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ASSESSING MATHEMATICAL CREATIVE THINKING: AN ETHNOMATHEMATICS-BASED TEST AND FACTORS INFLUENCING THE ACHIEVEMENT OF SECONDARY SCHOOL STUDENTS IN INDONESIA

SUMMARY OF THE DOCTORAL DISSERTATION

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Mathematical creative thinking: Theoretical Perspectives and Factors Influencing the Indonesian Educational Policy Context

This main of the dissertation follows a study-based format, aiming to assessing secondary school students' mathematical creative thinking skills through ethnomathematics based test and the factors that influencing them. To accomplish this goal, a review study and five empirical studies were carried out.

In contemporary education, creativity has become an essential focus for educators and researchers, especially in response to the rapid technological advancements of the 21st century. These advancements have significantly transformed the way individuals live and interact, including their creative processes (Borodina et al., 2019; Suherman & Vidákovich, 2022b). As a result, individuals must develop the ability to adapt to unpredictable challenges and cultivate innovative solutions to address real-world problems. This shift has positioned creativity as a critical skill in many countries worldwide to keep pace with global innovation and economic growth (Nakano & Wechsler, 2018). However, despite its recognized importance, creativity's application in educational research remains underexplored, particularly in classroom settings (OECD, 2018).

The need to measure creativity is highlighted by Treffinger & Houtz (2003), who argue that quantifying creative thinking helps recognize individual strengths and allows educators and policymakers to identify and nurture untapped potential. While numerous theories have attempted to define and assess creativity (Beghetto & Kaufman, 2022), empirical research has sought to establish a more concrete understanding of how creativity functions in learning environments (Fauzi et al., 2019). In mathematics education, creative thinking is essential for problem-solving and conceptual understanding. It can be assessed through indicators such as flexibility, originality, and appropriateness (Haylock, 1997).

In the context of the Indonesian education system, it is important to note that creative thinking is not a subject or skill that is explicitly included as a standalone course. Instead, creative thinking is integrated and woven into the core curriculum and educational practices (Ministry of Education, 2016). This means that students are not formally taught creative thinking, but rather, the development of creative thinking skills is embedded within various subjects and educational activities. In essence, the Indonesian education system recognizes the value of nurturing creative thinking skills in students but chooses to do so by infusing creative thinking elements throughout the entire curriculum. As a result, students are exposed to creative thinking organically within the broader framework of their education, helping them develop these vital skills as they progress through their academic journey. Unfortunately, this approach has come under scrutiny as teaching and learning practices are exam-oriented, with a greater emphasis placed on passing examinations rather than applying knowledge in real-world situations.

Although this skill is important for all students, it is especially critical for those in secondary education. Unfortunately, there has been no significant improvement in mathematical achievement at the secondary school level over the years (Okpala et al., 2001). The average performance results from the PISA 2022 creative thinking assessment show that Indonesia had the lowest score, achieving 19 points out of 33, compared to the OECD average (PISA, 2024). Furthermore, the national assessment program for 2019 revealed that the average maths score for middle school students was a mere 46.56 out of 100 (Ministry of Education and Culture, 2019). This situation highlights a pressing need for improvement in mathematics assessment practices.

Given the significance of creative thinking in mathematics, researchers have explored ways to integrate creativity into the curriculum. Visual culture and ethnomathematics, which recognize the cultural aspects of mathematical learning have been suggested as valuable approaches to fostering creativity (Rosa & Orey, 2015). However, despite its importance, many

secondary school students struggle to apply creative mathematical thinking in real-world contexts, as traditional curricula often separate theoretical mathematics from practical applications. Consequently, creativity has been incorporated into mathematics curricula to make learning more relevant and problem-based. Nevertheless, students continue to experience challenges and demonstrate low performance in mathematical creative thinking (PISA, 2024).

To address these challenges, researchers have proposed several approaches to improving students' mathematical creative thinking, including: (1) analyzing cognitive development across grade levels to determine optimal instructional periods, (2) examining the influence of background variables to promote equity in mathematics education, (3) identifying key factors that contribute to mathematical creativity to develop effective teaching strategies, and (4) incorporating real-world applications to foster engagement and deeper conceptual understanding.

Despite these advancements, there remains a gap in understanding the combined influence of various factors— such as socio-economic status, ethnic identity, attitude toward mathematics, and creative style— on students' mathematical creative thinking. Prior studies have examined these factors individually, but limited research has investigated their interactions and overall impact. This gap underscores the necessity of further exploration, as understanding these relationships could lead to more effective instructional strategies and policy decisions aimed at fostering creativity in mathematics education.

The primary objective of this study is to evaluate the mathematical creative thinking abilities of Indonesian secondary school students through an ethnomathematics-based contextual task while analyzing the influence of affective and socioeconomic status factors using structural equation modeling. Before conducting this assessment, a comprehensive review of current trends in mathematical creativity assessment and the development of appropriate test instruments is necessary. The test is designed to integrate mathematical concepts with cultural contexts through an ethnomathematical approach, focusing on an accessible and student-centered evaluation method.

This research aims to provide valuable insights for teachers and researchers, particularly in Indonesia, to develop instructional strategies that target the optimal stages of students' cognitive development. By focusing on underrepresented groups and addressing key influencing factors, this study seeks to reduce students' challenges in mathematical creative thinking and enhance their overall performance in the subject.

Hence, the general research questions of this dissertation are listed below.

1. RQ1: What is the trend of mathematical creative thinking assessments across all educational levels, including assessment tools, topics, and the evidence of the psychometrics properties used?
2. RQ2: Is it possible to develop a reliable and valid instrument to measure students' attitude toward mathematics in Indonesian context? (Fennema & Sherman, 1976; Tapia & Marsh, 2004)
3. RQ3: What are effective ways to integrate local culture into the assessment of students' mathematical creative thinking? (Fouze & Amit, 2019; Matthews, 2018).
4. RQ4: To what extent do attitude and ethnicity interact in students' mathematical creative thinking skills? (De-La-Peña et al., 2021; Kozlowski & Si, 2019; Martinez-Fuentes et al., 2021; Matsko & Thomas, 2014; Yoon et al., 2015).
5. RQ5: To what extent do attitude, ethnic, creative style, and parents' education variables interact in predicting students' mathematical creative thinking skills? (De-La-Peña et al., 2021; Matsko & Thomas, 2014; Yoon et al., 2015)
6. RQ6: To what extent do variables such as perceived creativity, creative self-efficacy, and computational thinking predict students' mathematical creative thinking? (Alt et al., 2023; Goncalo et al., 2010; Haase et al., 2018; Hershkovitz et al., 2019; Pretz & Nelson, 2017).

Main Methodology of the Empirical Studies

This dissertation employed a mixed-methods empirical design, encompassing pilot and main studies involving secondary school students (grades 7–9) across rural and urban schools in Lampung Province, Indonesia. Participants were selected using random and convenience sampling, representing diverse ethnic backgrounds. The study utilized ethnomathematics-based open-ended tests and several validated questionnaires to measure mathematical creative thinking and related influencing factors such as attitudes, ethnic identity, creative style, perceived creativity, self-efficacy, and computational thinking. Instruments were developed and validated through expert review, pilot testing, and Rasch analysis. The main data collection involved online administration of tests and questionnaires, with ethical approval and school collaboration. Data were analyzed using Rasch modeling (Winstep), exploratory and confirmatory factor analysis, and structural equation modeling (SEM), supported by SPSS, Mplus 8, SmartPLS 4, and R software. A systematic review was also conducted using PRISMA guidelines, with 70 empirical studies analyzed to support the instrument development and contextual understanding.

Study 1: Assessment of Mathematical Creative Thinking: A Systematic Review

The research on mathematics education has promoted the exploration of Creative thinking to develop a deep understanding of mathematics concepts. Some researchers have argued that the essence of mathematics is thinking creatively, not merely arriving at the correct answer. Some studies have analyzed the work related to mathematical creative thinking assessments using diagnostic tools.

Since its emergence, mathematical creative thinking skills competence has contributed to various fields of research. However, systematic reviews of the mathematical creative thinking assessment's current practice and the assessment have been limited, particularly in mathematics education. To tackle this gap, study 1 aimed to systematically review studies on the assessment of mathematical creative thinking, including: (1) the educational levels, (2) the mathematics contexts, (3) tools, and (4) the evidence that tools (Suherman & Vidákovich, 2022b). By conducting this study, it provides information the best assessment and frameworks to be used in mathematical creative thinking.

1. To conduct the review, this study applied the PRISMA model to filter English-language articles published between 2011 and 2021. The findings revealed that most studies on mathematical creative thinking assessments were conducted at the secondary school level, with high school and college levels also being commonly examined. In contrast, only a small portion of the reviewed studies focused on mathematical creative thinking assessments at the primary school level. Among grade levels, seventh grade had a notable share, followed closely by eighth grade, which had the second-highest representation in mathematics-related creative thinking assessments. Interestingly, a considerable number of studies also explored mathematical creative thinking at the senior high school and college levels, with a noticeable portion focusing on tenth grade and undergraduate students.
2. The study observed that mathematical materials used to assess mathematical creative thinking vary widely across different studies. Among the topics reviewed, geometry and measurement emerged as the most frequently misinterpreted areas, followed by algebra, numbers, and, to a lesser extent, probability and statistics.
3. Open-ended questions are the most commonly used assessment tool for measuring students' mathematical creative thinking, as they allow students to express their ideas freely and explore multiple solutions.
4. Among the 70 reviewed studies, fewer than half reported evidence of validity and reliability, with only a small portion explicitly addressing validity.

Study 2: Adaptation and Validation of Attitudes Toward Mathematics to Indonesia

The goal of mathematical education is to foster positive attitudes toward mathematics. Research on attitude has been conducted extensively, highlighting the close relationship between attitude elements and successful mathematics performance. However, there were sample size limitations; the collected sample did not represent a student population. Moreover, (Barkoukis et al., 2008) showed that the drop-out rate of students correlates with their attitudes toward mathematics.

The is need and relevance of developing such instruments is to assess students attitude in mathematics. However, the lack of popularity might also be because only samples from Mexico or US have been used to test attitudes toward mathematics scale; thus, a culturally diverse sample is required to explore the characteristics of attitudes toward mathematics. Most other existing instruments are based on western samples and require a significant amount of time to operate. The objective of this study is to develop and validate a variant of attitudes toward mathematics inventory in Indonesia context (Suherman & Vidákovich, 2022a).

The study involved 502 secondary school students from grades 7 to 9. The questionnaire was initially in English but was translated into Indonesian to enhance comprehension and validity, then back-translated into English by experts in mathematics education and linguistics.

The study used CFA to validate the latent factors in the measurement model, showing good model fit. Construct validity was supported through convergent and discriminant validity. Composite reliability values exceeded 0.60, and HTMT ratios were below 0.90, confirming that the factors were both internally consistent and distinct. Eight items were removed due to low factor loadings, resulting in a refined 26-item attitude toward mathematics scale with balanced subscales for enjoyment, self-perception, value, and perceived achievement. The final instrument showed strong reliability and validity, making it a useful tool for assessing students' attitudes in the Indonesian context.

Study 3: Tapis Patterns in the Context of Ethnomathematics to Assess Students' Creative Thinking in Mathematics: A Rasch Measurement

To preserve national culture and promote cultural education, it is essential to understand and embrace cultural diversity, particularly in the context of transforming culture (Suherman & Vidakovich, 2022). Ethnomathematics offers a unique opportunity to explore various cultural perspectives within education, especially in mathematics. However, despite its broad application, ethnomathematics is often mistakenly equated with ethnic or indigenous mathematics.

Previous studies have shown that traditional woven patterns, such as Yogyakarta batik and Dayak Tabun tools, reflect mathematical concepts like geometry, algebra, and trigonometry (Hartono & Saputro, 2019; Prahmana & D'Ambrosio, 2020). Ethnomathematics in Sundanese culture also highlights how indigenous practices relate to mathematical ideas (Muhtadi, 2017). However, many of these studies lack standardized methods to measure mathematical understanding. As Pais (2011) emphasized, connecting local culture with school mathematics serves as a bridge, empowering students to better grasp formal mathematics through culturally grounded experiences.

The study involved 157 secondary school students. The research focused on exploring culture, specifically using Tapis Lampung as a symbol within that culture. It provided insights into how people think and act, as well as the sights and sounds they experience. The research tools centered on analyzing the patterns of Tapis in the context of ethnomathematics (Suherman & Vidakovich, 2022).

The study revealed that students' answers reflected their creative thinking and understanding of ethnomathematics, specifically through the use of Tapis Lampung patterns.

Students with higher mathematical creative thinking abilities showed different responses to the patterns. For example, one student identified four shapes, triangle, rhombus, circle, and square—while another student mentioned three shapes: triangle, rhombus, and hexagon. Both students were able to draw pictures based on these shapes, such as a rocket or an angry bird, demonstrating their creative ability to visualize and interpret geometric patterns. Further analysis using regression tests showed that only 2.9% of the variance in students' creative thinking could be explained by factors like ethnicity, school type, and living place, suggesting that other factors contribute more significantly to creative thinking development.

Study 4: Relationship between ethnic identity, attitude, and mathematical creative thinking among secondary school students

The past few years have witnessed a surge in the interest towards mathematical creative thinking as a feasible remedy for these predicaments. Previous research has shown that attitude plays a significant role and has a strong connection with creative thinking skills (Basadur et al., 2000). Likewise, Sánchez et al. (2022) found that some participants noted a connection between students' attitudes and the development of activities that support creativity. Additionally, studies emphasize the importance of ethnic identity in shaping educational experiences, with students from diverse backgrounds facing unique challenges in engaging with mathematics (Zhao et al., 2005).

Despite some research exploring the role of positive attitude toward mathematics and cultural understanding in fostering mathematical creative thinking, the existing literature remains limited. Moreover, there has been little investigation into how these variables specifically relate within the Indonesian context. This paper examines the connection between these variables (Suherman & Vidákovich, 2024b).

The study included 896 secondary school students from Lampung province, Indonesia, covering grades 7 through 9. Data was gathered through online tests and questionnaires via Google Forms. The study employed a SEM approach to analyze the data and assess the model.

The study found that both attitude and ethnic identity had significant positive effects on mathematical creative thinking. Specifically, a positive attitude and strong ethnic identity were both linked to higher levels of creative thinking in mathematics. The data indicated that these two factors together explained a substantial portion of the variation in students' creative thinking abilities. In addition, a higher positive attitude led to an increase in both creative thinking and ethnic identity, while ethnic identity also had a positive, albeit smaller, effect on creative thinking. After incorporating ethnic identity as a mediator into the model, the direct effects of attitude on creative thinking decreased, but ethnic identity significantly mediated the relationship between attitude and creative thinking. The results showed that attitude indirectly influenced creative thinking through ethnic identity. While the direct effect of ethnic identity on creative thinking was not statistically significant, the mediation effect was robust, highlighting the importance of cultural and ethnic background in shaping students' creative thinking abilities in mathematics.

Study 5: Mathematical creative thinking-ethnomathematics based test: Role of attitude toward mathematics, creative style, ethnic identity, and parents' educational level

Exploring creative thinking is important for students' success in mathematics and their overall learning experience. Integrating visual culture and ethnomathematics into education helps connect students' cultural backgrounds with mathematical concepts, enhancing both academic performance and their sense of cultural identity. Previous research has shown that mathematical creative thinking is closely tied to students' competence in math and their cultural identity, suggesting that creativity in math can strengthen their connection to their ethnicity (Soler Pastor et al., 2022). Similarly, research showing that students' attitude toward math is

positively related to their metacognitive awareness and mathematical creative thinking (Kurdal & Kaplan, 2023), parental education level and creative style, also influence math achievement and creativity (Hidayatullah & Csíkos, 2023).

While previous studies have looked at the individual effects of these factors on mathematical creative thinking, there is a gap in understanding how they interact together. This study aims to fill that gap by examining how factors such as ethnic identity, attitude toward mathematics, parents education, and creative style combine to influence mathematical creative thinking across different grade levels (Suherman & Vidákovich, 2024a).

The study included 896 students from grades 7 to 9, attending both private and public secondary schools in Lampung province, Indonesia. Through path analysis, the study found that ethnic identity and attitude toward mathematics were found to have positive influences on mathematical creative thinking scores across different grade levels. In particular, the 9th graders exhibited a significant direct effect from both ethnic identity and parental education (father education), indicating that cultural identity and family background play a significant role in students' creative thinking in mathematics. Surprisingly, creativity style did not show a significant direct effect on mathematical creative thinking scores, and the creative style had only weak negative correlations with fluency and elaboration, suggesting other factors may be more influential in fostering creativity. Interestingly, parental education, especially fathers' education, had a positive effect on mathematical creative thinking performance, which could be an important consideration for future educational strategies.

Grade-level differences also revealed important trends. Seventh graders had the most significant associations between ethnic identity, attitude toward mathematics, and creative style with mathematical creative thinking, while eighth and ninth graders displayed different patterns of influence, with ethnic identity and attitude toward mathematics showing weaker effects in higher grades. For example, while the 7th and 8th graders showed positive relationships between creative thinking and ethnic identity, these associations weakened in 9th grade, where ethnic identity and parental education became stronger predictors of creative thinking. In contrast, the 9th-grade model showed that parental education had a direct positive effect on mathematical creative thinking, unlike attitude toward mathematics and creative style, which were negatively related to creative thinking.

Study 6: Role of creative self-efficacy and perceived creativity as predictors of mathematical creative thinking: Mediationg role of computational thinking

In the constantly evolving field of education, mathematical creative thinking has extended beyond traditional boundaries, becoming an essential skill across a variety of disciplines such as mathematics and music, art, engineering, and science. According to prior research, incorporating perceived creativity, creative self-efficacy, and computational thinking has the potential to strengthen mathematical creative thinking by enhancing both depth and logic (Israel-Fishelson & Hershkovitz, 2022).

Together, these factors not only deepen the understanding of mathematical creative thinking but also emphasize its significance in preparing individuals for the diverse challenges of today's dynamic world. To address this gap, this study, therefore, investigates the predictors of mathematical creative thinking among secondary school students in Indonesia (Suherman & Vidákovich, 2024c).

The study involved 896 secondary school students who participated by completing both a test and a questionnaire. In addition, the students provided personal background information. The findings reveal that creative self-efficacy has a strong positive correlation with both computational thinking and perceived creativity, with significant path coefficients, indicating that higher levels of creative self-belief boost computational thinking and perceived creativity. Furthermore, while perceived creativity positively influences computational thinking, it only

has a marginal effect on students' creative performance on the mathematical test, suggesting a more indirect relationship.

In terms of student performance, there were notable differences based on gender, grade level, school type, location, and ethnicity. Female students demonstrated slightly higher performance across all variables, while 9th-grade students scored the highest in computational thinking, creative self-efficacy, and perceived creativity. Private school students outperformed those in public schools, and students from urban areas generally had better scores than those from districts. Ethnic differences also emerged, with Batak students showing the most variability in their creative thinking test performance, while Minang students scored the lowest on the mathematical test.

Conclusions

Based on the six studies, the research provides comprehensive insights that directly address the overarching research questions of this dissertation. First, regarding RQ1**,** the systematic review revealed that most mathematical creative thinking assessments have been implemented at the secondary level, especially in grades 7 and 8, using open-ended questions as the most frequent tool. Geometry and measurement emerged as the dominant topics, though the psychometric rigor of these tools remains underdeveloped, with less than half of the studies reporting validity and reliability evidence. For RQ2**,** the adaptation of the attitudes toward mathematics inventory demonstrated that a culturally responsive and psychometrically sound instrument can indeed be developed for the Indonesian context, offering valid and reliable measurement across enjoyment, self-perception, value, and perceived achievement. Regarding RQ3**,** the integration of local culture through ethnomathematics specifically using Tapis Lampung patterns, has proven effective in capturing diverse expressions of mathematical creative thinking, bridging local and formal knowledge, and reinforcing cultural relevance in assessment.

In terms of individual and contextual factors, the results from RQ4–RQ6 highlight the complex interplay of psychosocial and cognitive dimensions. Attitude and ethnic identity showed a mutually reinforcing relationship in predicting mathematical creative thinking, with ethnic identity mediating the influence of attitude (RQ4). The study on RQ5 expanded this by including creative style and parental education, revealing that while creative style had minimal impact, fathers' education and ethnic identity were significant predictors, especially for 9th-grade students. Finally, addressing RQ6, the inclusion of creative self-efficacy, perceived creativity, and computational thinking offered a novel perspective. Computational thinking emerged as a key mediating variable, linking self-efficacy and perceived creativity to creative performance in mathematics.

Importantly, the novelty of this dissertation lies in its multi-dimensional and culturally grounded framework for understanding mathematical creative thinking in the Indonesian context. By integrating psychological constructs (attitude, creative self-efficacy, perceived creativity), sociocultural factors (ethnic identity, parental education), and cognitive dimensions (computational thinking, creative style), this research uniquely bridges cognitive science, cultural relevance, and educational practice**.** While prior studies often treated these variables in isolation, this dissertation uncovers the complex interactions between them using advanced methods such as SEM and Rasch analysis across diverse student populations. This integrative approach not only fills methodological and contextual gaps in the literature but also offers a novel culturally responsive model for assessing and fostering mathematical creative thinking—an area that remains underdeveloped, particularly in Southeast Asian educational research.

Implications

The implications of this study emphasize the importance of developing culturally relevant assessment tools for measuring mathematical creative thinking, particularly within the Indonesian context. The validation of an ethnomathematics-based test highlights the need for more inclusive and context-sensitive approaches to evaluating creativity in mathematics. By integrating local cultural elements and considering factors such as ethnicity, parental education, and attitudes toward mathematics, educators can create more engaging and effective learning environments. This research suggests that such adaptations are essential not only for improving students' mathematical creativity but also for fostering a positive attitude toward learning and overcoming cultural barriers in education. Teachers can use these insights to personalize their teaching methods, supporting diverse student needs and backgrounds.

Additionally, the study provides valuable guidance for policymakers and educators in enhancing the mathematics curriculum to focus on creativity and critical thinking. The identification of factors such as computational thinking, creative style, and parental involvement further underscores the complexity of academic achievement in mathematics. Incorporating these elements into curricula can help bridge the gap between theoretical knowledge and real-world problem-solving skills. The findings suggest that providing professional development for teachers on creative teaching strategies and promoting a supportive, inclusive atmosphere could significantly improve student outcomes. These efforts will better prepare students to face the challenges of the 21st century by fostering the necessary skills in mathematics and beyond.

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