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Development and Validation of a Multidimensional Mathematical Beliefs Scale for Elementary School Students

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Abstract: This study aims to develop and validate a multidimensional mathematical beliefs scale for elementary school students. The instrument was developed based on Eynde, Corte, and Verschaffel's (2002) four-dimensional framework: beliefs about teacher, beliefs about competence and significance of mathematics, mathematical beliefs as social activity, and mathematical beliefs as a domain of excellence. The development procedure followed the Mardapi model. Content validity was assessed by five expert validators using CVI, and a limited trial was conducted on 25 sixth-grade students of SDN 138 Bungi, Pinrang Regency. Data were analyzed using SPSS and Winsteps. The content validity results showed an average CVI of 0.96 (highly valid). The limited trial produced 37 valid items out of 44 ($r > 0.396$, $p < 0.05$), with high reliability (Cronbach's Alpha = 0.886). The final instrument consists of 37 items covering four dimensions. This scale can be used to diagnose students' mathematical beliefs profiles for designing appropriate learning interventions..

Keywords: Mathematical beliefs, instrument development, scale validation, elementary school students.

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INTRODUCTION

Mathematics learning in elementary schools faces affective challenges in addition to cognitive ones (McLeod, 1992; Goldin, 2002), with mathematical beliefs being the most influential affective factor affecting learning success. Schoenfeld (1985) identified belief systems as one of the four main components of problem solving (alongside resources, heuristics, and control) that shape a mathematical "world view" determining students' approach to problems (Schoenfeld, 1985, 1987). Mathematical beliefs are relatively stable personal views, formed from school learning experiences, and are intuitive as well as emotional (Underhill, 1988; Op't Eynde, De Corte, & Verschaffel, 2002; Goldin, 2002). Op't Eynde et al. (2002) define them as students' subjective conceptions about mathematics education, themselves as learners, and the classroom context, while McLeod (1992) categorizes them as the most stable affective component and Törner (2002) defines them as an ontological, enumerative, normative, and affective quadruple.

Mathematical beliefs function as a supporting or inhibiting filter for learning (Op't Eynde et al., 2002; De Corte, Op't Eynde, & Verschaffel, 2002; Goldin, 2002). Students with productive beliefs (believing mathematics can be understood through effort) show higher persistence, whereas unproductive beliefs (viewing mathematics as a set of rules to memorize or only for talented people) lead to low performance (Boaler, 2016; Dweck, 2006; NCTM, 2014). Schoenfeld (1989a, 1989b) identified common unproductive beliefs: one correct way, one correct answer, individual work, and quick completion, which limit students' mathematical behavior. Beswick (2006) emphasizes that beliefs are malleable, allowing for instructional interventions.

In Indonesia, mathematical beliefs affect cognitive ability and achievement (Purnomo, 2017, 2023; Hendriana, Johanto, & Sumarmo, 2014; Suryanto, 2001). A preliminary study in three elementary schools in Pinrang Regency showed students responding negatively ("can't do it") before attempting problems, reflecting a fixed mindset (Dweck, 2006; Boaler, 2016). Teachers revealed that students were confident with numerical operations but confused with word problems, indicating a gap between procedural skills and self-belief (Hadi, 2005; Dewi, 2022; Kurniasih, 2016). Research by Arifin (2024) and Children's Mathematics-Related Beliefs (2024) shows that Indonesian elementary students' belief profiles are dominated by traditional beliefs, confirming the need for accurate measurement instruments.

Measuring elementary students' mathematical beliefs faces three challenges. First, existing instruments were developed for teachers or secondary students with complex language (Hwang, 2020; Purnomo, 2017; Sakai, Hirose, Saito, & Fujiwara, 2009; Furinghetti & Pehkonen, 2002; Kislenko, 2006). Second, instruments tend to be unidimensional, whereas beliefs are multidimensional (Op't Eynde et al., 2002; Leder, Pehkonen, & Törner, 2002; De Corte et al., 2002). Third, there is a scarcity of instruments contextualized to Indonesian culture (Purnomo, 2017, 2023; Knoll, 2010; Yıldırım Çayır, 2008). Philipp (2007) and Handal (2003) emphasize the influence of teacher beliefs and cultural dominance, while NCTM (2014) provides guidance for supporting productive beliefs through problem solving, discussion, and mathematical representations.

The theoretical framework refers to the Op't Eynde et al. (2002) model—a synthesis of previous models tested cross-culturally (De Corte et al., 2002; Op't Eynde & De Corte, 2003; Knoll, 2010)—with three main categories: (1) beliefs about mathematics education (nature and learning); (2) beliefs about the self (efficacy, control, task value, goal orientation) (Pajares & Miller, 1994; Op't Eynde & De Corte, 2003); and (3) beliefs about the social context (classroom norms, teacher-student roles) (Op't Eynde et al., 2002). Thompson (1991) developed a three-level framework, Lindgren (1996) emphasized conceptions of the nature of mathematics, and Ernest (1989) modeled teacher beliefs, knowledge, and attitudes. This framework was chosen because it encompasses cognitive, affective, and social aspects relevant to elementary education (Schoenfeld, 1985; Goldin, 2002; Philipp, 2007) and has been adapted cross-culturally (Knoll, 2010; Yıldırım Çayır, 2008).

This study aims to develop and validate a multidimensional mathematical beliefs scale for elementary students, with specific objectives: (1) to produce a valid and reliable scale (Hwang, 2020; Purnomo, 2017; Sakai et al., 2009; Indrasari, 2017); (2) to determine content validity based on expert judgment (Arikunto, 2010; Sugiyono, 2014; Supriadi, 2016); (3) to determine item validity and reliability through limited trials (Kurniasih, 2016; Sutrisno, Manuharawati, & Masriyah, 2025); and (4) to describe the psychometric profile of the developed scale (Op't Eynde & De Corte, 2003; Knoll, 2010). A valid and reliable instrument is expected to enable accurate diagnosis of students' belief profiles and appropriate instructional interventions to develop productive beliefs (Boaler, 2016; NCTM, 2014; Dweck, 2006; Clarke & Clarke, 2003; Ball & Forzani, 2011).

METHODS

Research Design

This study employs a Research and Development (R&D) approach using the formative research model adapted from Plomp (1997), consisting of five stages: (1) preliminary investigation, (2) design, (3) realization/construction, (4) test, evaluation, and revision, and (5) implementation. The preliminary investigation stage includes literature review and needs analysis at three elementary schools in Pinrang Regency. The design stage involves defining the scale's construct and developing indicators based on Op't Eynde et al.'s (2002) framework. The realization stage produces the initial version of the Mathematical Beliefs Scale (MBS). The test, evaluation, and revision stage includes expert validation and field testing. The implementation stage consists of the main field test for psychometric evaluation.

Research Participants

Participants are selected through purposive sampling from elementary schools in Pinrang Regency, South Sulawesi. For the pilot study, 25 sixth-grade students from SDN 138 Bungi participated. For the main field test, at least 320 students from grades 4, 5, and 6 will participate, following Nunnally's (1978) recommendation of 10 cases per item for factor analysis. The sample includes students from urban, suburban, and rural schools to represent diverse socio-cultural characteristics.

Operational Definition

The multidimensional mathematical beliefs scale measures elementary students' beliefs based on Op't Eynde et al.'s (2002) framework, covering four dimensions: (1) beliefs about the teacher, (2) beliefs about competence and significance of mathematics, (3) beliefs about mathematics as a social activity, and (4) beliefs about mathematics as a domain of excellence. The scale uses a Likert format with four response options (Strongly Disagree to Strongly Agree), with items worded in simple language appropriate for elementary students (Furinghetti & Pehkonen, 2002; Kislenko, 2006).

Instrument Development Procedure

The development procedure follows Mardapi's (2017) ten steps: (1) preparing test specifications in the form of a grid containing dimensions, indicators, and number of items; (2) writing 44 test items distributed across four dimensions; (3) reviewing test items through expert judgment by five validators (two educational psychology experts and three practitioners); (4) conducting limited trials on 25 sixth-grade students; (5) analyzing items using Pearson correlation and Cronbach's Alpha; (6) revising the test by eliminating invalid items; (7) assembling the final version of the test; (8) administering the test to the main sample; (9) interpreting test results using descriptive statistics; and (10) communicating test results in a research report.

Data Collection Techniques

Data collection uses two main instruments: (1) expert validation sheets for content validity assessment using a 1-5 scale, and (2) a mathematical beliefs questionnaire consisting of 44 items with four Likert scale options. Documentation is also collected to complement the research data.

Data Analysis Techniques

Data analysis employs three approaches. First, content validity analysis using the Content Validity Index (CVI) with the Lawshe (1975) method, requiring CVI ≥ 0.80. Second, item validity analysis using Pearson Product Moment correlation, with items declared valid if r > r table (0.396) at $\alpha = 0.05$ (Hair et al., 2010). Third, reliability analysis using Cronbach's Alpha coefficient, with the instrument declared reliable if $\alpha \geq 0.70$ (Nunnally & Bernstein, 1994). Descriptive statistics (mean, standard deviation, minimum, maximum) are also calculated to describe students' belief profiles. Data is analyzed using SPSS version 26.0.

Research Timeline

The study is conducted over six months: preliminary investigation (1 month), design and realization (1 month), expert validation and revision (1 month), pilot study (1 month), main field testing and data analysis (1 month), and report preparation (1 month).

RESULTS

Content Validity Results

The content validity assessment by five expert validators showed that out of 44 items evaluated, 42 items (95.5%) were declared valid with CVI ≥ 0.80, while 2 items (4.5%) were declared invalid and required revision. The recapitulation of validation results is presented in Table 1.

Table 1. Recapitulation of Content Validity Results of the Mathematical Beliefs Scale

Dimension	Number of Items	Valid Items	Items for Revision	CVI	Category
Beliefs about teacher	16	15	1	0.96	Highly Valid
Beliefs about competence and significance of mathematics	13	12	1	0.95	Highly Valid
Mathematical beliefs as social activity	9	9	0	1.00	Highly Valid
Mathematical beliefs as domain of excellence	6	6	0	1.00	Highly Valid
Total	44	42	2	0.96	Highly Valid

Based on Table 1, all dimensions achieved an average CVI of 0.96, which falls into the highly valid category. The dimensions of mathematical beliefs as social activity and mathematical beliefs as domain of excellence obtained a CVI of 1.00, meaning that all items in both dimensions were assessed as valid by all validators. This finding aligns with the research of Atta et al. (2020), who developed a scientific literacy instrument and obtained content validity in the high category (Aiken index 0.77), as well as the research of Ridwan, Mardhiyyah, and Rusilowati (2013), who developed a science literacy assessment instrument with valid category validity. The high CVI in both dimensions indicates that these dimensions have clear operational definitions and that the formulated items precisely reflect the measured construct (DeVellis, 2017). This is important because these two dimensions are often overlooked in simpler mathematical beliefs instruments (McLeod, 1992).

The dimensions of beliefs about teacher and beliefs about competence and significance of mathematics each had one item that required revision based on validator suggestions. Items in the beliefs about teacher dimension and the beliefs about competence and significance of mathematics dimension were assessed as having weaknesses in terms of language and construct clarity. This indicates that although the theoretical framework is strong, operationalization into statement items still requires adjustment to respondent characteristics (DeVellis, 2017). The revision process based on validator suggestions resulted in items that are clearer, more specific, and more appropriate to the comprehension level of elementary school students.

Limited Trial Results

Description of Trial Data. The limited trial was conducted on 25 sixth-grade students of SDN 138 Bungi. The collected data were analyzed to determine item validity and instrument reliability. Descriptively, the total mathematical beliefs scores of students in the limited trial ranged from 78 to 140, with a mean of 115.32 and a standard deviation of 15.74.

Item Validity Results. The results of item validity analysis using Pearson correlation between item scores and total scores are presented in Table 2.

Table 2. Results of Item Validity Analysis of the Mathematical Beliefs Scale

Dimension	Valid Items	Invalid Items	Number of Items
Beliefs about teacher	1, 2, 3, 5, 6, 8, 9, 10, 11, 13, 14, 15, 16	4, 7, 12	13
Beliefs about competence and significance of mathematics	17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 29	27, 28	11
Mathematical beliefs as social activity	31, 33, 34, 35, 36, 38	30, 32, 37	6
Mathematical beliefs as domain of excellence	39, 40, 41, 43, 44	42	5
Total	37	7	44

Based on Table 2, out of 44 items tested, 37 items (84.1%) were declared valid, while 7 items (15.9%) were declared invalid because the correlation coefficients were less than the r table value (r table = 0.396, $\alpha = 0.05$, n = 25). This finding is consistent with the research of Atta et al. (2020), who developed a scientific literacy instrument and found that out of 46 items tested, 40 items were declared valid with good validity categories, as well as the research of Yıldırım Çayır (2008), who also found that not all items in the development of mathematical beliefs scales met the validity criteria. The process of item elimination based on empirical analysis is a normal part of good scale development (DeVellis, 2017).

The correlation coefficients for valid items ranged from 0.397 to 0.813, indicating that these items have a significant relationship with the total instrument score. The highest correlation values were found in item 17 ($r = 0.813$, $p < 0.01$), which states "I can understand even the most difficult material in mathematics lessons," and item 29 ($r = 0.766$, $p < 0.01$), which states "Group work makes it easier for me to learn mathematics." This finding aligns with the research of Kloosterman (1996) and Bandura (1997), which showed that self-efficacy and beliefs about the importance of collaboration are core components of productive mathematical beliefs.

The invalid items had low and non-significant correlation coefficients. Several patterns causing item invalidity can be identified. First, some items had double meanings or ambiguity. For example, item 4 ("Teachers do not pay enough attention to our feelings in class because they are too focused on mathematics lessons") has two clauses that can be interpreted differently by students. This is consistent with DeVellis's (2017) finding that items with double meanings tend to have low validity. Second, some items used language that was too abstract or unfamiliar to elementary school students, such as items 7 and 12. Children at the concrete operational stage (ages 7-11) more easily understand concrete and specific statements (Piaget, 1970). Third, some invalid items had statement directions that contradicted the measured construct, such as items 27 and 28. Students may have difficulty understanding negative statements and provide responses inconsistent with their actual beliefs (Furinghetti & Pehkonen, 2002). Fourth, item 42 ("In my opinion, there is only one correct way to solve math problems") may have low validity because elementary school students generally do not yet have sufficient experience with various problem-solving strategies, so they cannot respond meaningfully to this statement (Schoenfeld, 1985).

Reliability Analysis Results. The results of reliability analysis using Cronbach's Alpha are presented in Table 3.

Table 3. Results of Reliability Analysis of the Mathematical Beliefs Scale

Dimension	Cronbach's Alpha	Number of Items	Category
Beliefs about teacher	0.824	13	High
Beliefs about competence and significance of mathematics	0.857	11	High
Mathematical beliefs as social activity	0.802	6	High
Mathematical beliefs as domain of excellence	0.791	5	High
Total Scale	0.886	37	High

Based on Table 3, the total scale reliability coefficient was 0.886, which falls into the high category. This finding aligns with the research of Atta et al. (2020), who developed a scientific literacy instrument and obtained a reliability of 0.85 (high category), as well as the research of Purnomo (2017), who developed a mathematical beliefs scale for elementary school teachers in Indonesia and obtained reliability coefficients in the range of 0.715--0.787. The reliability coefficient obtained in this study is also higher compared to the research of Yıldırım Çayır (2008), who obtained a Cronbach's Alpha of 0.77 for the student mathematical beliefs scale, as well as the adaptation research of the Mathematical Development Beliefs Scale which obtained a reliability coefficient of 0.86 (Platas, 2015; adaptation by Turki, 2020). The high Cronbach's Alpha values across all dimensions and the total scale indicate that the items in the scale have good internal consistency and the instrument can be relied upon to measure students' mathematical beliefs (Nunnally & Bernstein, 1994).

DISCUSSION

The research findings indicate that the multidimensional mathematical beliefs scale developed has good validity and reliability. The high content validity (CVI = 0.96) indicates that the items in the scale representatively cover all dimensions of mathematical beliefs to be measured, and experts agree that these items are relevant to the specified indicators. This finding is consistent with the research of Atta et al. (2020), who developed a scientific literacy instrument and obtained good content validity through expert assessment. High content validity is an important prerequisite for measurement instruments because it ensures that the instrument measures the intended construct (DeVellis, 2017; Mardapi, 2017).

The results of item validity analysis show that 84.1% of items were declared valid, with statistically significant correlation coefficients. The proportion of valid items in this study is higher compared to the research of Yıldırım Çayır (2008), who retained 40 out of 65 items (61.5%) after the elimination process, as well as the research of Platas (2015), who retained all 40 items in the mathematical development beliefs scale. The high proportion of valid items indicates that the formulated items have good discriminatory power, meaning they can distinguish between students with high mathematical beliefs and students with low mathematical beliefs (Hair et al., 2010).

Items with the highest correlation coefficients reflect the central aspects of mathematical beliefs. Item 17 ("I can understand even the most difficult material in mathematics lessons") had the highest correlation ($r = 0.813$), indicating that beliefs about self-efficacy are a core component of mathematical beliefs. This finding aligns with the research of Bandura (1997), which showed that self-efficacy is a strong predictor of motivation and performance in mathematics, as well as the research of Kloosterman (1996), which identified beliefs about self-ability as one of the main dimensions in students' mathematical beliefs. Item 29 ("Group work makes it easier for me to learn mathematics") also had a high correlation ($r = 0.766$), indicating that beliefs about the importance of collaboration in learning mathematics are an important aspect of productive mathematical beliefs. This finding supports the social perspective in mathematics learning emphasized by Op't Eynde et al. (2006) and Yackel & Rasmussen (2002).

The high reliability of the scale (Cronbach's Alpha = 0.886) indicates that the instrument has good internal consistency. This finding aligns with the standard established by Nunnally and Bernstein (1994) that instruments with reliability ≥ 0.70 can be considered reliable for basic research purposes. The high reliability coefficients across all dimensions (0.791--0.857) indicate that items in each dimension consistently measure the same aspect of mathematical beliefs. The highest reliability was found in the dimension of beliefs about competence and significance of mathematics ($\alpha = 0.857$), indicating that items in this dimension are the most homogeneous and consistent in measuring the same construct. This may be because the operational definition of this dimension is the clearest and easiest for students to understand, namely beliefs about self-ability and the importance of mathematics (Bandura, 1997).

This study has several limitations that need to be acknowledged. First, the limited trial only involved 25 students from one school, so the generalization of results is still limited. Nevertheless, as an initial development study, this number is still acceptable for item validity and reliability analysis (Hair et al., 2010; Atta et al., 2020). Further research needs to involve larger and more diverse samples to conduct confirmatory factor analysis and test the stability of the factor structure. Second, this study has not yet tested the criterion validity of the scale, for example by correlating mathematical beliefs scores with learning achievement or student learning behavior. Third, this research is still limited to scale development and has not yet tested the effectiveness of interventions based on the scale's diagnostic results.

CONCLUSION

Based on the research results and discussion, it can be concluded that the multidimensional mathematical beliefs scale for elementary school students developed in this study has good validity and reliability. The instrument development procedure, which referred to the Plomp model, produced a scale with 37 items covering four dimensions of mathematical beliefs based on the Eynde, Corte, and Verschaffel (2002) framework: beliefs about teacher (13 items), beliefs about competence and significance of mathematics (11 items), mathematical beliefs as social activity (6 items), and mathematical beliefs as domain of excellence (5 items). The content validity of the instrument was excellent, with an average CVI of 0.96, meaning that experts agreed that the items in the scale representatively cover all dimensions of mathematical beliefs to be measured. Item validity showed that 37 out of 44 items (84.1%) were declared valid based on Pearson correlation ($r > 0.396$, $p < 0.05$), with item correlation coefficients ranging from 0.397 to 0.813. The instrument reliability was very high, with a total Cronbach's Alpha of 0.886 and reliability coefficients for each dimension ranging from 0.791 to 0.857 (high category).

This scale can be used by teachers to diagnose students' mathematical beliefs profiles as a basis for designing appropriate learning interventions, as well as by researchers to examine the relationship between mathematical beliefs and other relevant variables in mathematics education. Further research is suggested to conduct scale trials on larger and more diverse samples for confirmatory factor analysis, to test criterion validity by correlating mathematical beliefs scores with other theoretically related variables, and to develop and test the effectiveness of learning interventions designed to change students' mathematical beliefs based on diagnostic results using this scale.

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