academic achievement and learning (Krapp, 1998a, 1998b; Schiefele et al., 1999). According to Atwater et al. (1995), students who were more interested in mathematics enrolled in more mathematics courses and had higher grades in mathematics than those who were less interested. In addition, interest and performance in mathematics are also related (Ganley & Lubienski, 2016). From some of these studies, interest has the potential to be one of the components that determine how one's mathematical identity is. For example, students who do not have an interest in mathematics and how to teach mathematics may not maximize their learning process. Furthermore, someone who has no interest in teaching mathematics has the possibility of being careless while teaching mathematics. As a result, the learning objectives of mathematics are not optimal.

Recognition

The second factor, recognition, is critical when looking at how someone sees other people's views of him. It is because recognition considers social aspects in constructing one's identity. Cribbs et al. (2015) argue that recognition is how a person sees other people's views of himself concerning mathematics. Moreover, how a person views himself is related to academic achievement (Shen & Pedulla, 2000). A person's attitude in viewing himself is an essential mediator in academic achievement in the field of mathematics (Skaalvik & Skaalvik, 2006). Similarly, being noticed by others, such as parents and teachers, impacts a student's self-perception and math performance (Bouchey et al., 2010; Jacobs et al., 2002). Darragh (2015) similarly emphasizes the relevance of kids recognizing themselves as "excellent at mathematics," bolstering the notion that recognition and performance play a critical part in students' identity formation. Parents' and teachers' attitudes toward mathematics and how they see their children as learners of mathematics have been shown to influence children's perceptions of their competence and values (Singh et al., 2002). Their achievement in mathematics is mediated by teachers' and parents' expectations (Frenzel et al., 2010). It can be interpreted that self-perception related to mathematics can be used as an essential prerequisite in learning and achieving mathematics. Self-perceptions have a direct and indirect positive effect on value and engagement (Chouinard et al., 2007). Thus, self-perception about mathematics needs to be considered when discussing mathematical identity. From the results of some of these studies, one's perception of the views of others and one's perception of oneself need to be considered when wanting to know one's mathematical identity.

Competence

Numerous studies have looked into people's perceptions of competence and their importance on academic activities and domains (Chouinard et al., 2007). Many studies have found that mathematical competency views and the importance placed on the topic are strong predictors of achievement-related behaviours (Greene et al., 1999; Meece et al., 1990; Singh et al., 2002). Competence is said to be a person's belief about their ability to understand mathematics (Cribbs et al., 2015). In particular, students' perceived competencies have been the subject of research in motivation, learning, and achievement. This research was triggered by previous theories such as Bandura's (1997) self-efficacy theory. Individual competence beliefs affect their choices when participating in an activity (Bandura, 1997; Bussey & Bandura, 1999). Furthermore, mastery goals and competence views account for most mathematic effort, implying that competence beliefs significantly impact mathematic effort (Chouinard et al., 2007). Students who score high on self-perceived academic competence are more persistent than others, perform better, experience less anxiety, understand learning materials more profoundly and achieve better learning outcomes (Ferla et al., 2010). Similarly, pupils with lower competence views will place less value on accomplishment, set lower achievement objectives, and put forth less effort to succeed (Berndt & Miller, 1990). Furthermore, research has shown that mathematical competence views and the importance placed on the topic are good predictors of accomplishment-related behaviour and achievement in this domain (Greene et al., 1999; Singh et al., 2002). According to Meece et al. (1990), self-perceptions such as competence beliefs have a direct positive effect on the value and an indirect positive effect on achievement and achievement behaviours. Beliefs about competence can affect one's persistence and goals (Cribbs, 2012), so this aspect is relevant to be considered part of mathematical identity construction.

Performance

Beliefs about performance and competence are closely related. In contrast to competence, performance is defined as a person's belief about his ability to perform in mathematics (Cribbs et al., 2015). Much of the research on self-beliefs and their links to performance has come from Western countries, primarily North America and Western Europe (Williams & Williams, 2010). More general efficacy belief assessments are good predictors of future performance (Pietsch et al., 2003). Furthermore, the research findings demonstrate that emotive elements, such as beliefs, are highly linked to mathematical ability (Grootenboer & Hemmings, 2007). Concerning mathematics performances, confidence in one's ability to succeed in math-related courses was a better predictor of significant choice than confidence in solving issues or performing math-related tasks (Pajares & Miller, 1995). The findings of various prior research highlight the relevance of taking into account students' beliefs of their mathematical ability because this can influence their actual performance. Investigating mathematics-related beliefs (Kloosterman, 1988; Malmivuori & Pehkonen, 1996; Mason, 2003) such as students' beliefs about mathematics and problem solving could be one of the elements determining their mathematical performance. There is a link between students' mathematical beliefs and their academic achievement, showing that the greater or better the perception of mathematics beliefs, the better the academic performance, and vice versa (Rincon et al., 2020). Therefore, performance is one of the components that need to be considered in one's mathematical identity.

Beliefs about Nature of Mathematics

Belief is the basis of a person's motivation to behave and understand an event. A person uses his beliefs to predict events that will occur. Pre-service mathematics teachers or math teacher also owns beliefs. The pre-service mathematics teachers' beliefs impact differences in motivation and problem-solving strategies that will be used (Kurniawati et al., 2022). Furthermore, teachers' views on the nature of mathematics significantly influence their teaching approaches and their other beliefs (Thompson, 1984; Green, 1971; Philipp, 2007). Teachers' beliefs about learning and teaching mathematics, for example, are based on these beliefs (Thompson, 1992). A teacher who views mathematics as a subject made up of operations and definite rules governing these operations is prone to believe that learning mathematics entails numerous repetitions and practices of these operations and rules (Bütün, 2021). Raymond (1997) explains that mathematical beliefs refer to mathematics as a discipline and how mathematics is learned and taught. Belief about the nature of mathematics is concerned with what mathematics accomplishes and the quality of that achievement (Dede & Karakuş, 2014; Ernest, 1989). It was argued that these views are intertwined and that beliefs about the nature of mathematics serve as the foundation for attitudes about learning and teaching mathematics (Dede & Karakuş, 2014; Philipp, 2007; Richardson, 1996; Thompson, 1992). Malmivuori & Pehkonen, (1996) divided beliefs into three categories: beliefs about mathematics as a field, ideas about teaching, and beliefs about acquiring mathematics. Ernest (1989) outlines three ideas regarding mathematical perspectives. First, the instrumentalist viewpoint states that mathematics is a collection of facts, rules, and skills. Second, platonic considers mathematics static and a synthesis of different types of knowledge. Mathematics is something that is discovered rather than something that is created. Third, some argue that state mathematics is dynamic, implying that it is a constant development process resulting from human creativity. Mathematics is an endless cycle of learning with no end in sight. In addition, McLeod (1992) suggests four categories of student mathematical beliefs: beliefs about mathematics, beliefs in one's own ability to learn mathematics, attitudes about teaching mathematics, and beliefs in the social context.

Regarding beliefs about mathematics, Presmeg (2002) uses two basic questions when looking at students' beliefs about mathematics: 1) what is mathematics and 2) is there a relationship between mathematics and everyday life. Asking these two questions can give an idea that beliefs about mathematics are related to the definition and relationship of mathematics to life. Solomon (2009) includes belief about the nature of mathematics as one of the constructs of mathematical identity. It is pretty reasonable because one's beliefs about the nature of mathematics have a role in one's mathematical abilities (Presmeg, 2002). For example, there is a complex connection between pre-service mathematics teachers' belief systems and the implications of solving the problem during their problem-solving process (Muhtarom et al., 2017b). Furthermore, pre-service mathematics teachers held varied beliefs about the nature of mathematics, which are reflected in the teaching-learning process in math classes. (Muhtarom et al., 2017a, 2019). Preservice teachers' opinions on mathematics integration and teaching strategies are influenced by their notions about the nature of mathematics (Yaman et al., 2018). Thus, beliefs about the nature of mathematics need to be known as part of their mathematical identity.

Measurement of Mathematical Identity

Several researchers have conducted previous research relating to mathematical identity instruments using questionnaires. For example, Cribbs et al. (2015) examined the mathematical identities of 9000 students in the United States using questionnaires that were part of the FicsMath (Factors Influencing College Success in Mathematics) project. The results showed that competence and performance indirectly affect their mathematical identity, emphasizing that interests and roles also play a role in developing mathematical identities.

Kaspersen et al. (2017) developed an instrument in a mathematical identity questionnaire aimed at STEM students. The study results showed that the instrument was validly used to measure mathematical identity. Using the same instrument, Kaspersen & Ytterhaug (2020) then used the instrument to measure the mathematical identity of high school students. Again, the results showed that the same instrument turned out to be valid for use in school students.

Haciömeroğlu (2020) attempts to adopt an identity instrument developed earlier by Dou et al. (2019). The adaptation in question is to translate the previous questionnaire into Turkish. The study results showed that valid adaptation questionnaires were used in Turkish. Furthermore, from previous research that developed mathematical identity questionnaires, no questionnaires have been found that were developed to measure the mathematical identity of pre-service mathematics teachers. Thus, developing a mathematical identity instrument reveals how the mathematical identity of pre-service mathematics teachers is developed to fill the limitations of the instruments developed previously.

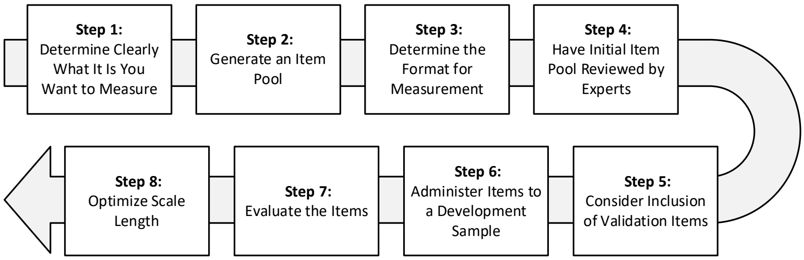
METHODOLOGY

Research Design

Researchers employ scale development to measure a phenomenon that they believe exists but is not directly observable (DeVellis, 2012). The scale development process is not merely the assembly of items for measuring a concept; scale development denotes a careful methodology for arriving at a valid and reliable scale. The eight scale-development stages suggested by DeVellis (2012) were followed during the development of this scale. DeVellis (2012) suggested that the eight steps that should be followed while developing the scale are summarized in Figure 1.

Figure 1

Eight Stages of Scale Development (DeVellis, 2012)



Step 1: Determine clearly what it is you want to measure

At this stage, the researcher wants to develop a scale that measures pre-service mathematics teachers' mathematical identity to fill the literature gap. This gap in the literature was discovered in the study process while investigating mathematical identities. The gap in question is the unavailability of a scale that can measure the mathematical identity of pre-service mathematics teachers.

Step 2: Generate an item pool

Due to the lack of a structured scale, the researcher then conducted a literature study to learn more about mathematical identity. From the research results, 50% of articles focus on the mathematical identity of kindergarten through undergraduate students, while the research on mathematical identity that focuses on pre-service teachers is still 17% (Darragh, 2016). It means that the focus of mathematical identity on pre-service teacher research is still limited and opens up opportunities for further exploration. In addition, the researchers found that the mathematical identity that had existed and was used by previous researchers included several components. Regarding the components of mathematical identity that have been used previously, some experts use different components of mathematical identity. For example, Cribbs et al. (2015) use four components to see mathematical identity: interest, recognition, competence, and performance. Martin (2000) reveals that mathematical identity is formed from six main aspects: the value of instrumental mathematics, motivation, opportunities, strategies, constraints, and capacity. Solomon (2009) views that beliefs form mathematical identity about oneself as a mathematical learner, perception of oneself as a potential participant in mathematics, beliefs about the nature of mathematics, and engagement in mathematics. There are similarities between the components used by Martin (2000), namely the importance of mathematics, and the components used by Solomon (2009), namely beliefs about the nature of mathematics, which did not exist in the Cribbs component. Based on the researcher's analysis and looking at existing instruments, the researcher considers it necessary to add a component of beliefs about the nature of mathematics into the components used by Cribbs et al. (2015) because one's beliefs about the nature of mathematics have a role in one's mathematical abilities (Presmeg, 2002). Thus, the components of mathematical identity used by researchers for scale development in this study consist of interest, recognition, competence, performance, and belief about the nature of mathematics (Cribbs et al., 2015; Solomon, 2009). The researcher feels that the five components are considered compatible with the mathematical identity of mathematics education students.

To create the P-STMI, we looked at the existing mathematics identity instrument (Cribbs et al., 2015; Dou et al., 2019; Haciömerolu, 2020; Kaspersen et al., 2017; Kaspersen & Ytterhaug, 2020), adapted some of their items, and added several items that reveal pre-service mathematics teachers' mathematical identity in terms of teaching mathematics, not just when learning mathematics. This type of comment exemplifies the distinctiveness of the researcher's instrument, which is designed exclusively for pre-service mathematics teachers. On the basis that a pre-service teacher should learn and teach mathematics, the researcher created items that attempted to disclose the mathematical identity of pre-service teachers when teaching mathematics (not just when learning mathematics).

Step 3: Determine the format for measurement

The components of the mathematical identity used were then developed into the items of the questionnaire statement. Questionnaire statement items are closed statement items. The five components of the mathematical identity were then developed into 18 statement items. The scale used is a 5-point Likert scale. Each statement item is rated 1 (strongly disagree) to 5 (strongly agree).

Step 4: Have the initial item pool reviewed by experts

In the fourth stage, seven mathematics education experts were invited to give their opinions and assess the validity of the contents of the developed questionnaire. A 5-point ordinal rating scale was used to assess content validity. The content validity index uses the Aiken formula to calculate expert agreement. Furthermore, the calculation of the Aiken index using Excel software. The statement item is valid if the Aiken index value obtained is more than or equal to 0.4 (Aiken, 1980, 1985).

Step 5: Consider the inclusion of validation items

DeVellis (2012) proposes transferring the items to the trial form to examine structural or legibility in the fifth stage. The scale applied to 5 different students. The items were restructured and corrected based on their feedback about the clarity of the statements.

Step 6: Apply items to a development scale

The questionnaire was distributed to respondents using a google form link at this stage. The trial process for distributing questionnaires was carried out within one week, and feedback was obtained from 196 mathematics education students.

Step 7 and Step 8: Evaluate the items and optimize scale length

For the seventh and eighth stages, i.e., the process of making validity and reliability tests. After the questionnaires were distributed at the pilot stage, the data from the questionnaires were analyzed. The analytical methods used include exploratory factor analysis (EFA) and bivariate Pearson correlation for construct validity and alpha coefficient to calculate reliability. Data analysis for construct validity and reliability using SPSS 25.0 software. Furthermore, exploratory factor analysis (EFA) was conducted to determine the contributing factors (Kumar, 2012).

Participants

According to Boomsma (1982), a large number of samples will increase the accuracy of research results, and he suggested the minimum number of samples is 100. From the results of distributing questionnaires at the trial stage, as many as 196 pre-service mathematics teachers from 7 universities in Indonesia are willing to fill out the mathematical identity questionnaire. Furthermore, the pre-service mathematics teachers mentioned in this study are students in the mathematics education department at a higher education level. A total of 196 people took part, with 128 women and 68 males. The participants were between the ages of 20 and 25. At home, Bahasa is the primary language spoken. 17.3 percent of the sample were pre-service teachers in the first semester, 44.9 percent in the third semester, 23.5 percent in the fifth semester, 10.7 percent in the seventh semester, and 3.6 percent in the ninth semester.

Procedure

All of the tests were performed online by the participants. The researcher shared the google form link with many social media groups. Those who fit the requirements (pre-service mathematics teachers) answered an online questionnaire containing questions about their mathematics identity. Researchers examined participants' responses.

Data Analysis

The data analysis technique used to prove content validity uses the Aiken index. The formula used for Aiken's calculation is shown as follows.

$$V = \frac{\sum s}{n(c-1)}$$

Each statement item is valid if the Aiken index value obtained is more than or equal to 0.4 (Aiken, 1980, 1985). After testing content validity and distributing the questionnaire at the trial stage, the data from the test results were analyzed descriptively by looking at the normality of the data based on the value of skewness and kurtosis with a recommended value ranging from -1.96 to +1.96 at a significance level of 0.05 for each item of the questionnaire statement (Hair et al., 2010; Kline, 2005). After that, the data analysis was continued with construct validity and reliability tests.

The construct validity used bivariate Pearson correlation and exploratory factor analysis (EFA). The results of the exploratory factor analysis (EFA) are based on: the Kaiser Meyer-Olkin (KMO) value, the Bartlett test value, the Measure of Sampling Adequacy (MSA), the communality values, the total variance values that are described related to eigenvalues, factor loading, and also the plot scree (Daryono et al., 2020). In addition, the value of the alpha coefficient is used to test the reliability.

RESULTS AND ANALISES

Content Validity

Table 1

Results of Aiken Index Assessment and Calculation

Item No	Rater 1	Rater 2	Rater 3	Rater 4	Rater 5	Rater 6	Rater 7	*V*
1	5	4	4	5	5	4	4	0.857
2	5	5	5	5	5	5	5	1.000
3	5	4	5	5	5	4	5	0.929
4	5	4	5	5	5	5	5	0.964
5	5	5	4	5	5	4	5	0.929
6	5	3	4	5	5	3	4	0.786
7	5	5	5	5	5	3	4	0.893
8	5	5	5	5	4	4	4	0.893
9	5	5	5	5	4	3	4	0.857
10	5	5	5	5	4	4	4	0.893
11	5	5	4	5	5	4	5	0.929
12	5	5	5	5	5	5	4	0.964
13	5	5	5	5	5	4	5	0.964
14	5	4	5	5	5	4	4	0.893
15	5	5	4	5	4	3	4	0.821
16	5	4	4	5	4	3	4	0.786
17	5	3	5	5	5	3	3	0.786
18	5	5	5	5	5	5	3	0.929

Seven mathematics education experts were involved in the Aiken index's content validity test. The questionnaire instrument can meet content validity if the experts believe that the questionnaire can measure something to be measured. The experts assessed each item of the questionnaire statement. The digit numbers 1, 2, 3, 4, and 5 are used to provide values for each item. One denotes invalid, two denotes less valid, three denotes quite valid, four denotes valid, and five denotes highly valid. The results of the expert's assessment can be seen in Table 1.

Based on the data above, the instrument's range of values is 0.79-1.00. While utilizing the Aiken index as a criterion for content validity, it can be said that all of the items were found to be validly reviewed from the content validity aspect.

Normality

The normality test results of 18 items (six items corresponding to interest, four items corresponding to recognition, four items corresponding to competence, and two things corresponding to performance and beliefs about the nature of mathematics) based on the value of skewness and kurtosis are shown in Table 2.

Table 2

Results of Statistical Descriptive Analysis and Data Normality (N=196)

Construct and Items	Full sample				
	Mean	SD	Var.	Skew	Kurtosis
Interest					
I am interested in learning math	4,18	0,839	0,705	-0,569	-0,536
I want to teach math to other people	4,24	0,822	0,676	-0,695	-0,262
When studying mathematics, I want to know the material more deeply	4,18	0,833	0,694	-0,572	-0,488
I want to know how to teach math to other people	4,17	0,840	0,705	-0,537	-0,569
I enjoy learning math	4,15	0,855	0,732	-0,538	-0,572
I enjoy when I teach math to other people	4,16	0,862	0,742	-0,516	-0,741
Recognition					
My parents see me as good at math	4,03	0,726	0,528	-0,201	-0,612
Lecturers see that I have good ability in mathematics	3,62	0,738	0,545	0,438	-0,600
My friends see that I have good ability in math	3,76	0,770	0,593	0,034	-0,625
I see myself as having a good ability at math	3,81	0,806	0,649	-0,049	-0,421
Competence					

Construct and Items	Full sample				
	Mean	SD	Var.	Skew	Kurtosis
I believe I understand the mathematics given	3,82	0,726	0,527	-0,038	-0,473
I believe I understand how to teach math to others	3,87	0,797	0,635	-0,012	-0,918
When I encounter a problem, I keep trying and persevering in studying mathematics	4,32	0,759	0,576	-1,028	1,227
When teaching mathematics, I still try to be persistent in teaching the material well even though I encounter problems	4,34	0,730	0,532	-1,018	1,429
Performance					
I complete math assignments well	4,23	0,755	0,570	-0,563	-0,565
My math work/grades are satisfactory	4,05	0,753	0,567	-0,221	-0,795
Beliefs about the nature of mathematics					
Mathematics is not just the science of numbers and formulas	4,06	0,827	0,683	-0,225	-1,224
Mathematics is used by humans in everyday life	4,07	0,850	0,723	-0,238	-1,330

Based on Table 2, 18 questionnaire statements met the normality of the data with the skewness values ranging from -1.028 to 0.438, and then the kurtosis values ranging from -1.330 to 1.429. Furthermore, the descriptive statistics reveal that the mean value ranges from 3.62 to 4.34. The value of the deviation standard ranges from 0.726 to 0.862. The variance ranges from 0.527 to 0.742.

Construct Validity

Pearson's Bivariate Correlation

The validity test results with bivariate Pearson correlation using SPSS are shown in Table 3.

Table 3

Pearson Bivariate Correlation Validity Results

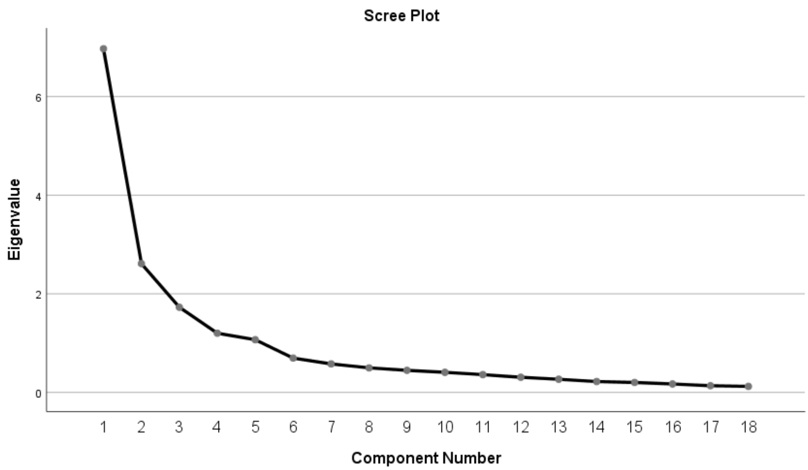
Item No	R-value	Sig.
1	0.626	0.000
2	0.622	0.000
3	0.561	0.000
4	0.604	0.000
5	0.629	0.000
6	0.592	0.000
7	0.650	0.000

Item No	R-value	Sig.
8	0.665	0.000
9	0.639	0.000
10	0.701	0.000
11	0.632	0.000
12	0.670	0.000
13	0.661	0.000
14	0.631	0.000
15	0.663	0.000
16	0.686	0.000
17	0.404	0.000
18	0.415	0.000

The validity results in Table 3 show that the calculated R-value ranges from 0.404 to 0.701 and the significance value of each statement item is 0.000. These results indicate that the calculated R-value for each statement is more than the table R-value, which is 0.138, and the significance value of each statement is less than 0.05. So, every item of the statement is valid.

Figure 2

Screen Plot of Pre-Service Teachers' Mathematics Identity



Exploratory Factor Analysis (EFA).

EFA test criteria are based on the KMO Index values, Bartlett's Test, Measure of Sampling Adequacy (MSA), communalities, factor loading, eigenvalues, and plot scree. The KMO Measure of Sampling Adequacy results obtained a value of 0.845, which is more than 0.70, then the coverage of each factor is satisfactory. The Bartlett's Test of Sphericity Approx. Chi-Square obtained a value of 2273.708; df = 153; Sig. = 0.000. The screen plot pattern is shown in Figure 2.

The next step of identifying the extraction of communality values, eigenvalues, percentage variants, and loading factors is shown in Table 4.

Table 4

MSA, Communalities, Factor Loading

Item No	**MSA**	**Comm.**	**Factor Loading**				
			Components				
			1	**2**	**3**	**4**	**5**
1	0.785	0.879 [a]				0.875	
2	0.800	0.837 [a]				0.869	
3	0.851	0.670 [a]				0.683	
4	0.874	0.700 [a]				0.746	
5	0.783	0.861 [a]				0.879	
6	0.744	0.860 [a]				0.897	
7	0.939	0.638 [a]	0.759				
8	0.916	0.742 [a]	0.824				
9	0.888	0.701 [a]	0.815				
10	0.926	0.687 [a]	0.754				
11	0.899	0.678 [a]		0.689			
12	0.894	0.669 [a]		0.726			
13	0.866	0.794 [a]		0.827			
14	0.847	0.754 [a]		0.813			
15	0.880	0.681 [a]			0.721		
16	0.902	0.598 [a]			0.531		
17	0.602	0.918 [a]					0.943
18	0.619	0.913 [a]					0.938

Based on Table 4, the results of communalities range from 0.598 to 0.918; that is, more than 0.50 can be categorized as suitable variants in the instrument. MSA values range from 0.602 to 0.926, which is more than 0.50. The rotated component matrix shows the loading factor on each factor. The results of data analysis are recommended for all items to measure competency achievement. This value is obtained from high loading factors ranging from 0.531 to 0.943, more than 0.40.

Reliability of Instrument

The reliability value of an item is based on the Cronbach Alpha value. According to Lin (2002), if the Cronbach Alpha value is ≥ 0.7, then the item on the instrument is reliable, and vice versa, if the Cronbach Alpha value is < 0.7, then it is not reliable. The results of the instrument's reliability are shown in Table 5.

Table 5

Results of Reliability Analysis

No	Components	Cronbach's Alpha	Overall Cronbach's Alpha
1	Interest	0.876	
2	Recognition	0.863	
3	Competence	0.832	0.901
4	Performance	0.813	
5	Beliefs about the nature of mathematics	0.917	

Based on Table 5, the Cronbach Alpha results in this research instrument are in the reliable category. Overall, the Cronbach Alpha value obtained was more than 0.7; this value is included in the recommended value by Lin (2002). Therefore, the instrument to measure the pre-service teachers' mathematics identity has a good level of reliability.

In this study, a mathematical identity instrument was developed for pre-service mathematics teachers. This instrument was developed to examine the mathematical identity of pre-service mathematics teachers. The results of the exploratory factor analysis revealed that there are five components of mathematical identity, namely interest, recognition, competence, performance, and belief about the nature of mathematics. The development and validation results show that the developed mathematical identity questionnaire instrument meets the validity and reliability tests.

The mathematical identity instrument developed was intended for pre-service mathematics teachers in this study. Similar instruments have been developed, especially for STEM students and students at the lower secondary school level (Kaspersen et al., 2017; Kaspersen & Ytterhaug, 2020). Furthermore, the instruments developed in this study were developed by researchers from an early stage, using existing instruments and then being translated as has been done on the mathematical identity instrument used for student-teacher candidates in Turkey (Haciömeroğlu, 2020a).

Researchers interested in mathematics identity will find the findings in this paper helpful. For example, the instrument for assessing mathematical identity could examine how it connects to use variables in mathematics education. Conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, productive disposition (Kilpatrick et al., 2001), the ability to ask and answer questions in and with mathematics, and the ability to deal with mathematical language and tools are examples of these variables (Niss, 2004). In the future, the instrument could be used to analyze how different teaching and learning techniques affect the development of mathematical identity.

CONCLUSIONS

Developing a valid and objective instrument tool is thus critical to ensure pre-service teachers' mathematics identity. The final version, P-STMI, exhibits excellent reliability and validity consists of 18 items in five essential components related to mathematics identity. The EFA analysis shows that the instrument has good construct validity consisting of 18 items covering five components' aspects, namely interest, recognition, competence, performance, and beliefs about the nature of mathematics.

AUTHORS' CONTRIBUTIONS STATEMENTS

A.D.K. conceived the presented idea, developed the theory, built the questionnaire, collected the data, and analysed the data. All authors actively discussed the results reviewed and approved the final version of the work.

DATA AVAILABILITY STATEMENT

The data presented and supporting this research results are available at a reasonable request to the first author, A.D.K.

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