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Analysis of Motivation and Interest Instruments in Mathematics Learning Using Confirmatory Factor Analysis (CFA)

Nanang Supriadi[1]*, Nirva Diana[1], Iwan Kuswidi[2]
[1]Faculty of Education and Teacher Training, Universitas Islam Negeri Raden Intan Lampung, Indonesia
[2]Faculty of Education and Teacher Training, Universitas Islam Negeri Sunan Kalijaga, Indonesia

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***Correspondence Address:**
nanangsupriadi@radenintan.ac.id

Abstract: This study investigates the key indicators of interest and motivation in mathematics learning using confirmatory factor analysis (CFA) to validate their relevance and reliability. Conducted in Bandar Lampung, Indonesia, the research involved 111 junior high school students selected through cluster random sampling. Two latent variables were examined: interest, represented by four indicators (feeling of happiness, student curiosity, student attention, and student involvement), and motivation, represented by five indicators (perseverance, tenacity, sharpness of attention, achievement, and independence). Results revealed that only student curiosity (KMO = 0.611) and student involvement (KMO = 0.507) were valid indicators of interest, while perseverance (KMO = 0.685), tenacity (KMO = 0.628), and sharpness of attention (KMO = 0.616) were valid indicators of motivation. The validated indicators highlight the intrinsic and participatory nature of engagement, emphasizing the importance of fostering curiosity, involvement, and resilience in mathematics learning. The findings contribute to the theoretical integration of interest and motivation as interconnected constructs and offer practical implications for designing targeted instructional strategies. This study provides a robust framework for understanding student engagement in mathematics and serves as a foundation for future research on contextual and longitudinal dynamics of these constructs.

INTRODUCTION

Mathematics is a fundamental subject that plays a critical role in the development of logical reasoning, problem-solving skills, and the cognitive abilities of students. Despite its importance, mathematics remains one of the least favored subjects among students globally. Numerous studies have highlighted that students' lack of interest in mathematics often stems from anxiety, perceived difficulty, and the failure to connect mathematical concepts with real-life applications (Leyva et al., 2022; Li & Schoenfeld, 2019; Musa & Maat, 2021). This phenomenon presents a significant challenge for educators, as fostering students' interest and motivation in mathematics is essential to improving learning outcomes and ensuring their success in related disciplines.

Research on mathematics education has extensively analyzed various factors influencing students' learning, including emotional intelligence, mathematical communication, and cognitive development. For instance, Darling-Hammond et al. (2020) explored the impact of emotional intelligence on mathematical communication, demonstrating that emotional factors play a critical role in students' ability to engage with and articulate mathematical concepts. However, while such studies provide valuable insights, there is still a limited understanding of the specific indicators that contribute to students' interest and motivation in learning mathematics. Addressing this gap is crucial, as interest and motivation are key drivers of learning behaviors and academic achievement (Dev, 1997; Smiderle et al., 2020).

Interest in learning, as defined by Philip & Bennett (2021), refers to a student's stable tendency to pay attention to and remember specific activities. Similarly, Mazana et al. (2018) conceptualizes interest as a positive inclination or enthusiasm toward a particular subject or activity. In the context of mathematics, interest is reflected in students' willingness to engage actively in learning activities, persist in solving problems, and demonstrate curiosity about mathematical concepts. Several indicators have been identified as contributing to students' interest in mathematics, including feelings of happiness, curiosity, attention, and involvement (Amerstorfer & Freiin von Münster-Kistner, 2021). However, the extent to which these indicators accurately represent students' interest remains an open question, requiring further empirical validation.

Motivation to learn, on the other hand, encompasses the internal and external forces that drive students to engage in learning activities, sustain their efforts, and achieve desired outcomes (An et al., 2021; Šimić et al., 2021; Yeşilçınar, 2019). In mathematics education, motivation manifests in perseverance, resilience in the face of challenges, attentiveness, academic achievement, and independence in learning. As a latent variable, motivation cannot be directly observed but is inferred through measurable indicators. Previous research, such as Dash & Paul (2021), has utilized confirmatory factor analysis (CFA) to examine the validity of these indicators. However, inconsistencies in the selection and interpretation of indicators across studies highlight the need for a more systematic approach to understanding how motivation interacts with interest to influence learning outcomes in mathematics.

This study addresses two critical research gaps in the existing literature. First, while prior studies have focused on the relationship between emotional, cognitive, and motivational factors in mathematics learning, there has been limited exploration of the specific indicators that constitute students' interest and motivation. Understanding these indicators is essential for designing targeted interventions to enhance students' engagement with mathematics. Second, existing research often treats interest and motivation as separate constructs, neglecting their potential interdependence. This study adopts a novel approach by examining interest and motivation as interconnected latent variables, providing a more comprehensive framework for understanding students' learning behaviors.

The novelty of this research lies in its methodological and theoretical contributions. Methodologically, this study employs confirmatory factor analysis (CFA) to validate the indicators of interest and motivation in mathematics learning. By using CFA, the study not only confirms the validity and reliability of the proposed indicators but also provides insights into their relative importance in shaping students' attitudes toward mathematics. Theoretically, the study contributes to the broader discourse on mathematics education by integrating interest and motivation into a unified framework, emphasizing their dynamic interplay in influencing learning outcomes. This perspective aligns with contemporary theories of motivation, such as the Self-Determination Theory (Hattie et al., 2020), which highlights the importance of intrinsic and extrinsic factors in fostering sustained engagement in learning.

The findings of this study are expected to have significant implications for mathematics education, particularly in designing instructional strategies and interventions. For instance, understanding the key indicators of interest and motivation can guide educators in creating learning environments that are both engaging and supportive. Furthermore, the study's emphasis on validating indicators provides a foundation for developing robust measurement tools, enabling researchers and practitioners to assess students' learning behaviors more accurately.

In conclusion, this research underscores the importance of fostering interest and motivation in mathematics learning as critical factors in improving students' academic achievement and overall attitude toward the subject. By validating the indicators of these latent variables and exploring their interdependence, the study aims to provide a comprehensive framework for understanding and enhancing students' engagement with mathematics. The results of this research are anticipated to contribute not only to the academic literature but also to practical efforts in improving mathematics education at various levels. Future research directions may include exploring how these indicators vary across different demographic groups and educational contexts, further enriching the discourse on mathematics learning and teaching.

METHOD

This study employed a quantitative research design utilizing Confirmatory Factor Analysis (CFA) to validate the indicators of interest and motivation in mathematics learning. CFA, a multivariate analysis technique, is used to confirm whether a hypothesized model fits the data collected (Henseler & Schuberth, 2020; Lahey et al., 2012). This method allows for the examination of the relationship between latent variables and their observed indicators, ensuring that the selected indicators are appropriate representations of the constructs being studied.

Research Setting and Participants

The research was conducted in junior high schools in Bandar Lampung, Indonesia. A total of 111 students were selected as respondents through Cluster Random Sampling, ensuring a representative sample of the target population. Participants were chosen based on their enrollment in mathematics courses, which formed the basis for analyzing their interest and motivation levels.

Research Instruments

The primary instruments for this study were Likert-scale questionnaires designed to measure two latent variables: interest and motivation in learning mathematics. The indicators for interest were adapted from prior research and included four dimensions: feeling of happiness, student curiosity, student attention, and student involvement (Bowden et al., 2021).

Similarly, motivation was measured using five indicators: perseverance in learning, tenacity in dealing with difficulties, sharpness of attention in learning, achievement in learning, and independence in learning (Singh & Chukkali, 2021). Each indicator was rated on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Prior to full-scale data collection, the instrument underwent pilot testing to ensure reliability and validity.

Data Collection Procedures

Data were collected over a two-week period in collaboration with mathematics teachers at the participating schools. Before the questionnaires were distributed, students received a detailed explanation of the research objectives and procedures. Ethical clearance was obtained from the relevant institutional review board, and informed consent was secured from all participants and their guardians. Participants were assured of the confidentiality and anonymity of their responses. Teachers were briefed on their role in facilitating data collection, ensuring that the process was conducted smoothly and without undue influence.

Analytical Procedures

The collected data were analyzed using SPSS and AMOS software to validate the proposed CFA model. The analysis involved several sequential steps to ensure the robustness of the findings. First, the Kaiser-Meyer-Olkin (KMO) test and Bartlett's test of sphericity were conducted to assess the sampling adequacy and factorability of the data. A KMO value above 0.50 and a significant Bartlett's test ($p < 0.05$) indicated that the data were suitable for factor analysis. Following this, the Principal Axis Factoring (PAF) method was used to extract primary components, where indicators with factor loadings below 0.50 were excluded. To improve the interpretability of the factor structure, Varimax rotation was applied, ensuring that each indicator was strongly associated with only one latent variable. The model's goodness of fit was evaluated using standard fit indices, including Chi-square (χ^2), Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), and Tucker-Lewis Index (TLI). Acceptable thresholds were set at RMSEA < 0.08, CFI > 0.90, and TLI > 0.90, as recommended by Dash & Paul (2021).

Statistical Model

The Confirmatory Factor Analysis (CFA) model used in this study was based on the following general equation:

$$x = \Lambda_x \xi + \delta$$

with information:

x	:	indicator variable
Λ_x	:	loading factor (λ) between indicators
ξ	:	(KSI), latent variable
δ	:	measurement error related to X

In this equation, x represents the observed indicator variables, Λ_x denotes the factor loadings for each indicator, ξ is the latent variable being measured, and δ accounts for measurement errors. The CFA framework allows for the validation of hypothesized relationships between the latent variables and their respective indicators, providing a rigorous method for examining the constructs of interest and motivation in mathematics learning.

RESULT AND DISCUSSION

Latent Variables Interest in Learning Mathematics

The confirmatory factor analysis (CFA) conducted on the latent variable interest in learning mathematics revealed that, among the four proposed indicators feeling of happiness, student curiosity, student attention, and student involvement only two indicators met the required statistical thresholds. Specifically, the indicators student curiosity and student involvement demonstrated acceptable Kaiser-Meyer-Olkin (KMO) scores of 0.611 and 0.507 respectively, indicating their validity as measures of interest in mathematics learning. These results are depicted in Figure 1.

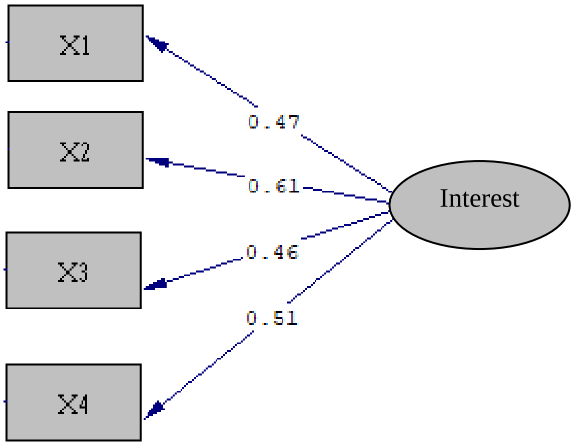

Figure 1. Confirmatory Factor Analysis diagram with the value of Kaiser Meyer Oikin in Latent Variables Interest in Learning Mathematics.

The exclusion of feeling of happiness and student attention suggests that these factors, while theoretically significant, may not directly capture the construct of interest in mathematics for the target population. Emotional responses like happiness could be influenced by external factors unrelated to the subject itself, as noted by Šimić et al. (2021). Similarly, student attention might be more appropriately classified as a behavioral outcome of curiosity and involvement rather than an independent indicator. Further validation of the two retained indicators was conducted through communalities analysis. The results are summarized in Table 1, showing that all items under student curiosity and student involvement exceeded the extraction value threshold of 0.50, indicating their relevance in explaining the variance within the factors.

Table 1. Communalities.

	Initial	Extraction
K.PSR 1	1.000	.719
K.PRS 2	1.000	.541
KPRS 3	1.000	.609
K.PRS 4	1.000	.614
K.PRS 5	1.000	.542
K.PRS 6	1.000	.618
K.PRS 7	1.000	.634

The total variance explained by the validated indicators was 61.109%, distributed across three components. This finding highlights the robustness of student curiosity and student involvement as central to understanding students' interest in mathematics.

Latent Variables Motivational Learning Mathematics

For the latent variable motivation in learning mathematics, the CFA identified three valid indicators: perseverance in learning, tenacity in facing difficulties, and sharpness of attention in learning. These indicators met the statistical requirements with KMO values of 0.685, 0.628, and 0.616, respectively. The remaining two indicators achievement in learning and independence in learning were excluded due to insufficient statistical support. The results are depicted in Figure 2.

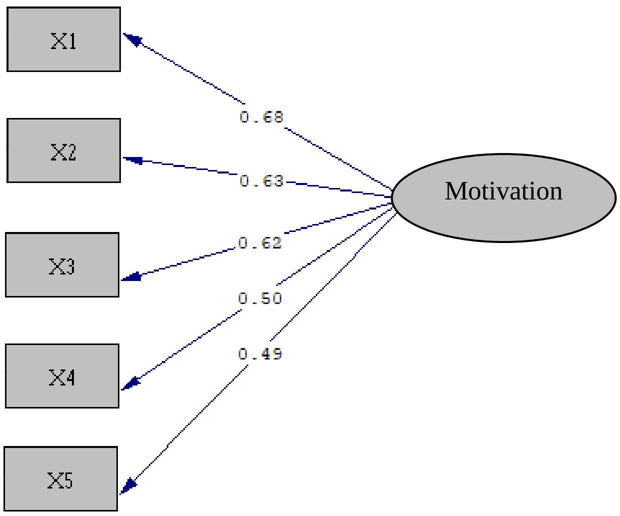

Figure 2. Confirmatory Factor Analysis diagram with the value of Kaiser Meyer Oikin in Latent Variables in Mathematics Learning Motivation.

The exclusion of achievement in learning and independence in learning aligns with findings by See et al. (2020), who emphasized that these factors are often mediated by external influences such as teacher feedback and parental involvement. The retained indicators reflect core motivational components directly linked to student engagement with mathematics. A detailed communalities analysis for the retained indicators is presented in Table 2, confirming their validity with extraction values exceeding 0.50.

Table 2. Communalities for Indicators of Student Motivation.

Initial	Extraction
KTRL 1	0.402
KTRL 2	0.229
KTRL 4	0.526

The total variance explained by the validated indicators was 68.549%, distributed across three components. These findings underscore the importance of perseverance, resilience, and focus as critical drivers of motivation in mathematics learning.

Discussion

The findings of this study provide critical insights into the constructs of interest and motivation in mathematics learning, contributing to the growing body of literature on student engagement. The validation of specific indicators within these latent variables offers a nuanced understanding of how students develop and sustain engagement with mathematics. By employing a rigorous confirmatory factor analysis (CFA), this study bridges the gap between theoretical constructs and their empirical measurement, paving the way for more targeted interventions and future research.

The validated indicators of interest in learning mathematics, namely student curiosity and student involvement, emphasize the intrinsic and participatory aspects of engagement. Student curiosity is a foundational element of intrinsic motivation, as it reflects a desire to explore and understand new concepts (Di Domenico & Ryan, 2017). In the context of mathematics, curiosity drives students to seek out patterns, question assumptions, and experiment with problem-solving strategies, ultimately fostering deeper cognitive engagement. This aligns with Chang & Shih (2019), who assert that curiosity underpins active cognitive engagement in academic settings. Similarly, student involvement represents an outward manifestation of engagement, encompassing active participation in classroom activities and collaborative learning. Involvement goes beyond mere compliance with instructions; it reflects a meaningful connection between the learner and the subject matter. This finding resonates with Lafuente-Lechuga et al. (2020) assertion that involvement is integral to the development of sustained interest in mathematics, particularly when students are given opportunities to take ownership of their learning.

The exclusion of feeling of happiness and student attention as valid indicators of interest provides a critical lens through which to examine the contextual nuances of engagement. While happiness is often perceived as an indicator of positive affect, its role in academic engagement may be limited, as it can be influenced by extraneous factors unrelated to the learning process (Alyahyan & Düştegör, 2020). For instance, a student may feel happy during a mathematics class due to the social environment or external rewards, rather than an intrinsic interest in the subject. Similarly, attention, while important, may not be an independent driver of interest but rather a consequence of heightened curiosity and involvement. These findings suggest that educators and researchers should focus on fostering the underlying components of interest, such as curiosity, rather than relying on general affective states or behavioral outcomes as proxies for engagement.

The validated indicators of motivation in learning mathematics perseverance in learning, tenacity in facing difficulties, and sharpness of attention in learning highlight the centrality of resilience and focus in sustaining motivation. Perseverance reflects a student's ability to maintain effort and commitment over time, even when faced with challenges. This finding aligns with Di Domenico & Ryan, (2017) Self-Determination Theory, which identifies persistence as a critical component of intrinsic motivation. In the mathematics classroom, perseverance enables students to tackle complex problems, revisit concepts they find difficult, and refine their understanding through iterative learning. Tenacity in facing difficulties underscores the importance of grit, or the ability to persist through obstacles, as a predictor of academic success (Park et al., 2020). Mathematics, often characterized by its abstract and sequential nature, demands a level of tenacity that allows students to approach problems with a growth mindset and resilience.

Sharpness of attention complements perseverance and tenacity by ensuring that students remain focused on the task at hand, particularly during cognitively demanding activities. This finding resonates with Sarker (2021) assertion that attention is a prerequisite for deep learning, as it allows students to process information, identify patterns, and make connections between concepts. Together, these three indicators form a robust framework for understanding how motivation drives sustained engagement in mathematics. The exclusion of achievement in learning and independence in learning as valid indicators of motivation highlights the potential influence of external factors on these constructs. Achievement, while an important outcome of learning, may be shaped more by extrinsic motivators such as grades and teacher feedback than by intrinsic drivers of motivation. Similarly, independence in learning, though desirable, may not be a universal characteristic of motivated students, as cultural and contextual factors can influence how autonomy is expressed and valued (Cook & Artino, 2016). These findings underscore the importance of focusing on intrinsic and universally relevant indicators, such as perseverance and attention, when designing interventions to enhance motivation.

Overall, this study advances the discourse on interest and motivation in mathematics learning by integrating these constructs into a unified framework. Unlike previous research that has often treated interest and motivation as separate entities, this study demonstrates their interconnectedness and mutual reinforcement. For example, curiosity a core component of interest can serve as a precursor to motivation by sparking initial engagement, while motivation sustains that engagement through perseverance and tenacity. This dynamic interplay provides a more holistic understanding of student engagement, offering valuable insights for both researchers and practitioners. The implications of these findings are far-reaching, particularly for educators seeking to enhance engagement in mathematics. By fostering curiosity and creating opportunities for meaningful involvement, teachers can cultivate a sense of interest that serves as a foundation for sustained motivation. Similarly, instructional strategies that build perseverance, such as incremental goal-setting and the use of formative feedback, can help students develop the resilience needed to navigate the challenges of mathematics. These findings also highlight the need for culturally responsive approaches to engagement, as the relevance and expression of certain indicators may vary across contexts. Future research could build on this study by exploring how these validated indicators interact with external factors, such as classroom climate and teacher-student relationships, to influence engagement. In conclusion, the findings of this study provide a nuanced understanding of interest and motivation in mathematics learning, validating specific indicators that capture the intrinsic and participatory nature of engagement. By bridging theoretical constructs with empirical measurement, this research offers a robust framework for understanding and enhancing student engagement, paving the way for more effective instructional practices and future studies.

CONCLUSION

The findings of this study validate key indicators of interest and motivation in mathematics learning, providing a robust framework for understanding student engagement. By employing confirmatory factor analysis (CFA), the study confirms that student curiosity and student involvement are critical components of interest, while perseverance, tenacity, and sharpness of attention are essential drivers of motivation. These validated indicators underscore the interconnected nature of interest and motivation, highlighting their role in fostering sustained engagement and academic success in mathematics. The exclusion of certain indicators, such as feeling of happiness and achievement in learning, further emphasizes the importance of focusing on intrinsic and participatory factors rather than external or context-dependent variables. This research contributes to the theoretical discourse by integrating interest and motivation into a unified framework and offers practical implications for educators in designing targeted interventions to enhance mathematics engagement. Future research should explore the contextual and longitudinal dynamics of these constructs to further refine their applicability in diverse educational settings.

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