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

DOCTORAL DISSERTATION

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CHAPTER I. INTRODUCTION

1.1. The Insight of Mathematical Creative Thinking

In contemporary education, creativity has become a central focus for educators and researchers, especially in response to the rapid technological advancements of the 21st century. These advancements have significantly transformed how individuals live, work, and think, reshaping creative processes in the process (Borodina et al., 2019; Suherman & Vidákovich, 2022b). As a result, individuals must cultivate the ability to adapt to unpredictable challenges and devise innovative solutions to real-world problems. Creative thinking, in this context, refers to the ability to explore novel ideas or generate original solutions when solving problems (Suherman & Vidákovich, 2022b). This global shift has elevated creativity to a critical competency, essential for driving innovation and maintaining economic growth (Binkley et al., 2012; Nakano & Wechsler, 2018). However, despite growing recognition of its importance, creativity remains underutilized in educational practice and underexplored in classroom-based research (OECD, 2018).

The need to measure and foster creativity in education is emphasized by Treffinger and Houtz (2003), who argue that quantifying creative thinking enables the identification of individual strengths and helps educators nurture untapped potential. While numerous theoretical frameworks attempt to define and assess creativity (i.e., Andreasen & Ramchandran, 2022; Beghetto & Jaeger, 2022; Beghetto & Kaufman, 2022), empirical research continues to explore how creativity manifests and can be supported in learning environments (Casing & Roble, 2021; Fauzi et al., 2019). In essence, creativity is commonly understood as the capacity to produce novel, original, and contextually appropriate ideas or products (Corazza, 2016). In mathematics education, creative thinking plays a pivotal role in enhancing problem-solving and deepening conceptual understanding. It is often assessed through indicators such as flexibility, originality, and appropriateness (Haylock, 1997). Divergent thinking, characterized by fluency, flexibility, originality, and elaboration, is particularly crucial in fostering mathematical creativity (De Bono, 1991; Guilford, 1967; Suherman & Vidákovich, 2022b). Researchers have further explored the role of fluency, flexibility, and elaboration in mathematical creativity (Gilat & Amit, 2013), emphasizing that students' ability to generate multiple solutions (Kozlowski et al., 2019) and shift between different strategies (Leikin & Lev, 2007; Mann, 2005) enhances their creative problem-solving skills.

Mathematical creative thinking involves the generation of diverse solutions and the evaluation of mathematical ideas from multiple perspectives (Hetzroni et al., 2019). It encourages students to move beyond conventional procedures by applying both divergent and convergent thinking to uncover patterns, explore alternative strategies, and make meaningful connections between concepts (Bolden et al., 2010; Hadar & Tirosh, 2019). Recognizing its importance, researchers have proposed integrating creativity into mathematics curricula through approaches such as visual culture and ethnomathematics, which acknowledge the cultural and contextual dimensions of mathematical learning (Grodoski, 2016; Orey & Rosa, 2007; Rosa & Orey, 2015). Yet, many students still struggle to apply creative mathematical thinking in real-life contexts due to the theoretical nature of traditional curricula (Jones et al., 2018; Shute et al., 2017). In response, curriculum developers have begun embedding creativity into math education to promote relevance, engagement, and problem-based learning (Bicer et al., 2021; Dilekçi & Karatay, 2023; Hadar & Tirosh, 2019; J. Liu et al., 2021; Ogunkunle et al., 2015). Nevertheless, student performance in mathematical creative thinking remains low (PISA, 2024).

Previous research has established a strong link between creative thinking and academic achievement (Akpur, 2020; Jankowska & Karwowski, 2019). As a foundational component of 21st-century skills, creativity enables students to make informed decisions and understand complex cause-and-effect relationships (Basadur et al., 2000). Moreover, various studies have explored how specific individual and contextual factors influence students’ creative thinking, particularly in mathematics. For instance, attitude toward mathematics refers to students' beliefs, feelings, and perceptions regarding the subject, has been shown to correlate with academic performance. A positive attitude enhances learning outcomes, while a negative attitude is associated with reduced motivation, achievement, and interest in STEM fields (Barkatsas et al., 2009; Butler-Barnes et al., 2021; White et al., 2019).

Ethnic identity is another critical factor. Drawing on Social Identity Theory (Hogg, 2016), research indicates that students' sense of belonging to cultural or ethnic groups can significantly influence their educational experiences and engagement. Cultural practices, language, and group-based comparisons can shape how students perceive and perform in mathematics (Zhao et al., 2005). Similarly, creative style, or how individuals approach creative tasks, has been shown to affect problem-solving, innovation, and academic achievement (Chen et al., 2015; Nori et al., 2018; Rodet, 2021).

Parental education also plays a pivotal role. It influences children's academic trajectories by shaping home learning environments and parental involvement (Gil-Hernández, 2019; Mönkediek & Diewald, 2022; Tazouti & Jarlégan, 2019). Parents with higher education levels tend to foster supportive conditions that promote educational success (Davis-Kean et al., 2021). In addition, perceived creativity, or students’ self-belief in their creative potential, has emerged as a key predictor of creative engagement and academic outcomes (Karwowski et al., 2018; Lau et al., 2004; Pretz & Nelson, 2017; Suherman & Vidákovich, 2024c).

A more recent and relevant construct is computational thinking, which includes problem decomposition, abstraction, and logical analysis. Beyond its applications in computer science, it has been linked to improved creative thinking and academic performance in mathematics (Belmar, 2022; Huang et al., 2020; W. Liu et al., 2017; Puente-Díaz & Cavazos-Arroyo, 2017). Together, these factors form a complex interplay of cognitive, affective, and sociocultural influences that shape students’ creative abilities. Together, these factors influences students’ creative potential in mathematics achievement. This integrated perspective not only underscores the need for a holistic approach to fostering creativity in education but also highlights the importance of contextualizing mathematical learning within students’ cultural experiences. Altogether, this conceptual framework, which visually represents how these elements converge to impact student outcomes.

Despite these findings, no large-scale empirical studies have examined the combined influence of these factors on mathematical creative thinking among Indonesian secondary school students. Most prior research has investigated these variables in isolation, offering limited insights into their interrelated effects. To bridge this gap, recent scholars have emphasized the importance of (1) identifying optimal periods for developing creative skills across grade levels, (2) examining the influence of background variables for equitable mathematics education, (3) identifying key determinants of mathematical creativity to inform instruction and teaching strategies, and (4) incorporating contextualized, real-world applications to enhance student engagement and understanding (Hidayatullah & Csíkos, 2023; Hongjia et al., 2018; Soler Pastor et al., 2022; Sujatha & Vinayakan, 2023; Tidikis et al., 2018; Wechsler et al., 2012).

In light of these challenges, this study-based dissertation aims to evaluate the mathematical creative thinking abilities of Indonesian secondary school students using an ethnomathematics-based contextual task. It further seeks to analyze the influence of affective and socioeconomic variables, such as attitude, ethnicity, creative style, parental education, perceived creativity, creative self-efficacy, and computational thinking through structural equation modeling. Before this assessment, a thorough review of current trends in mathematical creativity measurement and test development will be conducted. The assessment instrument is designed to integrate mathematical concepts with local cultural contexts, promoting accessibility and student-centered evaluation. In essence, this research aims to generate practical insights for teachers, curriculum developers, and educational policymakers. By identifying critical influencing factors and focusing on underrepresented student groups, the study seeks to reduce barriers to creative mathematical thinking and improve overall student performance. In doing so, it contributes to the broader goal of cultivating mathematical creativity as a core skill in 21st-century education.

1.2. Mathemaical Creative Thinking: Theoretical Perspectives and Factors Influencing the Indonesian Education Policy Context

The Indonesian curriculum has evolved from 1947 to 2013 to adapt to societal demands and changes. Curriculum, as a framework for education, must be developed dynamically. Currently, the 2013 curriculum (K-13) is in use, with the primary goal of shaping productive, creative, innovative, and empathetic Indonesian citizens through an integrated focus on attitudes, skills, and knowledge. Since its implementation, the Ministry of National Education and Culture has supported teachers in developing their skills, particularly in fostering students' cognitive abilities. In this context, teachers are expected to design assessments that identify mathematical creativity as an essential learning outcome. While the curriculum emphasizes the development of creativity, especially in subjects like mathematics, the way creative thinking is addressed within the Indonesian education system reflects a more integrated and implicit approach.

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. This means that students are not formally taught creative thinking in isolation, 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. This approach aims to foster creativity as an inherent and essential aspect of the learning process, encouraging students to think innovatively, solve problems creatively, and approach their studies with a fresh and imaginative perspective. 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 (Lengkanawati, 2015).

This gap between curricular intention and classroom reality becomes especially evident at the secondary school level, where the importance of creative thinking is critical. 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 (Burkhardt, 2006; Zakaria et al., 2010).

Addressing this issue requires a deeper understanding of how students engage in creative thought during mathematical activities. One area of study focuses on the cognitive processes involved in creative thinking (Suripah & Retnawati, 2019). This research explores what happens in individuals' perceptions when they engage in creative thought. One explanation comes from the concept of insight (Borodina, 2020). Scholars (e.g., (Hadar & Tirosh, 2019; Sternberg & Lubart, 1999) argue that creative thinkers utilize lateral thinking, which allows them to shift flexibly between different ideas rather than strictly following established patterns. Three primary types of thinking are often associated with creativity: lateral, divergent, and convergent-integrative thinking. Lateral thinking is a cognitive process that enables individuals to approach problems from various perspectives and systematically generate new ideas (Hadar & Tirosh, 2019). It also describes specific thought processes (De Bono, 1991). Researchers have identified fluency and flexibility as aspects influenced by lateral thinking (Hilmi & Usdiyana, 2020; Torrance, 1966). Another approach to understanding creative thinking is divergent thinking, which involves generating multiple solutions to open-ended problems (Volle, 2018). Divergent thinking has been proposed as a novel explanation of how the brain functions during creative processes (Nurkaeti et al., 2020). Assessments of divergent thinking typically include measures such as originality, novelty, fluency, flexibility, elaboration, and explanation (De Bono, 1991). By integrating these three cognitive processes, the framework captures the dynamic nature of mathematical creative thinking, illustrating how students shift between different modes of thought to develop original yet structured solutions.

To complement this framework, a third perspective on creative thought is convergent-integrative thinking, which involves identifying key aspects of a problem and determining how they interconnect. This type of thinking enables individuals to recognize relationships, integrate diverse ideas, identify patterns, and establish new connections between previously unrelated concepts (Hadar & Tirosh, 2019). Additionally, convergent thinking is closely linked to content knowledge, logical reasoning, and intelligence.

Given the complexity and importance of these thought processes**,** the need to engage students in creative thinking has been widely emphasized (Lai, 2011). Developing students' mathematical abilities requires nurturing creative thinking skills, particularly through problem-solving tasks that prompt out-of-the-ordinary responses. These responses can be evaluated using indicators such as flexibility, authenticity, and appropriateness (Sitorus, 2016; Suherman & Vidákovich, 2022b). In this context, problem-solving serves as a key method for understanding how students engage with and express creative thinking. However, promoting such skills requires not only effective pedagogical strategies but also cultural relevance.

To effectively support the development of such skills, it is essential to contextualize mathematics education within students' cultural environments. Descriptively, it is essential to teach mathematics in their various cultural settings. These help educational research efforts to incorporate culture into the curriculum, particularly in Indonesia. D'Ambrosio (2007) identified ethnomathematics as a concept that should be incorporated into the curriculum in order to promote creativity and cultural respect in teaching and learning in the difference demographic.

Building on this idea, our research adopts D'Ambrosio's approach to ethnomathematics as a philosophical framework for understanding how culture and mathematics intersect. D'Ambrosio (1985) introduced the term ethnomathematics to represent the study of mathematical concepts and practices as they manifest in the unique contexts of different cultural groups. The possibility of using mathematical modelling as a tool in the context of ethnomathematics has been acknowledged (Rosa & Orey, 2010). Furthermore, we consider that this perspective constitutes a new trend in the pedagogical operations of ethnomathematics of the 21st century.

To deepen this understanding, it is helpful to consider how ethnomathematics encompasses a broad and inclusive definition of mathematical practice. D'Ambrosio (1990) defined ethnomathematics as "The prefix ethno is today accepted as an extensive term that refers to the social-cultural context, and therefore includes language, jargon, and codes of behavior, myths, and symbols. The derivation of mathema is difficult, but it tends to mean explaining, knowing, understanding, and doing activities such as ciphering, measuring, classifying, ordering, inferring, and modeling. The suffix tics is derived from technology and has the same root as art and technique. In this context, ethno refers to groups defined by cultural traditions, codes, symbols, myths, and distinctive modes of reasoning and inference. Thus, mathematics is more than counting, measuring, categorizing, reasoning, and modeling. Ethnomathematics is an area of mathematics that connects cultural anthropology with institutional mathematics (Figure 1). Solve real-world problems using mathematical modeling and transform them into modern mathematical language systems.

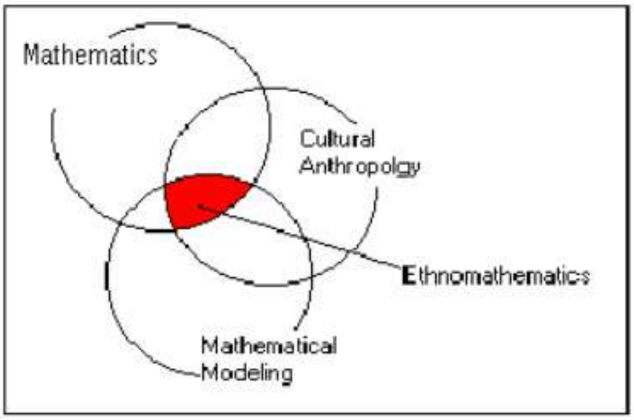

Figure 1. Ethnomathematics as a combination of three fields of study (Rosa & Orey, 2013).

While mathematics is often seen as a universal language, ethnomathematics challenges us to consider its cultural dimensions. Mathematics is often thought of as a universal language, with concepts and principles that are true and applicable regardless of cultural or geographic boundaries (Parker Waller & Flood, 2016). However, the reality is that mathematical knowledge and practices are deeply embedded in specific cultural contexts and can be understood and expressed in a variety of ways. Ethnomathematics is a field that seeks to explore the relationship between mathematics and culture, recognizing the diverse ways in which mathematical knowledge and practices are created, transmitted, and applied in different societies around the world (D'Ambrosio, 1985). In essence, this highlights the complex interplay between mathematics and culture, emphasizing that mathematical concepts and practices are not only universal, but also culturally influenced and expressed in a variety of ways. Ethnomathematics enriches our understanding of these cultural dimensions within the realm of mathematics.

Moreover, ethnomathematics emphasizes creativity and cultural diversity as central components of mathematical exploration. Ethnomathematics is an approach to the study of mathematics that emphasizes the role of creativity in problem-solving and mathematical exploration, with a focus on cultural diversity (Anhalt et al., 2018). It recognizes that mathematical thinking is not just about following established procedures, but also requires the ability to generate new ideas and approaches, to make connections between different concepts, and to explore problems in creative ways. This approach of ethnomathematics can explore the different ways in which people from diverse cultures use creative thinking to solve mathematical problems and engage in mathematical exploration (Johnson et al., 2022; Umbara et al., 2021). It recognizes that cultural context is an important factor in nurturing creativity in mathematics and seeks to identify a unique idea for creative mathematical thinking that exists in different cultural traditions and practices.

Expanding on D'Ambrosio's philosophical foundation, ethnomathematics emphasizes that mathematical reasoning and creativity emerge from culturally situated practices. For instance, traditional geometric patterns in *Tapis Lampung* demonstrate how artistic expression intersects with mathematical rules, revealing the potential of culturally grounded tasks to nurture students' mathematical imagination (Suherman & Vidakovich, 2022). Such examples illustrate how creativity in mathematics can be enhanced through exposure to diverse cultural forms of knowledge.

Beyond the cognitive dimension, ethnomathematics offers a framework for understanding the broader social and educational factors influencing mathematical creativity. Beyond cognitive processes, the framework includes ethnomathematics-based assessment and influencing factors to reflect the broader educational and socio-cultural context in which mathematical creativity develops. The ethnomathematics framework (D'Ambrosio, 1985) supports the idea that mathematics is not a culturally neutral subject but is deeply embedded in students' lived experiences. The inclusion of an ethnomathematics-based test ensures that creative mathematical thinking is assessed in ways that are meaningful and relevant to students' cultural backgrounds, reinforcing Vygotsky (1978) sociocultural theory, which argues that learning is shaped by interaction with one's environment.

This multidimensional framework reflects the interplay between individual, instructional, and socio-cultural factors in fostering creativity. Furthermore, factors influencing mathematical creativity such as cognitive-affective traits, educational settings, and socio-cultural influences are structured hierarchically to reflect their interconnected impact. At the individual level, motivation and prior knowledge are fundamental, aligning with Deci and Ryan (2013) self-determination theory, which emphasizes the role of intrinsic motivation in fostering creativity. At the instructional level, the learning environment and teaching approaches influence students' ability to engage with creative mathematical tasks, consistent with constructivist learning theories (Bruner, 1996; Piaget, 1952; Vygotsky, 1978). Finally, at the macro level, policy and socio-cultural influences establish the broader framework in which mathematical thinking creative is nurtured, ensuring alignment with national educational goals, particularly in contexts like Indonesia, where cultural heritage plays a significant role in shaping learning experiences.

By integrating both top-down and bottom-up perspectives, this framework provides a holistic view of mathematical creative thinking. The hierarchical structure of the framework is intentional, as it reflects the interaction between cognitive processes and external influences in shaping mathematical creative thinking. The top-down influence of socio-cultural and others factors determines the opportunities and constraints within educational settings, which in turn affect individual cognitive and affective factors. Meanwhile, the bottom-up process highlights how students' cognitive abilities and creative potential can be nurtured through appropriate instructional methods and culturally relevant assessments. These framework provides a comprehensive model for understanding and fostering mathematical creative thinking, ensuring that creativity is not viewed in isolation but as a product of cognitive, educational, and cultural dynamics.

Additionally, various affective and cognitive factors influence students' mathematical creativity in significant ways. Mathematical creative thinking skills are significantly impacted by a range of affective factors, including attitude (P.-H. Liu & Niess, 2006), ethnicity (Martinez-Fuentes et al., 2021), creative style (Chen et al., 2015; Rodet, 2021), parents' education (Pugsley & Acar, 2020), perceived creativity (Alt et al., 2023; Goncalo et al., 2010), and creative self-efficacy (Haase et al., 2018; Pretz & Nelson, 2017; Puente-Díaz & Cavazos-Arroyo, 2017), as well as cognitive factors like computational thinking (Hershkovitz et al., 2019; Knochel & Patton, 2015). These elements are important because they collectively shape how students engage with mathematical problems, approach challenges, and generate innovative solutions. Theories like Bandura (1969) social cognitive theory emphasize the role of self-efficacy, where belief in one's abilities enhances motivation and problem-solving capabilities. Vygotsky (1978) socio-cultural theory underscores the influence of social context, including familial and cultural factors, on cognitive development, highlighting the importance of parental education and ethnic background. Additionally, creativity points to the role of creative self-efficacy and perceived creativity in fostering a growth mindset toward innovation (Huang et al., 2020; Israel-Fishelson & Hershkovitz, 2022; Kreitler & Casakin, 2009). Furthermore, computational thinking is an essential skill that is not limited to students in computer science or mathematics fields, but is also crucial for individuals facing the complexities of the 21st century (Li et al., 2020). It can be applied to solve a wide range of problems, even those unrelated to programming (Román-González et al., 2018). Understanding the interplay between these factors can provide research with deeper results into fostering mathematical creative thinking skills. The framework of the creative thinking and cultural is illustrated in Figure 2.

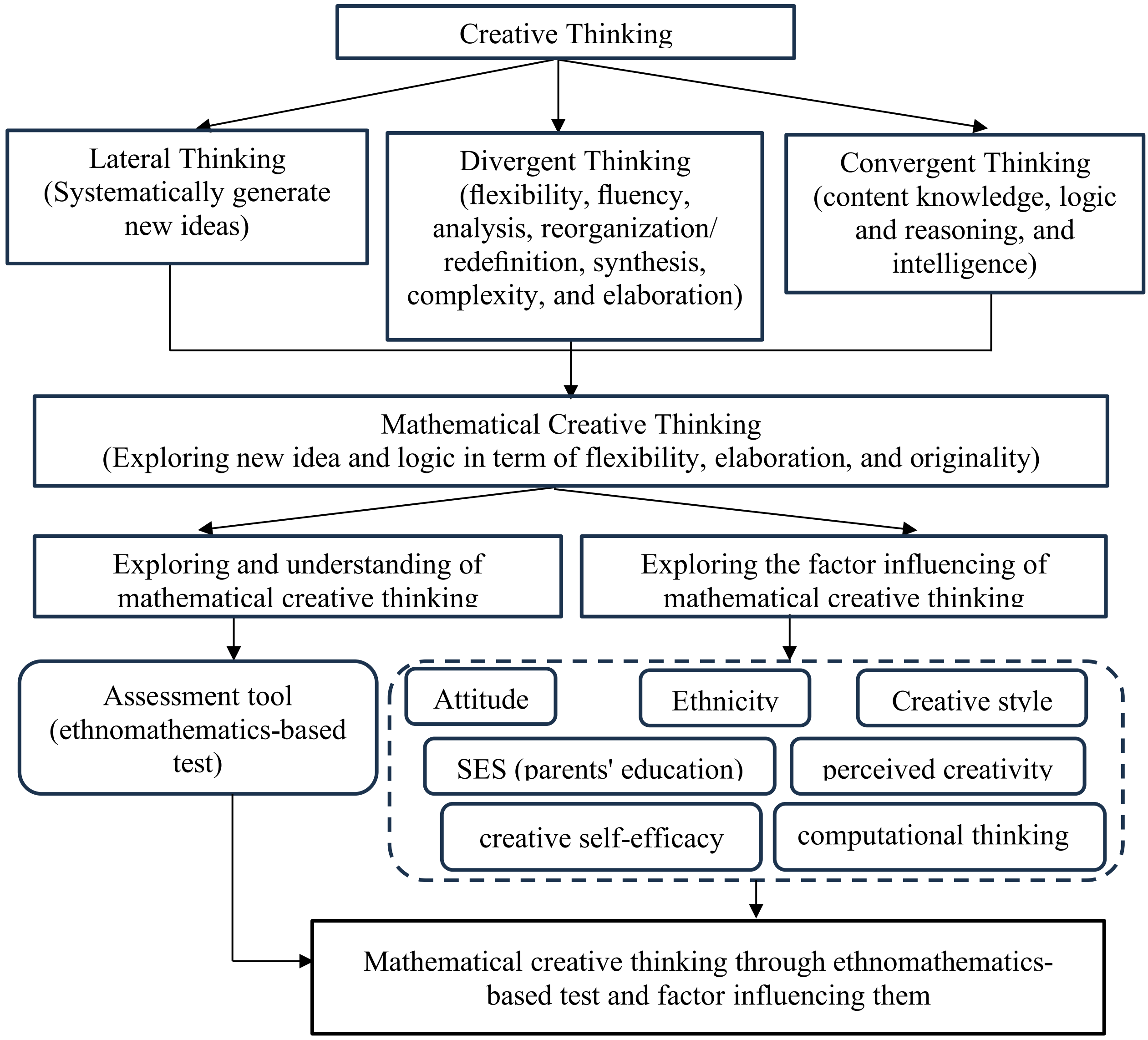

Figure 2. Mathematical Creative Thinking Framework with Influencing Factors and Key Concepts (own elaboration)

In response to these needs, the Indonesian curriculum underscores the importance of creativity in both classroom and real-life contexts. The Indonesian 2013 curriculum (K–13) emphasizes that creativity should be learned and implemented anywhere (in the classroom and in real live); therefore, education should focus on developing creative skills (Ministry of Education and Culture, 2014), including the assessment of mathematical creative thinking and exploring an idea from student' in the classroom. As is the case with creative thinking in mathematics, mathematics is an abstract and formal theory; thus, it must be creatively applied to real-world situations when resolving them (Ferrando et al., 2023). However, the instructional strategy between the educational and teaching levels does not establish the required concept that mathematics should be taught in real world contexts (Ogunkunle et al., 2015). Therefore, students are not taught creative problem-solving strategies relevant to their cultural background. According to research Xu et al. (2022), most of mathematics education in the world is totally based on structural models and algorithms in European content and have applied both realistic modeling and epistemological modeling perspectives.

Recognizing this gap, ethnomathematics offers a culturally relevant framework for fostering mathematical creativity among Indonesian students. In the Indonesian education system, creative thinking is not explicitly taught but rather incorporated into the core curriculum. Mathematical creative thinking has been a subject of growing interest and has received significant research attention (Wang & Chang, 2022; Wu et al., 2022). Ethnomathematics enhances students' understanding and appreciation by linking mathematical concepts to real-world contexts and diverse cultural practices (Orey & Rosa, 2007). The connection between mathematical creative thinking and ethnomathematics lies in the idea that studying and understanding different cultural mathematical practices can stimulate and improve mathematical creative thinking. When individuals are exposed to various mathematical ideas and problem solving methods from various cultural contexts, it can broaden their perspectives and encourage them to think creatively (Suherman & Vidákovich, 2022b) about mathematical concepts (D'Ambrosio & Rosa, 2017).

In addressing this challenge, it is crucial to distinguish between cognitive and non-cognitive (affective) variables that influence students' mathematical creative thinking. Cognitive variables pertain to mental processes such as memory, reasoning, problem-solving, lateral thinking, and divergent or convergent thinking processes that are directly involved in generating and applying mathematical ideas. Theoretical perspectives such as Sternberg and Lubart (1999) investment theory and Guilford (1967) structure-of-intellect model explain how these cognitive processes function as the foundation of creative output. In contrast, non-cognitive or affective variables refer to emotional, social, and motivational factors such as self-efficacy, attitudes, cultural identity, and parental involvement, which influence a student's willingness and capacity to engage in creative mathematical thinking. Theories such as Bandura (1969) social cognitive theory and Deci and Ryan (2013) self-determination theory provide a theoretical foundation for understanding how affective factors shape creativity by influencing motivation, perseverance, and the belief in one's capabilities. Recognizing the interaction between these two domains cognitive and affective is essential to understanding how mathematical creativity develops. Given the multidimensional nature of these influencing factors, it is helpful to conceptualize them in a layered framework that distinguishes between individual, instructional, and societal or cultural levels. This conceptualization allows me to analyze how personal traits (e.g., fluency, flexibility, intrinsic motivation), classroom practices (e.g., problem-based learning), and broader socio-cultural elements (e.g., curriculum design, educational policy, cultural traditions) interact to either support or hinder the development of mathematical creative thinking.

In the Indonesian context, this conceptual framework must be adapted to the unique educational, cultural, and policy environment. The implicit integration of creativity into classroom instruction, the socio-cultural significance of education, and the policy-driven emphasis on high-stakes testing create a complex setting for creativity to emerge. By situating the discussion within this national framework, it becomes possible to explore how these interrelated cognitive and non-cognitive factors function in practice. Therefore, this dissertation aims to offer new insights into achieving the primary goals of creative thinking and mathematics education within the Indonesian context.

1.3. The Present Study

This dissertation follows a study-based format, aiming to evaluate secondary school students' mathematical creative thinking skills and the factors that influencing them. Through an extensive literature review, several research gaps were identified, which served as the foundation for the empirical investigations presented in this dissertation. Firstly, although numerous studies have explored the core of mathematical creative thinking, there is a lack of clarity regarding its applicability and variation within the Indonesian context and across different academic disciplines. Differences in how mathematical creativity is expressed may emerge depending on the cultural and disciplinary context in which it is studied. Additionally, limited research has explored how creative thinking relates to individual factors such as academic discipline, ethnicity, attitude, achievement, etc. Therefore, further investigation into mathematical creative thinking is warranted.

Secondly, at the beginning of the study, the discipline, instruments, topics, and psychometric evaluation of mathematical creative thinking were reviewed following the PRISMA guidelines (Liberati et al., 2009). This led to the identification of key assessments needed to evaluate mathematical creative thinking in educational studies. Mathematical creative thinking was chosen for review, as it is essential for solving mathematical problems and generating new ideas (Hadar & Tirosh, 2019). Additionally, as a critical cognitive skill, it helps students process and apply new ideas or solutions (Sitorus, 2016). The review aimed to identify key assessments currently used in educational studies and revealed a significant gap in the availability of robust and reliable tools for measuring mathematical creative thinking. Despite increasing attention to mathematical creative thinking in mathematics education, systematic reviews on its assessment remain limited. While some studies have employed diagnostic tools to evaluate this construct, there is still a lack of comprehensive, validated instruments, particularly tailored to the educational context. This gap has contributed to uncertainty regarding the most effective approaches for assessing students' mathematical creative thinking skills. In response, this study proposes the development of a new test to address these limitations and provide a more accurate and meaningful assessment tool for educational use.

The following section consists of five empirical studies. The aim of the first study is to psychometrically evaluate a students' attitudes toward mathematics inventory in secondary education. While instrument evaluations have primarily been conducted in Western countries (Fennema & Sherman, 1976; Tapia & Marsh, 2004), we developed this inventory specifically for the Indonesian context. The second empirical study aimed to explore the local culture of the *Tapis Lampung* pattern as a context for ethnomathematics in assessing students' mathematical creative thinking skills. Numerous studies have shown that culture can serve as a transformative medium for exploring mathematical concepts, making mathematics more relatable and meaningful for learners (Fouze & Amit, 2019; Matthews, 2018). Culture also provides a foundation for integrating local knowledge into formal mathematics education. Ethnomathematics has been widely studied around the world, emphasizing its potential to bridge local cultural knowledge with formal mathematical understanding (Peni & Baba, 2019). This approach not only acknowledges and values students' cultural backgrounds but also enhances their comprehension of mathematical concepts by connecting formal learning to culturally rooted, informal knowledge. In this context, the structure of the *Tapis Lampung* pattern serves as a geometric representation of mathematical ideas and illustrates the existence of alternative mathematical forms (Muhammad, 2023; Prahmana & D'Ambrosio, 2020). Accordingly, there is a clear need for a test designed to assess mathematical creative thinking skills within such culturally contextualized frameworks.

The third empirical study is a cross-sectional analysis aimed at examining students' attitudes, ethnicity, and creative mathematical thinking among secondary school students. It provides an in-depth investigation into how the sample's characteristics contribute to differences in mathematical creative thinking skills, while also emphasizing the importance of fostering mathematical creative thinking as a crucial element of a modern, equitable, and effective education system. Nevertheless, there is a lack of information regarding how ethnicity serves as a mediator in the correlation between attitude towards mathematics and mathematical creative thinking. This study seeks to address the limitations of previous similar research (De-La-Peña et al., 2021; Kozlowski & Si, 2019; Martinez-Fuentes et al., 2021; Matsko & Thomas, 2014; Yoon et al., 2015).

The fourth empirical study is also a cross-sectional analysis examining whether factors (i.e., attitude, creative style, and parents' education) impact mathematical creative thinking skills, as suggested by previous research (Cabra & Guerrero, 2022; Chen et al., 2015; De-La-Peña et al., 2021; Karwowski, 2016; Matsko & Thomas, 2014; Pugsley & Acar, 2020; Rudowicz, 2003; Yoon et al., 2015). In this study, these factors are integrated into a new theoretical model and analyzed using SEM. This approach will provide a comprehensive understanding of the direct and indirect relationships among these factors and mathematical creative thinking skills, filling a gap in previous research. Additionally, the study compares the results of several developed models to yield more accurate and robust findings.

The final empirical study explores additional factors (e.g., creative self-efficacy, perceived creativity, and computational thinking) that influence mathematical creative thinking, as indicated by previous research (Alt et al., 2023; Goncalo et al., 2010; Haase et al., 2018; Hershkovitz et al., 2019; Knochel & Patton, 2015; Pretz & Nelson, 2017; Puente-Díaz & Cavazos-Arroyo, 2017). In this study, we validate the model using SEM to compare the results of several theories, with the aim of providing clearer and more meaningful results. Altogether, these elements not only enhance the understanding of mathematical creative thinking, but also emphasize its importance in preparing individuals to tackle the complex challenges of a rapidly changing world.

To accomplish this goal, a review study and five empirical studies were carried out with the following objectives: (1) systematically review studies on the assessment of mathematical creative thinking and to identify key trends, methods, and findings in this area. (2) develop and validate the instruments to assess mathematical creative thinking within the Indonesian context, ensuring cultural relevance and reliability. (3) explore the local culture can be integrated into mathematical creative thinking assessments. (4) investigate the relationship between students' attitudes toward mathematics, ethnicity, and the role of mathematical creative thinking abilities at the secondary school level. (5) examine various noncognitive factors, including attitudes, ethnicity, and other variables, interact and influence students' mathematical creative thinking skills. (6) Analyse the individual and collective influence of perceived creativity, creative self-efficacy, and computational thinking on students' mathematical creative thinking.

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; Knochel & Patton, 2015; Pretz & Nelson, 2017; Puente-Díaz & Cavazos-Arroyo, 2017).

1.4. Main Methodology

1.4.1. General Literature Review

To perform the review, we followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Liberati et al., 2009). The process involved four key steps: (1) identifying relevant topics and searching for studies, (2) screening documents to select essential research, (3) assessing the eligibility of studies, and (4) including documents for analysis, synthesis, and description. To gather relevant references, we conducted a comprehensive search across multiple academic databases, specifically targeting peer-reviewed journal articles. The primary objective was to collect studies on mathematical creative thinking tools, particularly those indexed in major academic repositories. We identified potential research through SCOPUS, ELSEVIER, Web of Science (WoS), ERIC, EBSCO, WILEY, DOAJ, JSTOR, and SAGE. Articles were selected based on predefined inclusion criteria: (1) the presence of keywords such as "mathematical creative thinking" or "creative thinking in mathematics" in the title, abstract, keywords, or main text; (2) written in English; (3) published between 2011 and 2021; (4) available in full-text format; (5) appearing in peer-reviewed journals; and (6) presenting empirical assessment results on creative thinking skills in mathematics. Following the selection and data extraction process, we narrowed down 644 original articles to a final sample of 70 studies focusing on mathematical creative thinking and assessment tools. The selected articles were analyzed based on specific recorded keywords, including (1) authors and publication year, (2) creative thinking indicators, (3) title, (4) diagnostic tools/instruments, and (5) key findings. This structured approach ensured a comprehensive and systematic evaluation of research on mathematical creative thinking and its assessment.

1.4.2. Participant of the Main Study

The study's population consists of secondary school students (grades 7 to 9) from both public and private schools in Lampung Province, Indonesia. The students were selected from a range of rural and urban areas, representing various ethnic groups such as Javanese, Lampung, Sundanese, Manado, and Padang, among others. A total of 896 students participated in the main study, which was conducted with a 95% confidence level and a 2.9% margin of error. The sample was randomly selected. This dissertation includes three distinct sample sizes. For the pilot study (Studies 2 and 3), which aimed to assess the psychometric properties of the developed tests and questionnaire, a convenient sampling method was employed. In contrast, the main study (Studies 4 and 6), which focused on examining the development, differences, and factors influencing mathematical creative thinking skills, utilized a random sampling approach. Table 1 provides details on the number of participants in each study.

Table 1
General methodology of an empircal study.

Aims	Timeline	Participants	Instruments & Procedures	Analyses
Validate an attitude toward mathematics inventory	July to August 2021	Grades 7-9 (*n* = 502)	Online questionnaire, with items and background questionnaire (Google form). Total time is 20 min.	CFA, reliability (Cronbach's alpha and composite reliability), convergent validity (Fornell–Lacker Criterion), discriminant validity ($HTMT_{0.90}$
Validate ethnomathematics-based test.	September-November 2021	Grades 7-9 (*n* = 157)	Online test (Google form) Total time is 90 min.	Rasch analysis
Investigate Tapis Patterns in the Context of Ethnomathematics	December 2021	Grades 7-9 (*n* = 157)	Online test (Google form) Total time is 90 min.	Rasch analysis
Investigate factors influencing mathematical creative thinking skills	August-October 2022	Grades 7-9 (*n* = 896)	1st day: 2 hours (using an ethnomathematics test) 2nd day: 40 min (using items and background questionnaire)	Descriptive statistics, correlation, multiple regression, and SEM (Path analysis)

1.4.3. Instruments

Ethnomathematics-based test. This instruments consisted of an open-ended test and a background questionnaire (Suherman & Vidákovich, 2021). The background questionnaire covered demographic information (e.g., gender, grade level, ethnicity, school category, and students' living area), while the instruments test were evaluated by expert with 20 items of mathematical creative thinking-based ethnomathematics. Tapis Lampung is used as an ethnomathematics context in the current study in the test. These test items assess fluency, flexibility, originality, and elaboration. Regarding the item domain, the ethnomathematical test includes both a figural (9 items) and a verbal (11 items) domain. The figural test focuses on image creation, in which a participant begins with a basic shape and builds upon it to create a picture, and picture completion, in which a participant is asked to be drawing for complete and incomplete pictures. Additionally, the verbal test is presented in this study. For instance, guessing requires a participant to identify plausible causes for a shown action, product improvement requires a person to make adjustments/write what they see in the picture, and unexpected uses requires a participant to consider numerous alternative uses of an ordinary object (Kaufman et al., 2008). In this study, several questionnaires were used. The attitude toward mathematics scale consisted of 26 items, which were divided into four subscales: self-perception of mathematics, value of mathematics, enjoyment of mathematics, and perceived mathematics achievement. The ethnic identity inventory included 19 items, categorized into three subscales: affirmation of belonging, achievement of ethnic identity, and ethnic belonging. The creative style inventory comprised eight subtests with 57 items, covering creativity capacity, belief in the unconscious, use of techniques, use of other people, final product orientation, environmental control/behavioral self-regulation, superstition, and use of the senses. The perceived creativity questionnaire included six items, and the creative self-efficacy questionnaire also contained six items. Finally, a computational thinking questionnaire was used, consisting of five items.

1.4.4. General Procedure

Before the main study was conducted, the ethnomathematics test and questionnaire, designed to assess factors influencing mathematical creative thinking, were developed. The original questionnaire was developed in English, but since all participants in the study were native Indonesian speakers and English was their second language, the questionnaire was translated into Indonesian to ensure better understanding. This translation was aimed at enhancing the questionnaire's validity. To further ensure accuracy, three Ph.D. candidates from the UK, US, and Australia, who had expertise in mathematics education and linguistics, translated the Indonesian version back into English. The revised English version was thoroughly reviewed, compared, and critiqued. Minor word adjustments were made to clarify any unclear terms. Finally, a pilot version of the questionnaire was created in Indonesia and sent by email to experts in the field, who provided feedback on the validity of the questions and the content. They suggested improvements in wording and phrasing to ensure the items were meaningful and easily understandable. The test instrument was developed. These instruments were then evaluated for content, construct validity, and reliability. Content validity was assessed by experts, while construct validity and reliability were examined using Rasch measurement analysis data from the pilot study.

The data collection for the pilot study took place over the course of one day for each instrument at each school. To conduct the main study, the researcher obtained consent from the institutional review board at the Doctoral School of Education, University of Szeged. Ethical approval was granted in May 2023, with the reference number 6/2023. Additionally, the researcher provided a formal permission letter to conduct the study, which was submitted to the principals of the candidate schools. Schools were required to confirm their participation within one week. Upon receiving confirmation, the researcher worked with the mathematics teachers to arrange the data collection schedule. The main study data collection took two days. The survey was deployed online via a google form test, and a link was sent to the students and their teachers via email or social media application. Under the guidance of their teachers, the participants responded to the test within 120 min, used 40 min to fill out the questionnaire, and their responses were delivered via the link. The data were recorded anonymously and privately and will be available for data analysis.

1.4.5. General Data Analysis

The instrument test was analyzed using Rasch statistical tools for data analysis. The total scores of the students were transformed into interval data on the log-odd unit scale (logits), covering a range from negative to positive infinity. Winstep software was used for the Rasch measurement analysis. The analysis procedures included various techniques, such as item-person mapping, model fit analysis, the Wright map, and reliability and validity analyses. For the questionnaire, exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) were conducted, along with construct validity assessments using convergent and discriminant validity. Reliability was assessed using internal consistency (Cronbach's alpha, Crbα) and composite reliability (McDonald's coefficient omega, ω). For the main study, structural equation modeling (SEM) was applied. Additionally, following the assessment of student performance, multivariate analysis of variance (MANOVA) was conducted. Statistical analyses were performed using SPSS, Winstep, and the R package.

1.5. The Structure of the Dissertation

The dissertation consists of three chapters: a general introduction, a review and empirical studies, and a discussion and conclusions. Chapter I provides an overview of the study, including its definition, research gaps, significance, and core essence. It also outlines the theoretical and educational policy in Indonesia contexts related to mathematical creative thinking skills and factor influencing them, the aims of the dissertation, and the structure of the dissertation, and general methodology of the empirical studies.

Chapter II covering the review and empirical studies. Study 1 presents a systematic review conducted to examine how mathematical creative thinking has been assessed in the existing literature. This review focuses on identifying the methods, tools, and approaches used in evaluating creative mathematical thinking, highlighting trends and gaps in current assessment practices. The study emphasizes that incorporating creative thinking in mathematics assessments, particularly through ethnomathematics based on creative thinking, can contribute to expanding the literature. This study was published in the *Thinking Skills and Creativity* journal (Suherman & Vidákovich, 2022b).

Following the literature review, the subsequent empirical studies (Studies 2 through 6) build on these findings by addressing the identified gaps, particularly the need for contextually appropriate assessment tools. Recognizing that students' attitudes toward mathematics significantly influence their learning outcomes, especially in secondary education. Study 2 focused on adapting an instrument known as the attitude toward mathematics questionnaire for use in Indonesia. Since, the lack of assessments to evaluate students' attitudes toward mathematics, coupled with the limited popularity of such assessments, may be attributed to the fact that most studies have relied on samples from western countries. Therefore, a culturally diverse sample is needed to explore the characteristics of students' attitudes more comprehensively. Data were collected from a sample of secondary school students in several Indonesian schools, and reliability and validity analyses were performed on the adapted questionnaire. The validity of the model's four-factor structure was evaluated using confirmatory factor analysis (CFA). Reliability values for the four subscales both consistency reliability using Crbα and composite reliability using ω are approved. The results of this study were published in *Pedagogika* (Suherman & Vidákovich, 2022a). The development of the ethnomathematics based test has been presented in the *ONK* conference (Suherman & Vidákovich, 2022c) and published in the Journal of Creativity (Suherman & Vidákovich, 2025).

Building on this work, Study 3 explored the local culture of Indonesia, specifically the Tapis Lampung pattern, as a context for mathematics teaching aimed at assessing students' creative thinking. The Tapis Lampung pattern, which is discussed in the literature review, represents geometric concepts rooted in the indigenous culture of Lampung. The study's findings demonstrated that the Tapis Lampung pattern can indeed be expressed through mathematical representations. To analyze the test items, Rasch modeling was employed to assess item difficulty and examine how students from different demographic backgrounds approached the tasks in relation to their mathematical creative thinking. This study, which positions Tapis Lampung as a valuable ethnomathematics resource, was published in the *Mathematics Teaching and Research Journal Journal* (Suherman & Vidakovich, 2022).

After conducting a literature review and developing several instruments, I applied these tools to evaluate students' mathematical creative thinking and relevant personal factors, as discussed in earlier sections. Building on this foundation, Study 4 had to explores the relationship between attitude and ethnicity in predicting mathematical creative thinking. Using a cross-sectional methodology and path analysis, this study highlights how attitudes and ethnic backgrounds contribute to improved idea generation and academic performance in mathematical creative thinking. The findings revealed that ethnicity and attitude are significant factors in promoting creativity in mathematics, suggesting that having a positive attitude and a positive ethnic identity are crucial elements in the development of mathematical creative thinking. This study has been published in the *Thinking Skills and Creativity* journal (Suherman & Vidákovich, 2024b).

While Study 4 identified two key predictors, further exploration was needed to understand how these and additional factors interact in shaping creative mathematical thought. To address this gap, Study 5 was designed to focus on research highlighting the importance of various factors influencing students' mathematical creative thinking abilities However, the combined and interactive effects of these factors have not been thoroughly explored. This study investigates the correlation between attitude, ethnic identity, creative style, parental educational background, and mathematical creative thinking. In this cross-sectional study, SEM analysis was conducted to examine how these variables influenced mathematical creative thinking. The results revealed that a positive attitude toward mathematics was associated with higher levels of fluency, flexibility, and originality in creative thinking, while a strong ethnic identity was linked to increased flexibility. Although creative style and parental education initially showed a negative correlation with overall creativity, this relationship became positive when examined across different grade levels. Notably, students' attitude toward mathematics served as a mediator, influencing how parental education impacted their creativity. Additionally, the students' performance across the four creative thinking tests was visualized using violin plots in R Studio, grouped by grade level. The study had currently published in the *Revista de Educación a Distancia (RED)* (Suherman & Vidákovich, 2024a).

Following this investigation into multifactor influences, Study 6 expands the scope further by integrating creative thinking with computational thinking, emphasizing the importance of psychological perceptions in fostering mathematical creativity. Study 6 highlights that cultivating mathematical creative thinking is essential for addressing both mathematical challenges and real-world problems, including those requiring computational thinking. It emphasizes the importance of students recognizing their creative self-efficacy and perceived creativity in solving unconventional problems. Using structural equation modeling, this study investigates these factors and examines students' performance across variables using density plots in R Studio. The results of the study revealed that there was a positive association between creative self-efficacy, perceived creativity, and mathematical creative thinking, but a negative association between creative self-efficacy and mathematical creative thinking. In addition, computational thinking played a positive mediating role in the relationship between self-efficacy, perceived creativity, and mathematical creative thinking. This study has been published in *Thinking Skills and Creativity* (Suherman & Vidákovich, 2024c).

Finally, Chapter III is summarizes the key findings, presents the conclusions, and the implications. It offers an overview of the main conclusions drawn from the study, along with the theoretical and practical implications of the findings. The section also addresses the limitations of the research and provides recommendations for future studies to build upon and extend the current work.

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CHAPTER II. REVIEW AND EMPIRICAL STUDIES

Study 1: Assessment of mathematical creative thinking: A systematic review

(Suherman & Vidákovich, 2022b)

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Assessment of mathematical creative thinking: A systematic review

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ABSTRACT

With the increasing attention to mathematical creative thinking (MCT) in mathematics education, there has been a concomitant rise in the need to and interest in investigating how to assess MCT skills. Thus, a systematic review was conducted on how MCT has been assessed in the literature. We reviewed 70 journal articles to analyze specific MCT assessments from four perspectives: educational context, assessment of the familiar mathematics context, measurement tools, and reliability and validity of evidence. We found that (a) additional MCT measurements tools are necessary for secondary and high school levels; (b) the most familiar mathematics context for assessing MCT focuses Aon the curriculum of students according to the class level; (c) tools for assessing MCT often used open-ended questions, interview, multiple-choice, questionnaire, open-ended based on ethnomathematics, and Torrance Test of Creative Thinking (TTCT); and (d) the validity and reliability of the evidence of the MCT assessment tool should be collected and reported in further research. This systematic review identifies research gaps and topics for further research to conceptualize and assess MCT skills. The findings are expected to benefit researchers and teachers, to help them decide the best measurement tool to use in MCT assessment.

1. Introduction

Creative thinking (CT) is essential in solving mathematical problems or generating new ideas (Hadar & Tirosh, 2019). This process involves identifying the latest regular properties of objects and their transformation (Perry & Karpova, 2017). CT can also promote students' learning from their actions and experiences (e.g., events) in novel, personally meaningful manners (Alismail & McGuire, 2015). In addition, CT as a cognitive skill is vital for students to understand that they have processed results of a new idea or solution (Sitorus, 2016). Mathematical CT (MCT) is an essential competence for students and is usually based on either an underlying process or a manifested product. On the basis of the 21st-century framework, creativity can help students' rapidly changing competencies in the world. Consequently, assessments for evaluating MCT ability should be implemented in educational studies. According to Programme for International Student Assessment (PISA), MCT is the competence to engage productively in the learning, evaluation, and improvement of ideas that can result in original, practical solutions (OECD, 2019). Creativity assessment might be regarded as an attempt to identify creative abilities, solutions, synthesis in any area, or characteristics among students to understand their creative strengths and potential (S Kim, Choe & Kaufman, 2019.; Kozlowski, Chamberlin & Mann, 2019). These are the reasons of MCT is essential for students in school.

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The research on mathematics education has promoted the exploration of CT to develop a deep understanding of mathematics concepts (Aizikovitsh-Udi & Cheng, 2015; Hadar & Tirosh, 2019). Some researchers have argued that the essence of mathematics is thinking creatively, not merely arriving at the correct answer (Grégoire, 2016). Because teaching CT in mathematics is difficult and demanding, incorporating CT in specifically designed assessment materials can support teachers and increase the likelihood of student engagement (Ketelhut et al., 2020). As a central resource for teaching and learning, assessment materials provide students with opportunities to engage with the content and new skills (Hadar & Tirosh, 2019).

Many MCT definitions and assessment tools have been used. Researchers have defined MCT as students performing mathematical activities on the presumed nature of the cognitive process. In this manner, MCT is a cognitive process involving processing (Yusnaeni, AD & Zubaidah, 2017). In addition, mathematical creativity is the combining of mathematical ideas, approaches, or techniques in a new manner (Boud, Lawson & Thompson, 2015; Suherman, Vidákovich & Komarudin, 2021). Similarly, CT is generating and constructing arguments and the competence necessary for students (Lucas, Claxton & Spencer, 2013; OECD, 2019). Based on the definition of MCT, our conclusion is that MCT is characterized by creating something new from the results, ideas, descriptions, concepts, experiences, and knowledge related to mathematics that covered fluency, flexibility, originality, and elaboration.

The MCT tool has drawn increasing attention from researchers since Torrance promoted it as the Torrance Test of Creative Thinking (TTCT). The use of CT assessment was recorded as early as the 1960s, in the area of creativity research (Bolden, DeLuca, Kukkonen, Roy & Wearing, 2020; Torrance, 1966). Because each student's creativity level may differ, their interests, characters, and degrees of creativity may also differ. Said-Metwaly claimed that an increase in students' interest can be observed in the CT aspect, especially in mathematics, by using the MCT assessment tool (Said-Metwaly, Fernández-Castilla, Kyndt & Van den Noortgate, 2018). Moreover, the justification assessment of creativity was used to establish baseline data useful in diagnosing students' needs and curricula, evaluating efforts for creativity enhancement, assessing creativity efforts for creativity enhancement, and assessing creativity aspects, which are invaluable in explaining creativity functions.

An adapted version of the TTCT encompasses three creative aspects: flexibility, fluency, and originality. Chesimet described fluency as the ability to produce several response ideas to a mathematical question; flexibility as the ability to generate a wide range of ideas and various solutions to a mathematical task; and originality as the ability to produce distinct, personal ideas and solutions to problems (Chesimet, Githua & Ng'eno, 2016).

Some studies have analyzed the work related to MCT assessments using diagnostic tools. The literature has demonstrated that the test instruments effectively measure CT (Hidayat, Susilaningsih & Kurniawan, 2018). However, the diagnostic tools of CT can cognitively achieve the indicator of the fluent, elaborated thinking of students but have not been able to measure the indicator of flexible, original thinking. Sitorus also researched assessment tools. He stated that the CT stage can be assessed by implementing realistic mathematics (Sitorus, 2016) but was not able to measure CT skills. Mathematics activities and tasks asking students to perform a procedure in a routine manner represent an opportunity for student thinking—but this is not CT (Hadar & Tirosh, 2019).

Since its emergence, MCT skills competence has contributed to various fields of research. However, systematic reviews of the MCT assessment's current practice and the assessment have been limited, particularly in mathematics education. Research has demonstrated that the test used has not been oriented to CT skills. In addition, the review of the research revealed a lack of assessment tools in mathematics, making further research on assessing MCT unclear. This study aimed to systematically review studies on the assessment of MCT.

1.1. *Creative thinking*

Individuals engaging in CT use their minds to create a new set of thoughts from a collection of memories containing various ideas, descriptions, concepts, experiences, and knowledge (Gie, 2003). In other words, CT is characterized by the creation of something new from the results ideas, descriptions, concepts, experiences, and knowledge. CT is not only the generating and constructing of ideas but also a competence necessary for students (Lucas et al., 2013; OECD, 2019).

CT refers to the skills used to explore novel ideas or generate solutions while problem-solving. This definition builds on Guilford's division of creativity into eight constructs: flexibility, fluency, novelty, analysis, reorganization, redefinition, synthesis, complexity, and elaboration (Guilford, 1967). Others have proposed variations of Guilford's definition (e.g., Sternberg & Lubart, 1999; Torrance, 1988), and it or a variation of it is frequently used in CT research (e.g., Kadir & Satriawati, 2017; KANİ Ülger, 2016).

One study area concerns the cognitive processes involved in CT (S Suripah & Retnawati, 2019.). This research asks what occurs in individuals' perceptions when they think creatively. One answer is from the perspective of insight (Borodina, 2020). Researchers (e.g., Hadar & Tirosh, 2019; Sternberg & Lubart, 1999) have advocated that creative thinkers employ lateral thinking, in which thoughts jump flexibly from one aspect to another instead of merely following existing paths. Three types of thinking may dominate how creative individuals think: lateral, divergent, and convergent-integrative. Lateral thinking is a part of the cognitive system responsible for operating different perspectives in generating thinking systematically of new ideas (Hadar & Tirosh, 2019), and describe processes (De Bono, 2006). Researchers have defined fluency and flexibility as mediated through lateral thinking (Hilmi & Usdiyana, 2020; Torrance, 1966). Divergent thinking is a second answer to the question about what individuals do when they think creatively (De Bono, 1991). Furthermore, divergent thinking is a novel idea regarding what occurs in individuals brains while thinking creatively (Nurkaeti, Turmudi, Pratiwi, Aryanto & Gumala, 2020). In this area of divergent thinking, students formulate multiple solutions to an open-ended problem (Volle, 2018). Divergent thinking assessment refers to originality, novelty, fluency, flexibility, elaboration, and explanation. A third answer is the description of convergent-integrative thinking in which individuals identify critical elements of a problem and figure out how the pieces fit together. Convergent-integrative thinkers see new relationships, combine different ideas, determine patterns, and form new links between formerly disparate entities (Hadar & Tirosh, 2019). In addition, convergent thinking is a skill related to content knowledge, logic and reasoning, and intelligence. The areas of lateral thinking, divergent thinking, and convergence thinking are presented in Fig. 1.

In its application, divergent thinking criteria develop and follow the field of study (scope) of CT skills. For example, mathematics emphasizes four aspects: fluency, novelty, flexibility, and originality (Beghetto, 2017; Kozlowski et al., 2019; Leikin & Lev, 2007).

1.2. Mathematical creative thinking

The importance of engaging students in CT is widely recognized (Lai, 2011). Therefore, the program education goals of many countries promote MCT to develop the next generation of innovators. For example, the new 2013 curriculum (K–13) in Indonesia includes a focus on "critical and creative thinking" for problem-solving in the mathematics curriculum as a national goal for education (Kemendikbud, 2017).

CT in mathematics is needed to develop students' abilities. It can be understood by focusing on the responses of problem-solving students with out-of-the-ordinary thought processes and examining divergent production by determining the criteria of results through MCT indicators namely, flexibility, authenticity, and appropriateness (Haylock, 1997). Thus, problem-solving can be an approach to understanding the MCT abilities of students.

Some research reviews have suggested that MCT includes skills to answer mathematical problems and assess students' ideas of the concept (Hetzroni, Agada & Leikin, 2019a). MCT relates to divergent and convergent thinking; problem finding; problem-solving; observing new relationships; and making associations among techniques, ideas, and application areas (Hadar & Tirosh, 2019). As a result, Haylock said that CT almost always involves flexibility and demonstrated criteria per the Torrance Test type for creativity (CT products), namely, the number of acceptable responses, the number of types of responses, and the statistical infrequency of the responses in relation to the peer group (Haylock, 1997). Thus, students with different abilities and backgrounds will have the ability to answer problems per their abilities.

Researchers have applied the concepts of fluency, flexibility, elaboration, and originality to MCT (Nufus, Duskri & Kuala, 2018; Sahliawati & Nurlaelah, 2020) and the concepts of fluency, flexibility, and elaboration to mathematics CT (Gilat & Amit, 2013; Huljannah, Sa & Qohar, 2018). Fluency refers to mathematical creativity, namely, the ability to conceive multiple solutions (Kozlowski et al., 2019). Another perspective of creative mathematical thinking is flexibility (Leikin & Lev, 2007; Mann, 2005), namely, the ability to change thinking paths when encountering an impasse or thinking obstruction (Krutetskii, 1976; Leikin & Lev, 2007). Originality is also cited as novel, because it is associated with the ability of individuals to seek out an answer path that is particularly distinctive and uncommon for their information level (Siswono, 2011) and then create a solution to and novel ideas (Kozlowski et al., 2019). Last, elaboration describes the ability to allow in-depth reasoning behind an answer path (H Kim, Cho* & Ahn, 2004.).

1.3. Mathematical creative thinking assessment

Assessment plays a critical role when educators introduce MCT into teaching and learning in classrooms and teachers have more discussions on how to assess students' mastery of MCT skills in their real-life situations. In this systematic review, we categorized MCT assessment by referring to paradigms of assessment methods or tools in the literature. Some MCT studies have employed a selected-response test or a constructed test (e.g. studies have developed a paper-and-pencil test to assess students' MCT skills (Butler, 2018), a multiple-choice test as an assessment of MCT to assess algebra expression concepts (Tabach & Friedlander, 2017a), and open-ended questions to assess students' application of MCT skills in mathematical problem-solving). The open-ended approach based on ethnomathematics are another commonly used assessment tool. Numerous research have created tool for open-ended approach based on an ethnomathematical assessment to evaluate students' work and observe their CT process (Faiziyah, Sutama, Sholihah, Wulandari & Yudha, 2020; Zaenuri, Nastiti & Suhito, 2019), namely, the batik motif (patterns that combine lines, shapes, and isen to create a single entity that embodies batik as a whole) content of ethnomathematics and an ethnomathematics that allows users to build concepts of geometry material. In these tool phenomena, using another landscape of ethnomathematics content, for example, a tapis motif (pattern that covers a variety of line elements, such as straight lines, curves, zigzags, spirals, and various shapes such as triangles, rectangles, circles, kites, and regular polygons) is important to assess MCT in the mathematics concept perspective. Interviews and questionnaires

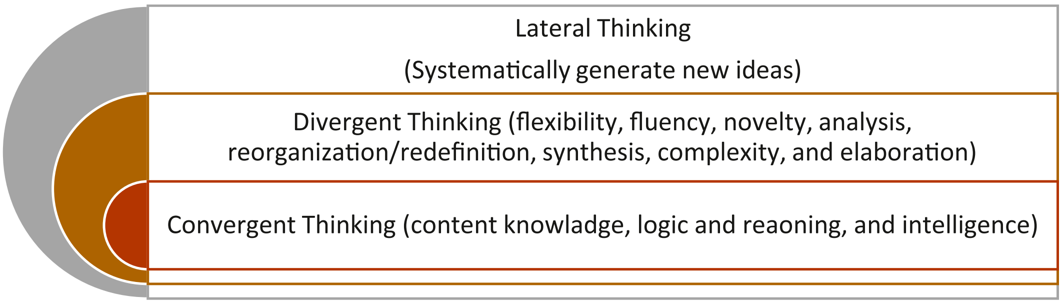

Fig. 1. Model of CT.

have also been used. For example, Istiqomah, Perbowo and Purwanto (2018) used interviews to examine secondary school students' cognitive knowledge of MCT concepts, and Murni, Bernard, Ruqoyyah and Chotimah (2020) designed a questionnaire to support students' final project in MCT. The TTCT has been used to explore mathematics solutions and thinking concepts: divergent thinking and convergent thinking (Ülger, 2016).

Researchers have examined the quality of MCT assessment, for instance, the validity and reliability of perception scales for MCT skills. Conducted validity has been designed as a multiple item test with a CT rubric devised by mathematicians and practitioners (Puspitasari & Wahyudin, 2020) that uses a confirmatory factor (Hetzroni, Agada & Leikin, 2019b).

This study aimed to systematically review the MCT measurement tool in more detail than other reviews have regarding CT in teaching and learning perspectives across all educational levels. In other words, we reviewed studies on assessment tools in MCT, what types of mathematical material were measured in those studies, and the validity and reliability of the evidence on MCT instruments (i.e., assessment tools).

Four research questions (RQs) formed the basis of this review:

- RQ1: What are the educational levels to which MCT assessments have been applied?
- RQ2: What are the mathematics contexts for assessing MCT?
- RQ3: What tools were used to measure MCT?
- RQ4: What is the validity and reliability of the evidence that supports assessing MCT?

2. Method

We conducted a systematic, structured literature review, in which we searched widely used, comprehensive digital databases for relevant information on MCT tools. To perform the review, we used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Liberati et al., 2009). The steps used were as follows: we (1) identified the topics and searched for relevant studies; (2) screened documents to identify essential studies; (3) examined eligibility studies; and (4) included the documents of the analyzing, synthesizing, and describing studies Fig. 1. illustrates these steps: this flow diagram provides the information analysis in the stages of the systematic review, showing the PRISMA steps in reviewing articles on CT tools in mathematics.

Regarding the reference type, the original search of several databases was conducted to investigate articles published in scientific journals. Our aim was to obtain data on the CT tools in mathematics content, particularly articles on indexing institutions. Potentially relevant research was identified by SCOPUS, ELSEVIER, WoS, ERIC, EBSCO, WILEY, DOAJ, JSTOR, and SAGE.

To select articles, we applied inclusion criteria: (1) the keywords "mathematical creative thinking" OR "creative thinking in

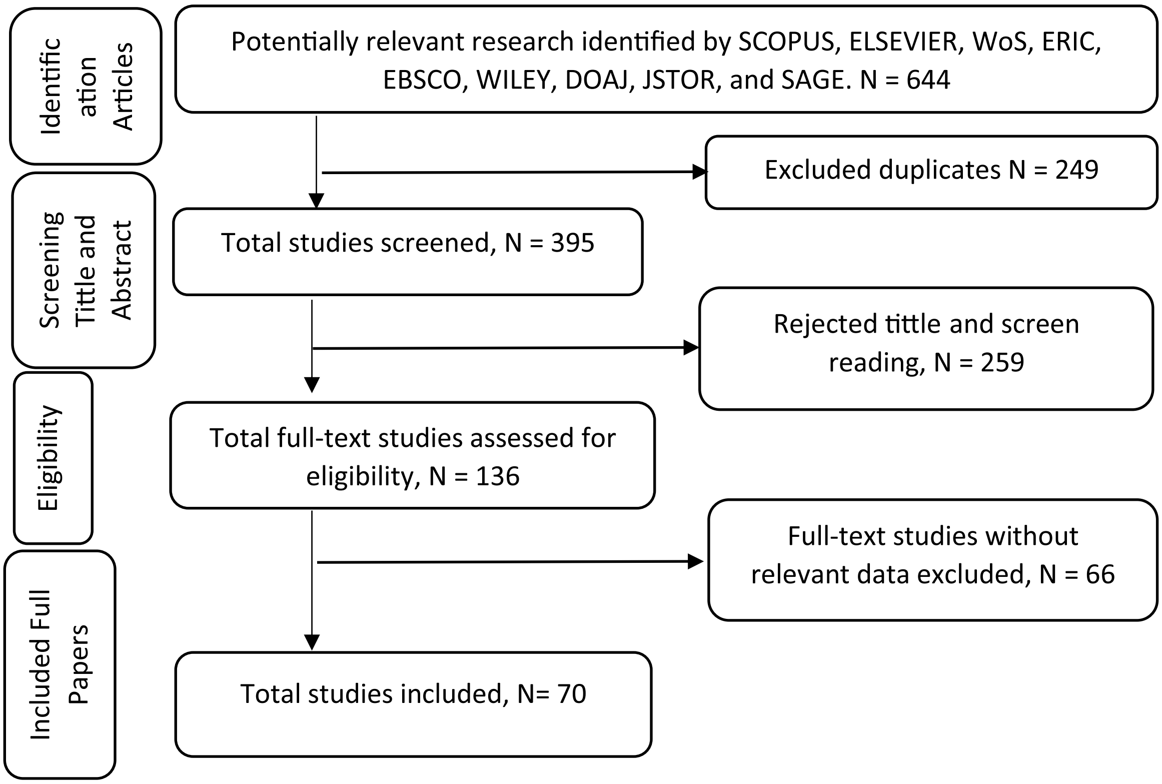

Fig. 2. Stages of the systematic review.

mathematics" in the, for instance, title, abstract and keywords, or main text; (2) written in English; (3) published between 2011 and 2021; (4) available in full text; (5) peer-reviewed journal articles; and (6) assessment results in empirical studies in terms of CT skills in mathematics. We found 644 articles. Next, the author downloaded the selected papers, each article was investigated by first and second authors, and two researchers analyzed and discussed the information.

To collect the articles, the author used articles on the search platform. In the first steps, the first author imported article references by using the EndNote XML format, the PubMed format, or the RIS text format. In this case, the author created a RIS text because this task is easy to perform in Mendeley Reference Management Software. After uploading the references, the system read multiple articles. The second steps are the title and abstract screening. In these stages, first and second authors reviewed titles and abstracts and decided whether to exclude or include an article on the basis of it being related to the research purposes. If the two authors' decisions on whether to include or exclude the article differed, an agreement was achieved by reviewing the article again. The next stage was a full-text review. In the last steps, extraction was conducted. Concerning the final investigation based on the extraction stages from the 644 original articles, the present 70 research studies on MCT and assessment tools. During the review, the selected articles were analyzed by using recorded keywords: (1) authors and publication year, (2) indicators of CT, (3) the tittle, (4) diagnostic tools/instruments, and (5) findings.

Based on the extraction data in Fig. 2, our focus was on the analysis and diagnostic instruments and the type of tests appropriate to assess MCT that were used. In the systematic review, we identified the level covered in the research, from elementary school through post-secondary education. In addition, the material was used primarily in mathematics. Next, a test tool was used to measure MCT, such as open-ended questions, multiple-choice questions, interviews, open-ended questions based on ethnomathematics, and the TTCT.

Bias risk was evaluated based on random sequence generation, disclosure, blinding, blinding the interveners, blinding of results evaluators, incomplete data results, selective data reporting, and other factors (Schuch et al., 2016). In this study, the factor that can be identified is selective reporting, namely, the journals' tendency only to publish articles that are considered significant. Because significant studies were more likely to be included in the systematic review than their unpublished counterparts, there is concern that the systematic review might overestimate the accuracy of the assessment tool (Keen, Blaszczynski & Anjoul, 2017).

3. Results

3.1. *Educational levels of mathematical creative thinking assessments*

A few studies have been conducted to implement MCT across several education levels. The education level for MCT assessment is presented in Table 1; in this table, we observe that 61.43% was from the secondary schools and that the high school and college levels are the levels used most in the studies on MCT tool use, at 20% and 14.29%, respectively. By contrast, in the reviewed study, the education level for MCT assessment was primary school, at 2.86%.

Although some MCT was in basic education programs, we present it also in the context of college to reveal the most recent developments in MCT. In general, studies on MCT assessment focused on elementary, junior, and senior high school. The finding indicates that research on CT, especially related to mathematics, is influential because it encourages students to perform their skills and can be used as a prior foundation to understand the other programs (Hsu, Chang & Hung, 2018).

The grade of the education level has also been demonstrated for MCT assessment. We analyzed several grades in the reviewed studies: the percentage of educational level at just 32.86% in 7th grade. In 8th grade, CT in mathematics assessment were second highest percentege, with 22.86%. However, consistent with the reporting finding, there were many results of MCT for senior high school and college students and, surprisingly, approximately 11.43% in 10th grade and 14.29% in undergraduate, respectively. Although CT was regarded as a critical component in this era (i.e., the 21st century), considerable evidence of the assessment in all levels of education is necessary (Wechsler et al., 2018).

Table 1
Educational levels of the reviewed MCT measurement.

Variables	Categories	Numbers	Percent (%)
Educational Level	Primary Education	2	2.86
	Junior Secondary Education	43	61.43
	Senior Secondary Education	14	20.00
	Primary + Junior Secondary Education	1	1.41
	College	10	14.29
Grade	4th	1	1.43
	6th	1	1.43
	7th	23	32.86
	8th	16	22.86
	9th	5	7.14
	10th	8	11.43
	11th	2	2.82
	12th	3	4.29
	5th and 7th	1	1.43
	Undergraduate	10	14.29

3.2. Familiar mathematics context for assessing mathematical creative thinking

The topic used on the MCT test varied across grade education levels. The sub-topic and subject competency are different from grades 4 to 12. For example, every subject competency was accommodated by The Ministry of Education and Culture, which organizes early childhood education, elementary education, secondary education and community education affairs, and culture management within the Indonesian Government. For the undergraduate level, there is no restriction because every higher educational institution can modify and create its curriculum. The general standard for higher education is provided by the national education department, but every institution or university has the authority to create and implement its educational system. The detailed topics of mathematical items are presented in Table 2.

Mathematical materials commonly used to assess CT are presented in Table 2; in this table, we observe that the mathematical materials from review studies have shown diversity in assessing CT and that the topics of mathematics placed first to be the most misled material was geometry and measurement with 19 concepts, followed by algebra with 10 concepts, number with 8 concepts, and probability and statistics with 1 concept. Hence, the material can facilitate the students in assessing CT from this material by following the applicable curriculum according to the class level (Huizinga, Handelzalts, Nieveen & Voogt, 2014; Taylor, 2013).

3.3. Tools for assessing mathematical creative thinking

In measuring and identifying students' MCT, assessment tools have been used. Examples of measurement tools are open-ended questions, interviews, questionnaires, the TTCT, and open-ended questions based on ethnomathematics. The frequency of each assessment tool is revealed in Fig. 3.

Open-ended tests comprise open-ended questions and are the most widely used tests to assess students' CT skills in mathematics. This test type provides students with the freedom to assume and write their ideas. The highest percentage of the assessment tool of MCT is open-ended to approximately 59% in the level of secondary school. Judging students' results or responses is difficult because students tend to write incomplete answers (Soeharto, Csapó, Sarimanah, Dewi & Sabri, 2019). However, open-ended questions provide flexibility for students to express their creative ideas. This argument was supported by Krosnick, who said that open-ended questions have many advantages, particularly prompting a limitless variety of answers, helping students categorize their ideas, and minimizing the answers given by students (Krosnick, 2018). Conversely, the drawbacks are that open-ended questions require specialized skills for obtaining purposeful answers, interpreting and analyzing student answers can be difficult, biased answers might be submitted if students do not perceive the topic of the question, and some responses might not be useful (Bartholomew, 2017). On open-ended tests, researchers used general questions that had many solutions and allowed students to work in various ways, and the goal were to help develop CT maximally per the abilities of each student.

In addition, we found a literature review that used open-ended questions based on ethnomathematics (e.g., Nuqthy Faiziyah et al., 2020; Zaenuri et al., 2019). An open-ended question can be formulated in several ways to obtain many correct solutions; otherwise, it can be solved in various ways. Students' answers to open-ended questions can be used to observe their CT process. In addition, students with low abilities can explain their thinking patterns in their answers to open-ended questions. Some research stated that mathematics is essential for students but that students often have difficulty learning it. This difficulty occurs because of cultural conflicts, namely, the mismatch between cultures observed inside schools and outside schools or communities (Khalifa, Gooden & Davis, 2016; Ogbu, 1992). Thus, understanding this phenomenon is the link necessary to bridge this problem. Observing the CT in mathematics that involves reality is possible with open-ended integration and ethnomathematics.

Table 2
Mathematics context for assessing CT.

Number	Algebra	Geometry and measurement	Probability and statistics
1 Number	1 Algebra	1 Triangle	1 Probability
2 Ratio	2 Equation	2 Prism	
3 Fraction	3 Functions	3 Pythagoras	
4 Arithmetic operations	4 Trigonometry	4 Pyramid-shaped	
5 Sequence and Series	5 Relational and Functional	5 Cube	
6 Imaginer number	6 Linear Equation	6 Cuboid	
7 Social Arithmetic	7 Algebraic Expressions	7 Circle	
8 Derivative	8 Two-variable linear equations system	8 Parallelogram	
	9 Three-variable linear equation	9 Rectangular	
	10 Matrix	10 Quadrilaterals	
		11 Square	
		12 Angle	
		13 Cone	
		14 Rotation	
		15 Reflection	
		16 Transformation Geometry	
		17 Three-dimension	
		18 Two-dimension	

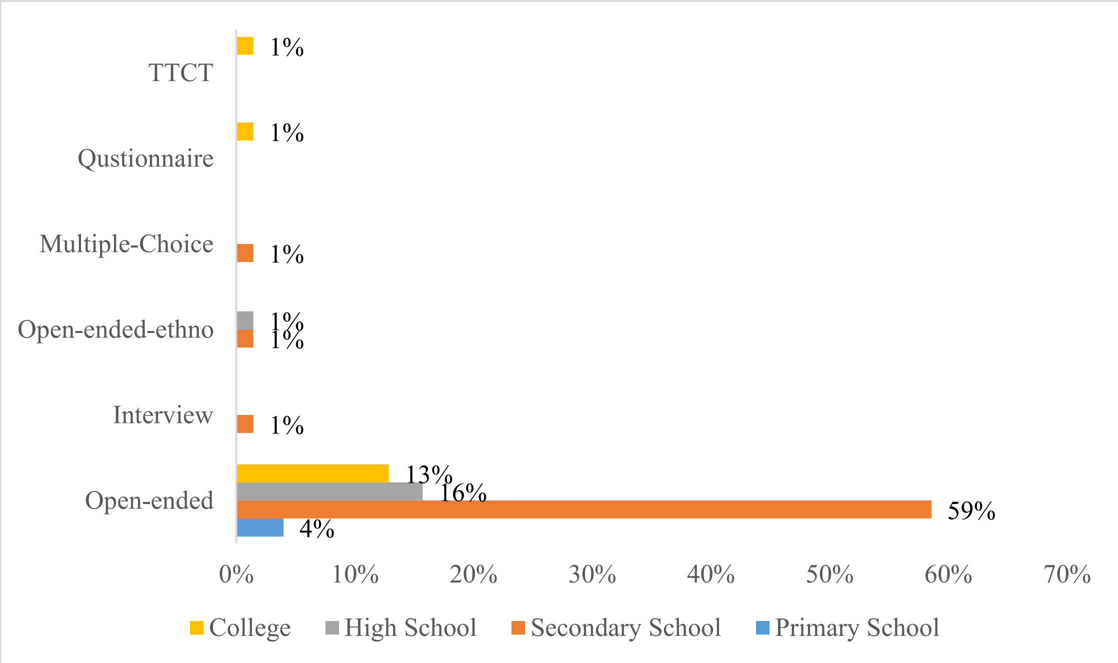

Fig. 3. Distribution of mathematical creative thinking tools used for measurement in the reviewed studies.

Ethnomathematics has cultural elements. It is a procedure to learn and combine the ideas, ways, and techniques used and developed by socioculture or members of different cultures (D'Ambrosio, 2016; Rosa & Orey, 2016). Ethnomathematics attempts to reposition mathematics from the different cultural roots of society so that it can connect to and revive students' critical reasoning and dialogues and so that students become critical reasoners, democratic, and tolerant by embracing cultural differences and seeing them as opportunities for mathematics education (D'Ambrosio, 2016; Prahmana & D'Ambrosio, 2020). Therefore, as a pedagogical innovation in mathematics teaching and learning, ethnomathematics aims to help students achieve in mathematics, become motivated, and improve creativity in performing mathematics.

The integration of ethnomathematics into open-ended problems adds a new nuance in mathematics and culture. Notably, we found in Indonesian society comprises various ethnicities and cultures. That is because we could see the potential of ethnomathematics context in terms of Indonesian context in classifying the rich of cultural characteristics. As aforementioned, approximately 2% of the studies used an open-ended integrated ethnomathematical assessment tool to measure CT in their research at the secondary and high school levels. For example, Zaenuri presented problems in learning by using a cultural context, especially Indonesian artifacts, namely, the Tomb of Kyai Semar, which are related to content on squares and rectangles. In addition, in measuring CT, open-ended questions integrated with ethnomathematics are used (Zaenuri et al., 2019). Furthermore, Indonesian batik motifs as a part of cultural heritage can be used to assess creative mathematical thinking regarding the geometry of transformation chapter (Faiziyah et al., 2020).

Multiple-choice tests as the MCT tool were observed. These tests can be used to assess students' CT in mathematics in large samples, are straightforward to use because they do not rely on complex answers, are often used to determine learning outcomes at the end of each semester and for graduation exams in the Indonesian context, and are used to determine the value that symbolizes the success of students after their participation in the learning process for a certain period. Based on the review results, multiple-choice tests are used because they are easy to manage and score, and conventional paper-and-pencil tests can be used, making it easy for researchers to assess MCT students. A limitation of multiple-choice tests is that they are restricted to the level of basic factual knowledge, whereas constructed-response formats require higher-order thinking. Notably, devising a multiple-choice test that measures CT is easy, although determining if a student is creative is difficult (Butler, 2018).

Researchers used questions with one solution to indicate the CT level. For example, Tabach and Friedlander (2017b) evaluated students' CT in mathematics by using three indicators: originality, fluency, and flexibility. According to the Fig. 3, 1% of the MCT assessment tool was from multiple-choice questions in secondary school.

The assessment of MCT widely uses multiple-choice tests, but these tests have limitations. First, some researchers reduce the use of multiple-choice tests because they do not promote cognitive processes (Yonker, 2011). However, for some researchers, their use of a multiple-choice tool depends on the purpose of the test, including evaluating students' ability in the classroom (Butler, 2018). Second, the feedback provided is usually limited. Hence, there is little scope for the personalization of feedback (Chattopadhyay, 2016). Third, the use of multiple choices is usually driven by the need for efficiency rather than pedagogical principles that aim to encourage effective learning (Nicol, 2007).

Interviews are also used to investigate mathematical thinking in learning outcomes, particularly progress in CT learning. Tests used a specific subject and a different material framework. In the reviewed study, 1% of studies developed interviews that used qualitative items. Notably, some researchers (e.g., Istiqomah, Rochmad & Mulyono, 2017) used the interview to explore detailed information on students' cognitive knowledge. Additionally, the aim of interviews is not to have questions answered but to understand what students think and how they think about a mathematics concept (Skilling, Bobis, Martin, Anderson & Way, 2016).

Questionnaires are a communication medium in which questions are posed to collect respondents' information as answers. Among the reviewed studies, as aforementioned, 1% reported using a questionnaire to assess MCT. The questionnaire typically assessed non-cognitive outcomes, and some researchers used a questionnaire to assess CT skills. For instance, Murni, Bernard, Ruqoyyah and Chotimah (2020) employed a questionnaire to support or elaborate on applying CT knowledge to complete their final project. Although a questionnaire can be used as a tool to measure CT on a large scale quickly, it does not represent visual or procreative components of how students process CT (Van de Oudeweetering & Voogt, 2018).

The Torrance Test of Creative Thinking comprises verbal activities (thinking with words) and figural exercises (thinking with pictures) that showcase students' creative abilities. Torrance developed the TTCT in 1966; it is the most frequently used technique used to measure creativity skills worldwide, has been translated into over 35 languages (Lemons, 2011), and is the most well-known test in creativity. However, the TTCT test is based on only divergent thinking (Vartanian et al., 2020), a thought process used to generate creative ideas by exploring possible solutions (Forthmann et al., 2016). Additionally, Joy Paul Guilford suggested that measuring the ability to think creatively involves two thinking concepts: divergent thinking and convergent thinking (Guilford, 1988). The researchers using the TTCT test to assess CT as a skill used the TTC indicators of fluency, originality, and elaboration.

3.4. Validity and reliability of the evidence of the mathematical creative thinking assessment tool

Concerning the 70 articles, fewer than two fifths (40%) reported the reliability and validity of the evidence; approximately 21% presented the validity of evidence. The reliability of the evidence (i.e., expert judgment reliability) was provided to identify questions, especially for interviews. Expert judgment was used to assess the questions on the basis of the given rubric. If the experts' assessment is insufficient, the result has a flawed decision unless the problem has been revised based on expert advice. Some reviewed studies that employed multiple-choice, open-ended, and questionnaire questions reported that the test's internal consistency was tested by a sample outside of the research to measure the same MCT constructs per the item indicators. In addition, to build good reliability, we found that the TTCT test was used without performing a reliability test. By contrast, they used the TTCT questions tested for reliability with reliability coefficients ranging from.50 to.93; thus, because of the complexity of CT given, the TTCT can be considered as having reasonable reliability for research applications (Treffinger, 1985).

Some studies reported the validity of the evidence (e.g Puspitasari & Wahyudin, 2020.) has been correlated item test with indicator CT rubric, which does by mathematicians and practitioners construct the validity of mathematical creativity by using factor analysis approaches such as confirmatory factor analysis (CFA) to analyze with loading factor value >1.96 (Zainudin & Subali, 2019). Another case emphasized the importance of using data by using validation and triangulation. In addition, several studies stated that in their use of data to assess the validity of a questionnaire's content on CT, perceptions had been reported in the context of a validity index as an acceptable level. In other words, the validity of the content instrument and the validity of the face have also been presented as evidence that the questions were feasible to use (H. R Suripah, 2019.).

As demonstrated before, Zainudin developed 15 test items to measure CT. The measuring instrument has been tested at an average age of 12–15 years old. Each indicator of CT (i.e., fluency, flexibility, and originality) is validated with CFA to determine the sub-items directly. Although evidence of validity and reliability has been provided for CT assessments, most CT assessment tools have insufficient evidence of both. Thus, for researchers, using MCT assessment tools is difficult, especially in high-risk tests if this evidence does not exist.

4. Discussion

Researchers have explored CT, and it is the ability in the 21st century that was most used. This systematic review aimed to assess CT in mathematics, identifying what researchers have discussed and research gaps. Despite our small sample of reviewed studies, this paper contributes to the understanding of CT in mathematical practice. The results demonstrate that MCT tests are available for elementary school through post-secondary school.

First, most research has focused on the end result of CT in learning at the elementary, middle, and college levels. Notably, although researchers find assessing CT difficult in regard to developmental students due to their limited understanding of mathematical concepts (Colmar, Liem, Connor & Martin, 2019), researchers have attempted to explore CT skills and apply cognitive development to them in the early stages in the classroom. However, there is no reason to suggest that primary and secondary schools are the only important stages for students to cultivate ideas in CT, and further research is necessary to enrich and deepen the literature on MCT measurement tools appropriate for primary and secondary school (Jablonka, 2020) and universities. Thus, researchers and practitioners can find appropriate resources for the CT skills development trajectory.

Second, more CT assessments should be developed to understand the process of CT applied in classroom educational contexts. We observed that all tests were designed for specific domains, and most of them used the CT indicators framework and CT indicators such as fluency, flexibility, originality, and elaboration. We also found studies that used a slightly different set of three indicators: fluency, elaboration, and novelty (Istiqomah et al., 2018; Nuha, Waluya & Junaedi, 2018). Fluency refers to mathematical creativity, namely, if the individual produces multiple solutions/ideas (Kozlowski et al., 2019). Regarding its relationship to mathematics, flexibility refers to individuals' ability to change thinking paths when they encounter an impasse or thinking obstruction or to generate different types of solutions/ideas (Krutetskii, 1976; Leikin & Lev, 2007). Inflexible individuals typically continue to pursue a solution path to no avail

(Imai, 2000; Kozlowski et al., 2019).

Additionally, originality has become an indicator of creative mathematical thinking (Beghetto, 2017; Silver, 1997), as it was initially by Chassell (1916), who suggested that originality was an indicator of mathematical creativity. Originality, also cited as novelty, is associated with an individual's ability to seek out an answer path that is particularly distinctive and uncommon solutions/ideas for that individual's information level (Siswono, 2011) and then create a solution and novel ideas (Kozlowski et al., 2019). Last, the indicator of mathematical creativity is elaboration (Imai, 2000). Elaboration describes the ability to allow in-depth reasoning behind an answer path (H Kim et al., 2004.).

Finally, in Indonesia context, the MCT tests are in the scope of certain content knowledge and mathematics subjects. The acquired knowledge from experience is applied to the current situation, helping students generate ideas and solutions. Furthermore, mathematics topics were provided in the curriculum of each education level. On the basis of the result, the test administered the topic from primary school to the undergraduate level for mathematics subjects.

Regarding the review and current search related to MCT conducted by researchers, they have demonstrated that open-ended questions on a test are frequently used as an assessment tool for MCT and that open-ended questions are used as the main instrument (Saputri, Pramudya & Slamet, 2020; Sari, 2019). The researchers also found open-ended questions based on ethnomathematics (Fig. 3) employed to integrate test instruments and produce valuable findings. This finding, namely, using an open-ended test and ethnomathematics to assess MCT, was novel. Thus, the assessment tool combines in mathematics both realistic and cultural aspects, namely, the ethnomathematics used in questions. And an open-ended ethnomathematics test is an appropriate tool to measure MCT.

Some studies presented promising results with a reasonable validity index (all the items are considered valid) and acceptable Cronbach's alpha reliability. That is, the assessment tool was appropriate to use. However, almost half the tests did not present validity and reliability. Presenting validity and reliability as indicators is an essential element of a quality assessment tool. This finding is aimed to assist researchers in developing new MCT instruments. In addition, other researchers preferred an assessment tool that had a validity index and reliability.

4.1. Limitations

This review has limitations. Primarily, the literature reviewed only emphasized using assessment tools to measure MCT, but most research emphasize the final outcome of MCT such as the effect of learning models on MCT skills. Additionally, our review did not focus on the students' intervention. Further, many studies report MCT interventions, but no research addresses MCT, especially in the development of assessment tools at all levels of education. In further research, developing an assessment tool is necessary, especially in an ethnomathematics context.

5. Conclusion

This systematic review assessed MCT measurement tools and identified research gaps and topics for further research in regard to measuring MCT skills. MCT skills improve the quality of education. Thus, this skill should be introduced in the early stages of schooling and focus on educational purposes. The implementation of MCT skills in educational practice can occur in many aspects, especially in assessment. A few studies of Indonesia context focused on MCT test development and used an ethnomathematics context.

In summary, the MCT assessment tools were used and applied to all education levels, especially secondary school students aged 13 – 15 years. Most studies employed open-ended assessments to evaluate MCT skills. The mathematics context was accommodated as a curriculum by the Government in every school. However, teachers are empowered to develop local curriculum-based assessment tools such as combining mathematics and culture, known as ethnomathematics. Finally, a few reviewed articles presented the validity and reliability of the evidence as an MCT assessment. These results might have been observed because MCT assessment is intentionally developed to help students avoid stereotyping and bias (Koch, D'Mello & Sackett, 2015). However, applying CT in mathematics measurement in regard to assessment MCT-based ethnomathematics at the education level may contribute to extending the literature.

6. Authors statement

All listed authors meet the ICMJE criteria. We attest that all authors contributed significantly to the creation of this manuscript, each having fulfilled criteria as established by the ICMJE

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Study 2: Adaptation and validation of students' attituted toward mathematics to Indonesia

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Adaptation and Validation of Students' Attitudes Toward Mathematics to Indonesia

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Annotation. In this study, it is aimed to psychometrically evaluate of students' attitudes toward mathematics inventory in secondary education (ATMSE). The validity of the model's four-factor structure was evaluated using confirmatory factor analysis (CFA). Reliability values for the four subscales ranged between 0.79 and 0.89 both consistency reliability using Crbα and composite reliability using ω. ATMSE is a viable instrument for assessing students' attitudes toward mathematics in Indonesia.

Keywords: *attitudes toward mathematics, confirmatory factor analysis, secondary school students.*

Introduction

The goal of mathematical education is to foster positive attitudes toward mathematics (ATMs). There are concerns about factors that possibly yield achievements and cultural differences in attitude among students. Success in mathematics is based on several influencing factors, such as the characteristics of students (attitude and creativity), students' environment (culture/ethnicity), and teachers. In the last two decades, the relevance of ATM education has been emphasized in systematic research in the context of social psychology under the assumption that affective and cognitive factors play a role in learning mathematics (Dutton, 1951; Hannula et al., 2016). Although attitude study has a lengthy history, there is no clarity on exactly what an attitude is and how an attitude may be identified.

Research on ATM has been conducted extensively, highlighting the close relationship between attitude elements and successful mathematics performance (Davadas & Lay, 2017; de-la-Peña et al., 2021; Karjanto, 2017; Tok, 2015; Van Praag et al., 2015; White et al., 2018). Particularly, Kartowagiran & Manaf (2021) performed an interesting meta-analysis with longitudinal modeling, showing that the positive attitudes of students toward mathematics learning have a significant influence. However, there were sample size limitations; the collected sample did not represent the student population. Moreover, (Barkoukis et al., 2008) showed that the drop-out rate of students correlates with their ATMs.

Lipnevich et al. (2011) studied students' perception of mathematics to predict ATMs achievement and provided data on reliability and validity. Osborne et al. (2003) also showed that pupils' ATMs have economic consequences for their futures, hypothesizing that students who have abandoned mathematics will earn less on the job market than students who did not. However, their study was limited by the lack of an instrument to measure the motivation aspect. Moreover, several scholars have noted that issues about the psychometric impact of evaluation instruments have been raised recently (Fabian et al., 2018; Kiwanuka et al., 2017; Lim & Chapman, 2013; Ren & Smith, 2018; Yáñez-Marquina & Villardón-Gallego, 2016). Further, researchers (e.g., Moliner & Alegre, 2020; Nedaei et al., 2019; Primi et al., 2020) have expressed dissatisfaction with the absence of appropriate instruments for assessing mathematics attitudes.

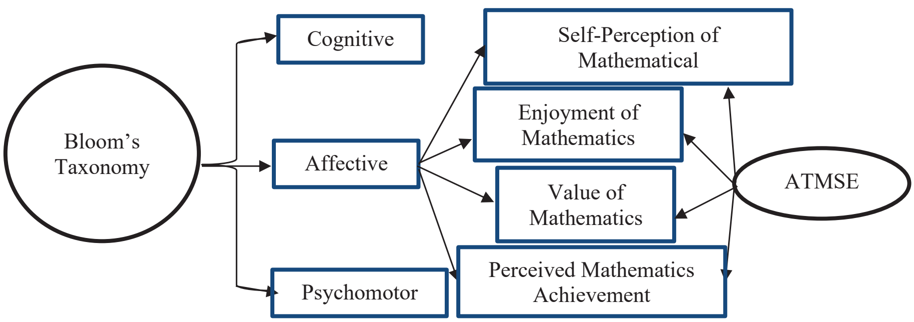
The relevance of developing such instruments is to assess mathematics achievement and personality variables (Tapia, 1996). The rationale for the popularity of Fennema-Sherman mathematics attitudes scales (FSMAS) by Fennema & Sherman (1976) over ATM inventory (ATMI) by Tapia (1996) might be because FSMAS was first developed, and no alternative instrument meant to evaluate mathematics attitudes had been adequately tested for validity and reliability between FSMAS and ATMI creation and testing. Thus, ATMI may require a longer time to achieve popularity than its predecessor. This lack of popularity might also be because only samples from Mexico or US have been used to test ATMI; thus, a culturally diverse sample is required to explore the characteristics of ATMI. 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 ATMI (Tapia, 1996; Tapia & Marsh, 2004)-ATMI in secondary education (ATMSE)-on an Indonesian sample space. Particularly, the major contributions of this study are: (a) adapting an instrument known as the ATMI questionnaire in Indonesia using data collected from a sample of secondary school students from several Indonesian schools and (b) performing reliability and validity analyses on the ATMI questionnaire.

Theoretical Background

The concept of students' attitudes relates to mathematics education and mathematics, which are the basis of success in their learning experiences (Di Martino & Zan, 2010; Reed et al., 2010). There is no doubt that learning has an affective component. The affective domain is related to values, enjoyment, self-perceptions, and attitudes. Bloom (1956) argued in his taxonomy of educational objectives that the affective domain includes how we handle things emotionally, such as feelings, appreciation, values, enjoyment, enthusiasms, and attitudes. The conceptual model of ATMSE is shown in Figure 1.

One commonly used definition of attitudes includes the three components: cognitive, affective, and psychomotor (Bloom, 1956). It is the domain in the Indonesian curriculum where the most precise definitions of objectives can be found, phrased as descriptions of student behavior (Arrafi, 2021).

Figure 1
The Model of ATMSE. Adapted From Bloom (1956)



Self-perception of mathematics

Measuring secondary students' mathematical self-perceptions is crucial because students with low self-esteem may avoid tasks that require mathematics, whereas those who believe they are capable will enroll in additional mathematics courses and demonstrate a greater interest in solving mathematics problems. Students' self-perceptions as learners encompass both their mathematical self-efficacy and self-concept in mathematics. Bandura (1997) and Bandura & Ramachaudran (1994) defined mathematical self-perceptions as follows: self-perception in mathematics is a person's perception of self as a mathematical learner, including beliefs about his/her ability to learn and to perform well in mathematics. Adelson & McCoach (2011) stated that mathematical self-perceptions consider students' "attitudes, feelings, and perceptions" regarding their mathematical abilities. In addition, they stated that mathematical self-perception involves perceptions of a student about his/her ability to learn and do mathematics. Examples of actual items in ATMI are as follows: (1) I am really good at math; (2) Math comes easily to me; and (3) Math is very hard for me.

Value of mathematics

The concept of values and valuing has long been recognized as important in school education, particularly moral education programs, but its importance in the teaching and learning of specific school topics is relatively new. Bishop (1988) introduced the concept of values in mathematics and mathematics education and then expanded it to include progress and control, mystery and openness, rationalism and objectivism, and other concepts. A person's internalized values, regarding convictions, are the things that are important and worthwhile in his/her eyes (Seah, 2018).

In mathematics, value is a belief in the usefulness or inutility of mathematics (Adelson & McCoach, 2011; Tapia & Marsh, 2004). In the above listed concepts, mathematics was referred to as a worthwhile and necessary domain of learning, the desire to improve one's mathematical abilities was expressed, and the importance of mathematics in everyday life and education outside the classroom were recognized. When the average score is approximately 4 or greater, the students are fully aware and convinced of the importance of mathematics, a point is awarded for each item on this subscale, and the total score is used to determine the importance of mathematics in students' lives. Examples of actual items taken from ATMI are: (1) I am good at math; and (2) Mathematics is interesting (Mutohir et al., 2018).

Enjoyment of mathematics

Recent educational research has begun to examine the role of positive emotions in mathematics success. The enjoyment of mathematics reflects the affective dimension of attitude (Kiwanuka et al., 2017). Enjoyment is the positive activating emotion associated with a particular subject that is particularly appealing to an individual (Van der Beek et al., 2017). It has been discovered through extensive research that there is a moderate to strong positive relationship between mathematical pleasure and academic achievement in a subject area. Fisher et al. (2012) discovered a positive concurrent relationship (ranging from 0.39 to 0.63) between preschoolers' mathematics abilities and their early mathematics interest, which included enjoyment. For eighth-grade students, Frenzel et al. (2007) also discovered a positive correlation between mathematics achievement and enjoyment (values ranging from 0.39 to 0.66) in mathematics.

Particularly, the degree to which students enjoy solving mathematics and attending mathematics classes has been measured in terms of the enjoyment of mathematics (Lim & Chapman, 2013; Ma & Kishor, 1997; Thorndike-Christ, 1991). Mathematics enjoyment can be defined as an aggregated measure of one's liking or disliking of mathematics (Palacios et al., 2014; Tapia & Marsh, 2004). This subscale measures how much students enjoyed mathematics, solving new problems, participating in mathematics discussions, and feeling happy in the mathematics classroom. This subscale comprises 12 items used to determine the level of enjoyment that students experience for mathematical concepts and operations. The following are examples of enjoyment items: (1) Doing math is easy for me; and (2) I feel comfortable doing math problems (Palacios et al., 2014).

Perceived mathematics achievement

Perceived competence or achievement in mathematics is essential to promote successful learning. The perception of learning is an integral part of creating, maintaining, and helping pupils to achieve learning objectives. With greater success, the perceived usefulness of mathematics is regarded as the key to achieving what students plan (Liao et al., 2019). Perceived mathematics achievement is defined as students' perceptions of their abilities as learners and their capacity to complete mathematical tasks successfully. This perception may correspond to reality to a greater or lesser extent, but it is a significant source of motivation for students in any case (García et al., 2016). Further, the perceived mathematics achievement is administered to assess perceived mathematics on the part of students' mathematical persistence and subsequent enrollment in future courses (Güner & Çomak, 2014; Tapia, 1996; Thorndike-Christ, 1991). This subscale comprises seven items, which are described in detail below. In the actual inventory, two of these items were found to be true: (1) My friends think that I am successful at Maths; (2) I am sure I will be successful in math class (Yaşar, 2014).

Assessment tools for measuring ATMSE

There have been numerous field reports of assessment tools developed to measure ATMs over the past four decades, e.g., FSMAS (Fennema & Sherman, 1976), ATMI (Tapia, 1996), ATMI in the UAE (Afari, 2013), and Short form of "Mathematics Attitude Scale" (Yaşar, 2014) (see Table 1 for more details).

FSMAS instrument comprises nine scales, each with 12 items. The name of each scale and the dimension it measures include mathematics usefulness as the mother scale, mathematics as a male domain scale, teacher's scale as the father scale, attitude toward success in mathematics scale, confidence in learning mathematics scale, effectance motivation scale in mathematics, and mathematics anxiety scale (Fennema & Sherman, 1976). A 5-point Likert-format instrument used for 10th- and 11th-grade students showed internal consistency reliabilities ranging between 0.86 and 0.93 (Cronbach's alpha) (Fennema & Sherman, 1976). Since the pioneering studies, many researchers focusing on mathematics attitudes have noticed the influence of employing such scales, which were originally intended to evaluate gender-related differences in mathematical achievement among high school students (Liau et al., 2007; Mulhern & Rae, 1998). Recently, some scholars have criticized the psychometric characteristics of assessment tools, which agrees with the criticism of FSMAS (Mulhern & Rae, 1998; Suinn & Edwards, 1982). Mulhern & Rae (1998) argued that rather than the nine scales proposed by the developers of FSMAS, the scales could be reduced to six (i.e., attitude toward success in mathematics, mathematics as a male domain, parents' attitudes, teacher attitudes, mathematics-related effect, and mathematics usefulness). Further, Suinn & Edwards (1982) argued that, although FSMAS is a widely used instrument, research on the reliability or validity of its scales is inadequate.

ATMI is one of the newest instruments in this field, and it measures students' ATMs in various manners (Chamberlin, 2010). Tapia & Marsh (2004) developed ATMI as a cost-effective and efficient alternative to previous mathematics attitudes scales. As originally written, ATMI comprised 49 items based on five scales, including value (Klein, 1985), anxiety (Hauge, 1991; Terwilliger & Titus, 1995), motivation (Dossey, 1994), and confidence (Thorndike-Christ, 1991). According to a 5-point Likert scale, the responses range from "strongly disagree" to "strongly agree" (Tapia, 1996; Tapia & Marsh, 2004). Using data from a high school sample, exploratory factor analysis was performed to combine the confidence and anxiety subscales into a single factor, which resulted in the creation of a single factor. In addition, owing to the subscale's extremely low item-to-total correlation, items on the parent/teacher expectation subscale were eliminated. Their 49-item questionnaire comprised 40 items: 10 enjoyment, 5 motivation, 15 self-confidence, and 10 value items. Cronbach's alpha was high (0.97 with a standard error of measurement of 5.67); therefore, the measurement tool had good internal consistency.

Afari (2013) developed an ATMI questionnaire focusing on students' attitudes toward a subject matter to determine whether they are interested in and motivated by the subject matter. After reading a paper, middle school students from the UAE were asked to rate it on a five-point Likert scale. After being tested using confirmatory factor analysis (CFA), the four factors (40 items) were divided into three factors (36 items): factors 1 (19 items), factor 2 (8 items), and factor 3 (9 items). The reliability of the questionnaire was measured using Cronbach's alpha coefficient, which ranged from 0.811 to 0.924. Yaşar (2014) studied ATMs and discovered that a short form of "Mathematics Attitude Scale" could be used to measure the mathematics attitudes of high school students more accurately using fewer mathematics attitude items. The scale used was a five-point Likert scale with 35 items divided into four categories (i.e., enjoyment; fear, anxiety and distress; place and importance of mathematics in life; and perceived mathematics achievement). Cronbach's alpha reliability coefficient for each scale ranged from 0.82 to 0.89, whereas the general Cronbach's alpha reliability was estimated to be 0.956.

The above findings lend support to the construct validity as a measurement of ATMs. However, there is a paucity of research into mathematics attitudes in Indonesia, particularly in the context of secondary education. Recent studies have revealed that there is an urgent need for research in this area, particularly for students with low and average mathematics achievement abilities (A et al., 2021; Tamur et al., 2020).

Table 1
Instruments of ATM

Study	Instrument	Number of items	Psychometric properties
(Aiken Jr & Dreger, 1961)	Math Attitude Scale	20 items (10 negative attitudes and 10 positive ones)	EFA (for test–retest (N = 310)
(Dutton & Blum, 1968)	Attitudes toward arithmetic with a Likert-type test	27 items between positive and negative feelings about arithmetic	The reliability of the scale by the Spearman–Brown test-retest formula, was 0.84 (N = 346)
(Alken, 1974)	Two scales of ATM (enjoyment/E and value/V)	21 items (Scale: 11 E and 10 V items)	EFA; Cronbach's alphas for E and V scales were 0.95 and 0.85, respectively (N = 190)
(Fennema & Sherman, 1976)	FSMAS	9 scales were developed: the success in mathematics, masculinity, mother (M), father (F), teacher, confidence in learning mathematics, mathematics anxiety, effectance motivation, and mathematics usefulness	EFA Split-half reliability (for the subscales): 0.86–0.93 (N = 1,600)
(Tapia & Marsh, 2004)	ATMI	40 item with 4 scales: 10 enjoyment, 15 self confidence, 5 motivation, and 10 value items	EFA and CFA; Cronbach's alpha for each dimension ranged from 0.88 to 0.95. Cronbach's alpha for the 4 scales was 0.97. Test–retest reliability for each dimension was within 0.70–0.80. Moreover, test–retest reliability for the 4 scales was 0.89 (N = 545)
(Michaels & Forsyth, 1977)	The use of an instrument to measure certain ATMs	4 subscales, including security with mathematics (S), enjoyment of word problems (EW), appreciation of the utility of mathematics (U), and enjoyment of pictorial problems (EP).	EFA Spearman-Brown Reliability: S =.61, U = 0.51, EP =.78, and EW =.78 (N = 299)

Study	Instrument	Number of items	Psychometric properties
(Sandman, 1980)	Mathematics attitude inventory	48 items in 6 subscales: perception of mathematics teachers, anxiety toward mathematics, value of mathematics in society, self-concept in mathematics, enjoyment of mathematics, and motivation in mathematics.	EFA Cronbach's alpha for 6 scales: 0.68–0.89 (N = 5,034)
(Arrebola & Lara, 2010)	ATM for students in compulsory secondary education	37 items divided into 7 factors: 3 positive self-concept, 7 affective component, 5 negative self-concept, 3 cognitive component, 13 behavioral component, 2 expectancy of accomplishment, and 2 demotivation toward the study of mathematics 2 items	EFA and CFA Cronbach's alpha coefficient was 0.923 (N = 236)
(Lim & Chapman, 2013)	A short version of ATMI	There are 19 items in total, divided into four subscales: 5 enjoyment of mathematics, 5 value of mathematics, 4 motivation, and 5 self-confidence in mathematics.	CFA Cronbach's alpha coefficient was 0.93 Test–retest reliability = 0.75 (N = 1,601)
(Yaşar, 2014)	Short form of "Mathematics Attitude Scale"	19 items in total, divided into 4 subscales: 6 enjoyment items, 4 role of mathematics in life items, and 4 perceived mathematics success items, and 5 items each for fear, anxiety, and distress.	EFA and CFA. Cronbach's alpha values for components ranged between 0.82 and 0.89. Cronbach's alpha value for the four-point scale was 0.956 (N = 1,801)

Note: EFA: exploratory factor analysis; CFA: confirmatory factor analysis ATM in Indonesia

Recent research on ATMs has primarily focused on western populations (Liau et al., 2007). As a result of cross-continental generalizations about the relationship between student attitudes and mathematics achievement, there is an urgent need to extend the research to nonwestern societies. Attitude development in Indonesia follows the applicable curriculum, namely the 2013 curriculum. It aims to produce Indonesian students who are productive, creative, innovative, and effective by strengthening integrated attitudes, skills, and knowledge (Kementerian Pendidikan dan Kebudayaan, 2014; A & B, 2022). In this curriculum, students must not only perform well in mathematics but also comprehend and evaluate mathematical concept-based ideas and arguments.

Several prior studies suggest that students who engage in mathematics learning have the potential to be high-performing, that student achievement changes over time with a potential linear trend (Yasin et al., 2020), and that students achieve well on student-perceived mathematics instructional characteristics (Lazarides & Rubach, 2017). A student is expected to take responsibility for his/her learning through a curriculum that inspires confidence and has an impact on the student, thereby increasing the student's ability to engage in active learning (Darling-Hammond, 2017).

According to international assessments conducted by the Program for International Student Assessment (PISA), Indonesian students performed poorly in mathematics compared with students in other countries. PISA comprises basic tests in reading, mathematics, and science that are not based on any national curriculum. The PISA process is widely regarded as having strong legitimacy in describing a country's educational quality. Indonesia has taken part in PISA since 2000. In the most recent PISA iteration, conducted in 2018, Indonesian students ranked 72 out of 78 countries studied in mathematics. Indonesian students have a lower average score than most Organisation for Economic Co-operation and Development countries, particularly in mathematics (Schleicher, 2019). Regarding the data of Trends International Mathematics and Science Study (TIMSS), Indonesia participated between 1999 and 2015. Luschei (2017) examined and interpreted Indonesia's TIMSS results and ATM results. For eighth-grade students, in 1999, Indonesia scored 403. In short, Indonesia achieved a standard deviation of 97% less than the international mathematical average. In 1999, Indonesia ranked 34th out of 38 participating countries in mathematics. The score for mathematical performance increased to 411 in 2003, then decreased to 397 in 2007, and further decreased to 386 in 2011. In 2015, the mathematical performance score increased to 397, whereas the scientific performance score decreased to 397; however, these data come from fourth – instead of eighth-graders and hence difficult to compare with earlier TIMSS rounds.

Luschei (2017) also studied students' ATM and indicated the IEA asked students how much they enjoy or value mathematics in every TIMSS round. These questions usually show that Indonesian students have a high level of mathematical value. About 92% of the students reported "looking a lot" or "loving" mathematics in 1999, and 71% of students in 2003 gave high priority to mathematics. In 2007, the percentage increased to 95%. The IEA changed the matter in 2011 to directly evaluate the value of the students in mathematics, and the percentages declined to 31%, meaning the students valued mathematics. Although TIMSS included fourth-graders in 2015, the IEA did not ask how valuable mathematics was to the fourth-grade students.

Method

Participants

A total of 502 secondary school students, ranging in age from 11 to 15 (mean: M = 13.57, standard deviation: SD = 0.990), participated in the study. The students were randomly selected from 14 different secondary schools in Indonesia and were asked to fill out a questionnaire online (because of the impact of the COVID-19 pandemic period), which took an average of 20 min. to complete. The demographic profile of the participants is presented in Table 2. The data collection was performed from July to August 2021.

Table 2
Demographic Characteristics of the Sample in this Study

Demographic		**Frequency**	**Percentage (%)**
Gender	Girls	193	38.4
	Boys	309	61.6
School Category	Private	185	36.9
	Public	317	63.1
Living Place	City	237	47.2
	District	265	52.8
Ethnicity	Batak	23	4.6
	Betawi	1	0.2
	Bugis	1	0.2
	Java	344	68.5
	Lampung	84	16.7
	Padang	1	0.2
	Sunda	12	2.4
	Others	36	7.2

Note. N = 502; M = 13.57 years of age; SD = 0.99; S.E = 0.04.

Instrument

The ATMSE developed by (Mutohir et al., 2018; Palacios et al., 2014; Yaşar, 2014) was examined through a 34-item questionnaire. In this questionnaire, students were asked to indicate their agreement with each statement by selecting from the following choices for positive items: 1 = Strongly Disagree, 2 = Disagree, 3 = Neither Agree nor Disagree, 4 = Agree, and 5 = Strongly Agree. For negative items, the opposite is the case. All items were composed and adapted based on the four core dimensions of ATM and categorized into four factors: the self-perception of mathematics (8 items), value of mathematics (10 items), enjoyment of mathematics (9 items), and perceived mathematics achievement (7 items). All items constructed were measured independently.

Procedures

The original questionnaire was created in English. Everyone in my study spoke Indonesian as their native language; English was their second language. Thus, the questionnaire was translated into Indonesian to ensure that everyone who speaks Indonesian as a first language could comprehend its contents, and the questionnaire's validity could be improved as a result of the translation. Three Ph.D. candidates in the UK, US, and Australia helped translate the Indonesian version to English again. They all had extensive knowledge in the field of mathematics education and linguistics. Everything about the new English versions was comprehensively examined, contrasted, and criticized. To clarify any ambiguous points, a few minor word choice modifications were requested. Finally, a trial version of the questionnaire was developed in Indonesia and sent via email to some experts in the field, who were asked to comment on the validity of the questions and document content. They offered suggestions on the words and phrases that should be used to describe the items to ensure that they were meaningful and easy to understand.

Data analysis

Analytical procedures followed three steps. First, the data analysis was performed using Mplus 8, and SPSS Version 25.0. CFA was performed to assess the fit of the measurement model (Jomnonkwao & Ratanavaraha, 2016). After the CFA, we used the following goodness of fit indexes to evaluate the model's fit: the chi-square test, comparative fit index (CFI), Tucker–Lewis index (TLI), root mean square error of approximation (RMSEA), standardized root mean square residual (SRMR), and Kaiser–Meyer–Olkin (KMO) index (Kline, 2015). The chi-square statistic, including its degrees of freedom and p-value, is represented mathematically. According to Kline (2015), the chi-square test statistic is highly sensitive to sample size, with statistically significant chi-square values being discovered more frequently when large samples are involved. Therefore, we considered CFI values, which are insensitive to sample size. Its values range from 0 to 1, and a value consistently greater than 0.90 indicates that the model is fit satisfactorily and is acceptable. RMSEA is an absolute fit index scaled as a statistic of poor fit, with zero representing the best result. A good model fit is typically defined as 0.08 or less. SRMR is a measure of absolute fit that can also be used to quantify fit inadequacy. It is a standardized version of the root mean square residual (RMSR), a statistical term that refers to the mean absolute covariance residual in a regression model. RMSR = 0 indicates that the model is perfectly fitted, and increasing values indicate that the model is becoming increasingly unfit. Hence, RMSEA ranging from 0.03 to 0.08 needs to be reported (Hair et al., 2010). The KMO test determines whether the data is appropriate for factor analysis. When factor loadings exceed

0.60, they are considered to be statistically significant. Our findings revealed that factor loadings of 0.80 or greater were considered statistically significant.

Second, after completing the CFA, we looked at Cronbach's alpha and composite reliability to determine the overall reliability of the research. To assess reliability, the internal consistency reliabilities (Crbα; Cronbach's alpha) and composite reliabilities (ω; McDonald's coefficient omega; Raykov (1997)) were calculated. As previously stated by Habók and Magyar (2018), values greater than 0.70 indicate favorable outcomes for empirical research (Habók & Magyar, 2018; Hair et al., 2010). Finally, the construction validity and discriminant validity tests were used to assess the validity of a measurement model's constructs. When evaluating the convergence of a theoretical model, it is important to consider the degree to which the elements of the model are related. When the sum of all factors in a single construct is greater than 0.70, it is considered to be confirmed. In addition, the construct reliability (CR) for each construct should be greater than 0.70, and the average variance extracted (AVE) for each construct should be greater than 0.50, according to the guidelines. Lower values are acceptable only when the CR value is greater than 0.60 (Fornell & Larcker, 1981). Further, we used HTMT as a discriminant validity criterion, which we calculated by comparing with a predefined threshold, to determine discriminant validity. As an eligibility criterion for discriminant validity, a threshold value of 0.90 is considered acceptable in terms of discriminant validity (Kline, 2015). This threshold is reached when the HTMT value is less than a certain threshold, indicating that the test has demonstrated discriminant validity. The last was multidimensional analysis. We performed multigroup analysis on measurement models based on gender differences to ensure that the measurement model used in this study measures the same thing across gender.

Results

CFA

CFA is used to confirm latent factors in the measurement model, which demonstrated that all latent factors were operating properly and achieving GoF indexes. According to Chuah et al., (2016) recommendation, we performed analyses for CR, convergent validity, and discriminant validity. To assess model fit, we created a CFA diagram in the measurement model using Gaskin & Lim (2016)'s pattern matrix builder plugin. In this structure model, single-headed arrows represent hypothesized one-way directions in the structured model, whereas double-headed arrows represent the correlation between two variables in the structured model. A latent variable (e.g., a questionnaire factor) is represented by an oval, whereas an observed variable (e.g., a questionnaire item) is represented by a rectangle. The small circles on the graph represent the measurement errors attributed to each of the observed indicators.

Moreover, KMO was 0.936. Then, the factor loading was less than 0.4. In conformance with Tabachnick et al. (2007), it is common to use a lower limit on item factor loadings to help determine whether to delete items from a database or keep them. A principal component analysis was performed, and values less than 0.4 were suppressed from further consideration. Some items with a value less than 0.4 were removed from the database. This was consistent with the 0.4 threshold value proposed by scholars in social science research (Straub et al., 2004). We analyzed the report using modification indices and covariance with items in the same factor that had values greater than 5 to obtain an exceptional result and improve the model fit in CFA. The modification to the most appropriate measurement model is to covary error terms that are part of the same factor (Hermida, 2015). A more accurate model fit was obtained (= 853.768; = 291; p =< 0.000; CFI = 0.918; TLI = 0.908; RMESA = 0.062, and SRMR = 0.056). The CFA diagram after modification indices is in Figure 2, along with information about the GoF values.

Reliability

Calculating internal consistency and reliability for each subscale was a necessary part of the process (Table 3). Reliability values for the four subscales ranged between 0.79 and 0.89 both consistency reliability using Crb and composite reliability using, indicating that they had satisfactory reliabilities on each of them.

Table 3

Internal Consistency Reliability and Composite Reliability

Factors		
Self-Perception of Mathematics	0.79	0.79
Value of Mathematics	0.79	0.79
Enjoyment of Mathematics	0.89	0.89
Perceived Mathematics Achievement	0.87	0.87

Note. Cronbach's alpha; , McDonald's coefficient omega

The reliability of the self-perception of mathematics subscale was the highest (Crb = 0.87; = 0.88); the reliability of the value of mathematics subscale was also high (Crb = 0.83; = 0.83). Cronbach's alpha and omega coefficients for enjoyment of mathematics (Crb = 0.72; = 0.78) and perceived mathematics achievement (Crb = 0.78; = 0.78) were also acceptable. The overall reliability values of ATMSE show that the instrument used is highly reliable.

Construct validity

Convergent validity

Convergent validity was used to assess the factor of correlation between multiple variables within a single construct in an instrument. In other words, convergent validity has been achieved when the variables within a factor are highly correlated. To ensure convergent validity in this study (Table 4), the CR and AVE should be calculated (Ab Hamid et al., 2017).

Table 4

Validity Measurement-Based on the Fornell–Lacker Criterion

	CR	AVE	SPM	VoM	EoM	PMA
SPM	0.79	0.39	.62			
VoM	0.83	0.45	.361**	.67		
EoM	0.89	0.52	.767**	.524**	.72	
PMA	0.87	0.54	.602**	.369**	642**	.73

Note: ** Correlation is significant at the 0.01 level. SPM, Self-Perception of Mathematics; VOM, Value of Mathematics; EOM, Enjoyment of Mathematics; PMA, Perceived Mathematics Achievement.

According to the results of AVE, all factors had values that were slightly less than the mean, with values ranging from 0.39 to 0.54 points lower than the mean, whereas the CR values were greater than 0.60 in all factors. The convergent validity of the construct is also accepting the minimum thresholds, as demonstrated by the fact that the CR values were higher than 0.60 in all factors (Fornell & Larcker, 1981; Malhotra & Dash, 2011), In addition, the convergent validity of the study was established.

Discriminant validity

Adiscriminant validity test was performed to assess whether latent factors differ from one another on an empirical level (Hair Jr et al., 2021). The HTMT ratio was used to determine discriminant validity (Henseler et al., 2015). The results are summarized in Table 5.

Table 5

$HTMT_{0.90}$ Ratio of the Correlations Four Factors

	PMA	EOM	VOM	SPM
PMA	-			
EOM	0.74	-		
VOM	0.43	0.61	-	
SPM	0.74	0.90	0.47	-

Note: SPM, Self-Perception of Mathematics; VOM, Value of Mathematics; EOM, Enjoyment of Mathematics; PMA, Perceived Mathematics Achievement. All correlations are significant at $p < 0.01$.

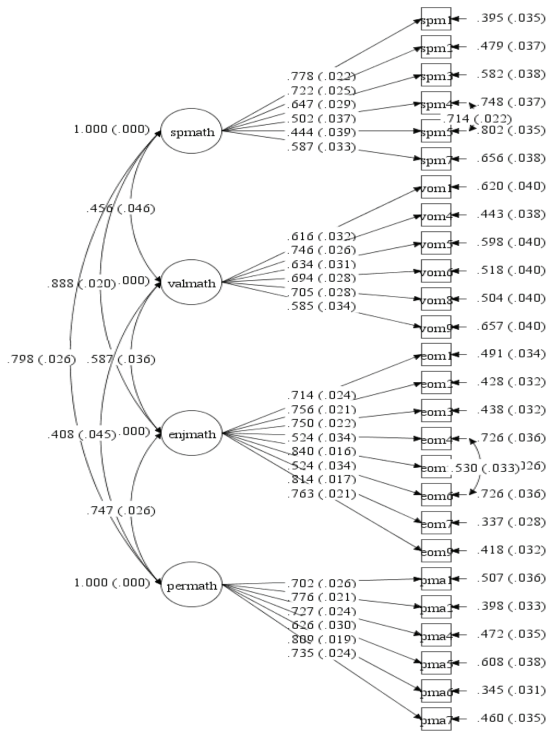
The values varied between 0.47 and 0.90. Consequently, discriminant validity has been established for all of the values less than 0.90 (Hair et al., 2010; Henseler et al., 2015).

Multidimensional analysis

We performed a multidimensional analysis of the measurement models and divided them into two groups based on gender, women and men, to ensure that the measurement model used in this study measures the same for all genders. In other words, the instrument remains unchanged when men and women are measured separately (Soeharto & Csapó, 2021). To analyze the scale scores for all ATMSE components, we compared the mean scores of the four latent factors in the ATMSE using the independent samples t-test. In addition, the effect size was determined according to Cohen's d. The effect size criterion includes the following categories: negligible (0-0.19), small (0.2-0.49), medium (0.5-0.79), and large (0.8 and above) (Cohen, 1992). We found the following: self-perception of mathematics ($t(502) = -2.668$, $p < 0.05$, Cohen's $d = 0.24$), value of mathematics ($t(502) = -2.932$, $p < 0.05$, Cohen's $d = 0.27$), value of mathematics ($t(502) = -2.662$, $p < 0.05$, Cohen's $d = 1.04$), and perceived mathematics achievement ($t(502) = -0.884$, $p > 0.05$, Cohen's $d = 0.08$). It is further evident from this analysis that self-perceptions of mathematics and the value of mathematics differ between males and females. In addition, the small effect sizes are both self-perception of mathematics and value of mathematics, while value of mathematics were large effect sizes.

Figure 2

CFA After Modification Indexes for ATMSE



Discussion

Students' ATMs are increasingly being studied because of the important role that they play in their engagement with and mastery of mathematics. Consequently, there has been an increase in interest in studying students' ATMs in recent years (e.g., Goldin, 2002; Grootenboer & Hemmings, 2007; McLeod, 1992). Despite this, the psychometric properties of the instruments used to assess ATMs have posed limitations to the study of attitude variables in mathematics. The results of a thorough review of the existing literature on instruments allow for the formulation of three general conclusions. Starting with FSMAS (Fennema & Sherman, 1976) and ATMI (Tapia & Marsh, 2004), two of the most frequently cited instruments, both of which have been translated into several languages and can be used in various sociocultural contexts, serve as good starting points for further research. Subsequent replication studies of these instruments (Mulhern & Rae, 1998; O'neal, 1988) have shown that, among other things, reconstructing some of their latent factors and reducing the scales to fewer subdomains results in a better fit to the data. The second point is that, while some scales (e.g., MAI, Sandman, 1980; Short Form of Mathematics Attitude Scale, Yaşar, 2014) have been ostensibly designed to assess ATMs, they incorporate both attitudinal and anxiety factors into their design. Despite this, Yáñez-Marquina & Villardón-Gallego (2016) argue that ATMs and mathematics anxiety are distinct subdomains of the broader domain of mathematical effect, as opposed to the other way around. This implies that ATMs have a distinct factor structure and should be evaluated separately from mathematics anxiety. The third point is that other measures do not consider students' self-esteem (e.g., the Math Attitude Scale, Aiken Jr & Dreger, 1961; the DAS, Dutton & Blum, 1968; the E and V Scales, Michaels & Forsyth, 1977).

In this study, we developed and validated an ATMSE questionnaire among an Indonesian sample of secondary school students using CFA techniques to address the gap between theoretical conceptualization and construct ATMs. Following the CFA performed in this study, it was determined that a modified four-factor model should be used, in which two items of self-perception of mathematics were removed (i.e., Math comes easily to me and I can spend hours studying and doing math problems, time goes by so fast!), then four items from the value of mathematics (i.e., Mathematics is less important to people than art or literature, Mathematics is not important in everyday life, Mathematics is not important for the advance of civilization and society, and There is nothing creative about mathematics; it's just memorizing formulas and things). In addition, one item for each of enjoyment of mathematics and perceived mathematics achievement (It's time for math, how awful! and I am not a model student in Math, respectively) were removed. The removals are because the loading factors are less than 0.5. The following was the final factor structure for the 26-item questionnaire (see Appendix). After this process, there are several items of ATMSE: eight items from the enjoyment of mathematics and six items from each of the self-perception of mathematics, value of mathematics, and perceived mathematics achievement. As a result of these findings, the ATMSE demonstrated good reliability and validity evidence of the instrument (i.e., construct validity and discriminant validity), as well as Cronbach's alpha and omega values comparable to those obtained with the original ATMSE. Although these results indicated that the eight removed items were essentially redundant, the decision was made to keep them. This was determined to be a significant contribution to the research on ATMs. The brief form is completed in only 10 min by secondary school students, whereas the developed scale is simple to administer and does not require a significant amount of time. It could be used to assess students' ATMs and provide early intervention in cases of low mathematical self-perception and enjoyment; as a result, school counselors and educators could make use of it.

Considering the funding, the validity of a scale that represents ATMSE in Indonesian was established through our research. Although his scale could be applied to a wide range of groups, it would be necessary to perform a completely new investigation into the measurement properties of the instrument. These investigations may yield a structure and strategy classification that is somewhat diverse, which will be characteristic of the sample in question, depending on the results of the investigation; however, this will be dependent on the results of the investigation. Different samples have varying degrees of variation in the factor that determines the structural characteristics.

Conclusion

Overall, we discovered that our questionnaire contains critical constructs for assessing the observed samples' ATMs. Our research is significant in that it provides empirical evidence for the viability of transferring Bloom's taxonomy theory from educational psychology to an attitude in mathematics teaching and for the possibility of developing a self-reported scale to assess secondary students' ATM in Indonesia. In conclusion, the Mplus enabled a new perspective on ATMSE. It was performed in-depth analyses of ATMSE data and confirmed the instrument's reliability and validity for assessing constructs related to "ATM."

Limitations and Future Research

Based on this study, we learned how to validate an instrument and measure ATMs, but there are some limitations to our findings. First, we could only identify four factors and were unable to include the remaining factors. The ATMSE was discovered to be composed of four factors based on previous research (Alken, 1974; Palacios et al., 2014; Yaşar, 2014). Consequently, the measurement model is only evaluated in this study, and no further investigation into the relationship between latent factors is performed. Second, we only included Indonesian secondary school students in our study. As a result, our findings can only be extrapolated to other countries with the help of additional research. The questionnaire's reliability for other populations may also be confirmed if it is made available for use by other age groups in addition to those who have completed the questionnaire. Third, although we followed appropriate procedures for data collection and took all necessary precautions, there is a possibility that the research will be somewhat skewed.

To assess students' enjoyment, value, self-confidence, and motivation toward a subject, the ATMSE can be used to determine their attitudes toward a particular subject matter. Using self-report questionnaires to determine students' psychometric levels in this study, existing literature on attitude measurements and self-report questionnaires has been further developed and expanded. In future studies, larger samples should be tested; also, the relationship between motivation, self-efficacy, and overall enjoyment, among other variables should be explored.

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Declaration of Competing Interest

No conflict of interest exists.

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Appendix: Attitudes Toward Mathematics Scale Items (after purification)

Self-Perceptions

1. I am really good at math.
2. I understand math.
3. I can solve difficult math problems.
4. Math is very hard for me.
5. Math is confusing to me.
6. I can tell if my answers in math make sense.

Value of Mathematics

1. I feel confident in my abilities to solve mathematics problems.
2. I am good at math.
3. I can understand my teacher's explanation easily.
4. Mathematics is interesting.
5. I would like to use math in my real job after I leave school.
6. I spend lots of time to practice mathematics or work on assignments.

Enjoyment of Mathematics

1. When I have to do math homework, I do it with some joy.
2. If given the opportunity, I would choose elective courses related to mathematics.
3. The subject taught in mathematics classes is very interesting.
4. Mathematics is one of the most boring subjects.
5. I like mathematics.
6. Studying mathematics is dead boring.
7. I feel comfortable doing math problems
8. Doing math is easy for me.

Perceived Mathematics Achievement

1. My friends think that I am successful at Math.
2. I see myself as a successful student in Math.
3. I think I am a good student in Math.
4. I am sure I will be successful in math class.
5. According to my friends, I am a successful student in mathematic.
6. I am sure that my teachers found me successful in math class.

Mokinių matematinės nuostatos: pritaikymas ir validumas Indonezijoje

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Santrauka

Esamos matematikos nuostatų vertinimo priemonės yra per ilgos, pasenusios arba pagrįstos tik vakarietiškomis imtimis. Tuo tikslu buvo parengtas ir patvirtintas specialiai Indonezijai skirtas vidurinio ugdymo matematikos nuostatų vertinimo klausimyno variantas (angl. *ATMSE*). Klausimynas matuoja keturias subskales: matematinę savivoką, matematikos vertę, pasitenkinimą matematika ir įgytus matematikos pasiekimus. Tyrime dalyvavo 502 dalyviai iš Indonezijos vidurinių mokyklų.

Keturių faktorių struktūros modelio validumas buvo įvertintas taikant patvirtinamąją faktorinę analizę. Kronbacho alfa ir omega koeficientai patvirtino veiksnių nuoseklumą, o konvergentinis ir diskriminantinis validumas nustatė reikšmingus ryšius tarp jų. Klausimynas yra tinkamas instrumentas mokinių matematinėms nuostatoms (angl. *ATM*) Indonezijoje vertinti. Nustatyta, kad klausimyne yra svarbiausių konstruktų, leidžiančių įvertinti mokinių vidurinio ugdymo matematines nuostatas. Tyrimas reikšmingas tuo, kad pateikta empirinių įrodymų, patvirtinančių Bloom taksonomijos teorijos pritaikymą mokinių mokymo perspektyvumui realizuoti ir galimybę savianalizės skalei sukurti, norint vertinti vidurinių mokyklų mokinių matematines nuostatas Indonezijoje. Be to, buvo naudota Rasch analizė ir Mplus, o tai leido naujai pažvelgti į vidurinio ugdymo mokinių matematines nuostatas.

Esminiai žodžiai: *matematinės nuostatos, patvirtinamoji faktorinė analizė, vidurinės mokyklos mokiniai.*

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Study 3: Tapis patterns in the context of ethnomathematics to assess students' creative thinking in mathematics: A Rasch measurement

(Suherman & Vidakovich, 2022)

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

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Abstract: Mathematics is employed in cultural activities in traditional and nontraditional societies. Ethnomathematics refers to mathematical ideas integrated into a culture. The culture can be used as a transformation effort to explore mathematical concepts in order to bring the mathematics closer to the reality and understanding of its people. Moreover, culture can be used as a groundwork for school mathematics. This study investigated ethnomathematics as geometry context illustrations of the patterns of Tapis Lampung in Indonesia. With an ethnographic approach and Rasch measurement that is to measure of persons and items on the same scale, this research is a quantitative study. Data were collected through test and documentation with tapis pattern results. It was discovered that the designs of the Tapis Lampung include geometric concepts that can be expressed as translations, rotations, reflections, and dilations. Moreover, students have different results of the creative thinking in mathematics. Each Tapis pattern also includes local values (i.e. sacred values, social stratification, history and understanding, creativity, inclusiveness, and economic value). Tapis Lampung can be used to disseminate and inform the world about Indonesian local wisdom and potentially as a source of contextual mathematics in rural schools and urban areas.

INTRODUCTION

Indonesia is a country with diversity in cultures and religions. Indonesia's population consists of indigenous people, descendants of Chinese, Egypt, India, and the Indo or Eurasian groups engaged in Indonesia and Europe. Indonesia has more than 500 ethnic groups and more than 600 languages (Roslidah et al., 2017). These must be maintained and managed by promoting the values of diversity so that no ethnicity stands as a closed and independent entity but rather interacts and interdepends on and mutually influence one another (Ewoh, 2013).

Lampung is a province in Indonesia, and it is strategically located. It lies at the southern end of the island of Sumatra, making it a gateway to the island of Sumatra. This makes Lampung the busiest

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due to migrants from various tribes. Therefore, Lampung people are not limited to Lampung in the Lampung province and those in Sumatra Island. Moreover, indigenous peoples of Lampung are divided into two Lampung customs and dialects, namely, Pepadun with O dialect and Paminggir (Saibatin) with A dialect. Papadun areas include Abung, Way Kanan, Sungkai, Tulangbawang, and Pubian, and the tribes under Paminggir include Paminggir Belalau/Ranau, Paminggir Krui, Pesisir Semangka, Pesisir Teluk, Pesisir Rajabasa, and Pesisir Melinting-Meringgai. The sixth customary entity inhabit the coastal West, South, and East Lampung. Thus, Lampung is diverse in culture.

Considering cultural diversity, transforming culture must be known to preserve national culture and cultural education (Nugraha, 2019). Regarding ethnomathematics, diverse cultures can be explored in education, especially in mathematics (Hartinah et al., 2019; Kieran et al., 2013). Despite its expansive scope, ethnomathematics is frequently confounded with ethnic or indigenous mathematics. In this article, I argue that ethnomathematics research should not be limited to the mathematical knowledge of culturally distinct people or people engaged in daily activities. The focus could be on academic mathematics, with an emphasis on the social, historical, political, and economic factors that have shaped mathematics into what it is today. With this background, ethnomathematics research has provided new and refreshing insights into the field of mathematics education, not only regarding ethnic or indigenous mathematical knowledge, but also regarding ethnomathematics approaches to mathematics and its education (Pais, 2011).

Mathematics is well-known in both traditional and nontraditional cultural activities of the societies (Kelly, 2018). Thus, this activities refers to cultural mathematics ideas and acknowledges that each culture and person develops unique ways and complex reasons to understand and modify their own realities (Presmeg et al., 2016; Rosa & Orey, 2017; Rubel, 2017). Furthermore, the ethnomathematics perspective is connecting mathematical concepts and local character value. These perspectives are contained in the 2013 Indonesian curriculum integrated the concept of education based on a character through culture, ethnicity, and values to promote by the Government of Indonesia (Suryadi et al., 2019).

Culture has many aspects that can be beneficially integrated into education. Cultural-based mathematics help students develop a greater interest in mathematics, enabling them to understand that mathematics extends beyond the classroom (Brown et al., 2019). Furthermore, because it investigates how mathematical ideas and practices are processed and used in daily activities, ethnomathematics shows how various cultural groups organize their realities (Brown et al., 2019; Rosa & Gavarrete, 2017; Rosa & Orey, 2016). Ethnomathematics is a dynamic, holistic, transdisciplinary, and transcultural field of study. Its evolution would benefit academic mathematics because it advances in a way that is much closer to reality and the agents immersed in reality (D'Ambrosio, 2020).

Furthermore, ethnomathematics can be seen as the process by which people from a particular culture use mathematical ideas and concepts to deal with quantitative, relational, and spatial

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aspects of their lives (Bender & Beller, 2018; Supiyati & Hanum, 2019; Widyastuti et al., 2021, p. 2). To describe the mathematical practices of identifiable cultural groups, d'Ambrosio (1985) coined the term ethnomathematics. It is defined as the study of mathematical ideas found in a culture. This perspective of mathematics validates and affirms all people's mathematics experiences by demonstrating that mathematical thinking is inherent in their lives due to the relationship between mathematics and culture (Balamurugan, 2015; Hannula, 2012; Pathuddin et al., 2021). In this context, mathematical development in different cultures is based on common problems encountered within a cultural context, according to an ethnomathematical perspective (Borko et al., 2014; Yuliani & Saragih, 2015).

Ethnomathematics have been widely researched in many countries worldwide. "Exploration of Ethnomathematics at the Margin of Europe – A Pagan Calendar" is one of the reported studies on ethnomathematics (Bjarnadóttir, 2010). In the study, in 930 in Iceland, researchers discovered a system for recording time, or a calendar influenced by the environment, specifically by observing celestial bodies, including the sun and moon. This is an example of empirical adjustment of mathematical models in which the length of the calendar year is adjusted to natural observations. d'Ambrósio, (2006) defined ethnomathematics as follows: "In the same culture, individuals provide the same explanations and use the same material and intellectual instruments in their daily activities." Nyoni (2014) reported that because a mathematics game known as "mutoga" in the local language of South Africa is played every day at home and in school, ethnomathematical epistemology can be implanted. Responding to curriculum and practice assessments, according to researchers, must be mediated by cultural pedagogy.

In Indonesia, few researchers still explore the mathematical concept in unique and rare patterns in traditional woven. However, some researchers have explored fabric patterns worldwide. Regarding the batik patterns, in Yogyakarta batik, the concept of geometry transformation is employed to make Yogyakarta's unique batik motif (Prahmana & D'Ambrosio, 2020). This research is an ethnography study, which shows moral, historical, and philosophical values. The author stated that the mathematics concept can be implemented for students who live in rural and urban areas. Additionally, previous studies have shown that mathematics basic concepts can be explored as Sundanese ethnomathematics (Muhtadi & Charitas Indra Prahmana, 2017). This study was focused on the activities of indigenous people and explored Sundanese culture. Unfortunately, the standards for the application of mathematical concepts in measuring the activity of mathematical rules have not been met. Furthermore, mathematics concepts can be described with ethnomathematics on Dayak Tabun traditional tools (Hartono & Saputro, 2019). This study focused on the aspect of motif as not only as geometry but also algebra and trigonometry concepts. Some researcher try to connect between local culture and students' official cognitive. As Pais (2011) argued that this resource, concerned in establishing a "bridge" between local and school knowledge, is prevalent in ethnomathematics research. This "bridging" of local and school mathematics knowledge is viewed as a way of valorizing students' cultures while also allowing students to gain a better understanding of formal mathematics through their own not yet formalized

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knowledge. Based on previous studies, this study investigates the local culture "Tapis Lampung" as an exploration ethnomathematics approach into the classroom to assess students' mathematical creative thinking. The Tapis Lampung will be explored in more detail in the literature review. Tapis Lampung was investigated as a geometry concept for the indigenes of Lampung, which is an ethnomathematics concept. Therefore, it is decided to develop an open-ended test supported by the Rasch measurement model in order to identify and assess the development of students' creative thinking in relation to grade level and gender (Soeharto, 2021). Rasch Analysis (RA) is a one-of-a-kind mathematical modeling technique based on a latent trait that achieves stochastic (probabilistic) conjoint additivity (conjoint means measurement of persons and items on the same scale and additivity is the equal-interval property of the scale) (Granger, 2008).

THEORETICAL BACKGROUND

Ethnomathematics approach

A fundamental change in mathematical instruction is required to account for the continuous change in the demographics of students enrolled in mathematics classes (Rosa & Orey, 2011). Numerous scholars have developed culturally relevant pedagogical theories that take a critical look at the teaching and learning process by incorporating cultural elements and values into mathematics (Fouze & Amit, 2017). It is required for the integration of a culturally relevant mathematics curriculum into the existing mathematics curriculum. From this point of view, it is critical for culturally relevant education because it proposes that teachers contextualize mathematics learning by connecting mathematics content to the student's culture and real-world experiences (Matthews, 2018).

According to the Rosa & Orey (2016) approach, culturally relevant mathematics should be centered on the sociocultural context, incorporating ethnomathematical concepts and ideas, and solving contextual problems from an ethnomathematics perspective. Additionally, ethnomathematics studies are increasingly being conducted, in which culture is linked to mathematical concepts and examples of the cultural context in mathematics are described (Barton, 1996, 2007). Following the recent Indonesian curriculum's emphasis on integrating culture into the curriculum, ethnomathematics may be a promising approach for assisting students in exploring their culture in order to generate mathematical concept ideas while also appreciating the cultures of others in a multicultural country (Peni & Baba, 2019). Additionally, schools must be established to teach the official knowledge while leaving the community's indigenous knowledge on its own (Pais, 2011). Therefore, including cultural aspects in the mathematics curriculum will benefit students in the long term; cultural aspects help students recognize mathematics as a part of everyday life, increasing their ability to make meaningful connections, and deepening their understanding of mathematics (Adam, 2004). This perspective was based on the numerous facets that the culture can be incorporated into the delivery of education to benefit students. The learners

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gain an understanding of how mathematics is used in everyday life, which improves their ability to make meaningful mathematical connections and broadens their understanding of all types of mathematics (Begg, 2001).

Tapis Lampung as Indonesian Traditional Pattern

One of the well-known and most respected cultural items is tapis. Tapis is an item of Lampung women's clothing; a shaped sarong made from cotton yarn woven with a motif or decoration material and silver or gold thread with embroidery. However, due to the increasingly modern times, Tapis Lampung can also be used as clothing for men (Figure 1). Tapis Lampung is rich in mathematical concepts, making it suitable as an alternative learning resource in teaching mathematics, especially material related to geometry (Figure 2). Geometric decorations found on tapis fabrics, in general, have firm contours with several line elements, such as straight lines, curves, zigzags, and spirals, and various shapes, such as triangles, rectangles, circles, kites, regular polygons, and geometric transformations.

Figure 1: Tapis Lampung in Wedding Ceremony

The nobility used Tapis Lampung in the past, but now, it is also used by ordinary people in Lampung. In the Lampung community, tapis is a source of income and a staple. It is a local commodity and source of revenue that needs to be preserved. The beauty of tapis is appreciated in the artistic forms spread on cloth sheets (Suherman et al., 2021). Current tapestry shapes show rhythmic regularity or pattern when closely observed. To create some forms of order on the rug, geometric transformations are employed. Euclidean geometry, in contrast, is used to identify forms made by human beings, including rectangles, circles, spheres, and triangles (Suherman et al.,

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2018). Thus, the structure of Tapis Lampung, which serves as a geometric representation of mathematical concepts, needs to be explored and made known globally.

We illustrate how cultural practices have been incorporated into mathematics education, with designs that adhere to the cultural geometry model, either explicitly or implicitly. These examples demonstrate the potential for Indigenous students to use their culture when designing and implementing school activities through the lens of the cultural geometry model.

Cultural Geometry: Integrating Ethnomathematics into Indigenous Students in the School

Mathematics constructed and evolved historically because of cultural norms or generally accepted and agreed upon practices. Consider how geometry developed during the Babylonian and ancient Egyptian civilizations between 5000 BC or 4000 BC to 500 BC (Muhtadi, 2017). Ancient civilizations made extensive use of visible geometry in their constructions, such as irrigation, flood control, swamp drainage, and large structures. In ancient Egypt, the geometry was used to define land boundaries along the Nile's banks because of flooding. Floods continue to strike the Nile's banks, erasing the boundaries of land owned by the indigenous community. Egyptians sought to redefine land boundaries while maintaining ownership of previously owned land. Later on, the Egyptians discovered a lengthy and extensive measurement system for community-agreed land boundary demarcation and for resolving the problem of tilled flooded land.

Additionally, the Babylonian and ancient Egyptian civilizations are regarded as the forerunners of the birth of the mathematical branches of knowledge, specifically geometry. The knowledge that appears first is cultural, such as experimentation, observation, assumption/estimation, or intuitive activities, which then evolved into standard and universal knowledge. Geometry then reaches a golden age during Euclid's (300 BC) era, when knowledge of geometry is constructed using an axiomatic system. Basic geometric shapes have been widely used as primitive concepts in previous community cultures (knowledge base, a concept which is not defined). The connections between these concepts resulted in the development of definitions, postulates/axioms, and theorems that comprise a deductive system. The deductive system is then accepted as mathematical knowledge, with geometry being classified as a subfield of mathematics.

Fundamentally, the development of human civilization is inextricably linked to the development of culture and mathematics. Nonetheless, because the method of obtaining it is unique, many people appear skeptical that culture cannot be separated from mathematical activity, but also cannot be considered separately or as a source of illumination for the development of mathematics today. In this context, culture encompasses a broad and distinct perspective, as well as being bound to the people's customs, such as gardening, playing, creating, and solving problems, as well as how to dress.

Integrating ethnomathematics into school mathematics for Indigenous students is viewed as significant because it demonstrates the existence of alternative forms of mathematics (Gerdes, 1985). However, the approach favored by these authors is:

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> *An integration of the mathematical concepts and practices originating in the learners' culture with those of conventional, formal academic mathematics. The mathematical experiences from the learner's culture are used to understand how mathematical ideas re formulated and applied. This general mathematical knowledge is then used to introduce conventional mathematics in such a way that it is better understood, its power, beauty and utility are better appreciated, and its relationship to familiar practices and concepts made explicit. In other words, a curriculum of this type allows learners to become aware of how people mathematise and use this awareness to learn about a more encompassing mathematics (Adam et al., 2003).*

Diverse perspectives on cultural traditions and practices enable a more nuanced understanding of how Tapis Lampung patterns become valued in general. As a result, while ethnomathematics has been hailed as a means of enriching students' understandings of mathematics through the use of contexts familiar to Indigenous students and enabling them to see themselves and their communities as mathematicians, concerns have been raised about how this integration may have unintended consequences. Even if Indigenous students gain mathematical insights through interaction with familiar cultural practices, the intrinsic value of the culture may be diminished if it is used merely to transmit mathematical ideas.

For many years in Indonesian educational discourse and on the school curriculum, indigenous culture was limited to the recognition of visual elements, such as signs, images, and iconography, that are immediately identifiable as representing indigenous culture and books of Indonesian myths. Cultural traditions and practices, on the other hand, should be valued in and of themselves.

Implementing the cultural geometry model in mathematics classrooms is challenging because all of the issues raised in each step must be considered concurrently. While mathematical concepts can contribute to cultural comprehension, if they are merely presented as representations of "Western mathematics," the possibilities for discussing Indigenous cultural artifacts and processes are likely to result in cultural imperialism (Bishop 1990). Rather than that, striking a balance between Indigenous cultural knowledge, including language, and mathematical cultural knowledge entails reflecting on the cultural geometry model's highlighted aspects.

Translation on tapis Lampung motif

According to Martin (2012), the mapping α is expressed as

$$\begin{cases} x' = ax + by + c, \\ y' = dx + ey + f, \end{cases}$$

This means that $(x', y') = \alpha((x, y))$ for each point (x, y) in the Cartesian plane, where $a, b, c, d, e, and\ f$ are numbers. A translation is a mapping having equations of the form

$$\begin{cases} x' = x + a, \\ y' = y + b, \end{cases}$$

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Theorem: Given points P and Q, there is a unique translation taking P to Q, namely, $\tau_{P,Q}$.

Thus, if $\tau_{P,Q}(R) = S$, then $\tau_{P,Q} = \tau_{R,S}$ for points $P, Q, R, and\ S$. Note that the identity is a special case of a translation as $l = \tau_{P,P}$ for each point P. Also, if $\tau_{P,Q}(R) = R$ for point R, then $P = Q$ as $\tau_{P,Q} = \tau_{R,R} = l$.

An image that depicts the translation of geometric transformations, for instance, is the slope motif. Slope motifs are the most common type of motivation in Lampung society. For this reason, fabric tapestry is always created with slope patterns as a job by craft/art teachers for students in schools (Lampung Province). Movements on the slopes are often the key reason for filter manufacturing. This motif is red, black, and yellow at the back, and the carpet is golden to make it more beautiful and harmonious. The pitch motions are regarded as simple motifs.

The form shown in Fig. 2 also results in the combination of the basic forms in the previous figure with vertical lines. The motif of the path is a variation of the type of fundamental motif that repeats or changes. The repetition of the motif moves over the desired range of the filter fabric. The length should be between 2 and 3 meters when a shawl fabric is considered. The following form of the next motif is generated by translation vectors $T_1 = \binom{0}{-b}$ when a pitch is a motif positioned on the Cartesian axis. The fundamental form of the pathway movement is shown in Fig. 4 as a form of translation. If the form is shifted the $T_n = \binom{0}{-nb}$ vector formulas can be used to convert the form geometrically to show the slopes' motifs.

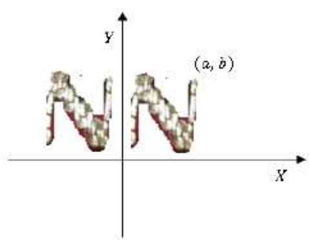

Figure 2: Cartesian coordinate of slop motif

Rotation on Tapis Lampung motif

Rotation is a transition in which a figure is rotated in a specific direction around a fixed point through an angle θ. In other words, a turning point around C by a directed angle θ is a turning point that sends every other C point to P so that P and P' have the same distance from the fixed C-point. A rotation with center C through an angle θ is usually denoted by $\rho_{C,\theta}$. It means that the image of any point P under $\rho_{C,\theta}$ is given as: $\rho_{C,\theta}(P) = \begin{cases} C, if\ P = C \\ P', \ if\ P \neq C, s.t. \overline{CP} = \overline{CP} \end{cases}$

Theorem. A rotation is an isometry.

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For distinct points C and P, circle C_P is defined as the circle with center C and radius CP. Thus, $\overline{CP}$ is a radius of the circle C_P, and point P is on the circumference of the circle. Then, $\rho_{C,180} = \sigma_C$ follows that each transformation fixes point C and, otherwise, sends any point P to a point P' such that C is the midpoint of P and P' (Fig. 3).

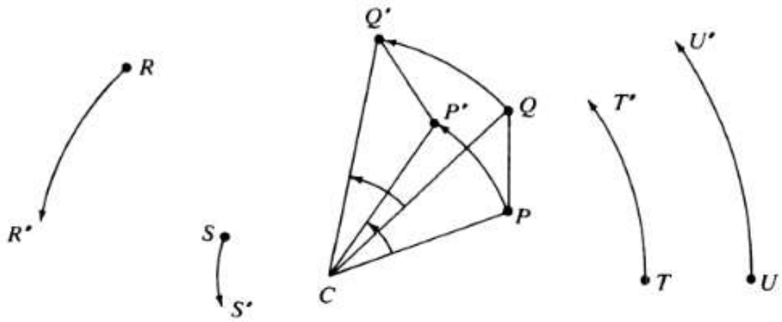
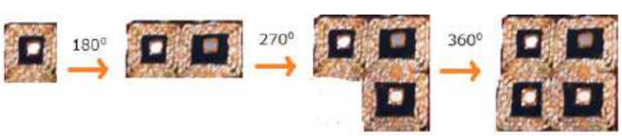


Figure 3: Rotation of illustration

To illustrate a rotation, the following is a motif of square on Tapis Gajah Meghem. If the image is rotated at angles of $90^0, 180^0, 270^0$, and 360^0 produces the original image. The rotation form of the basic shape in Fig. 10 are shown below.



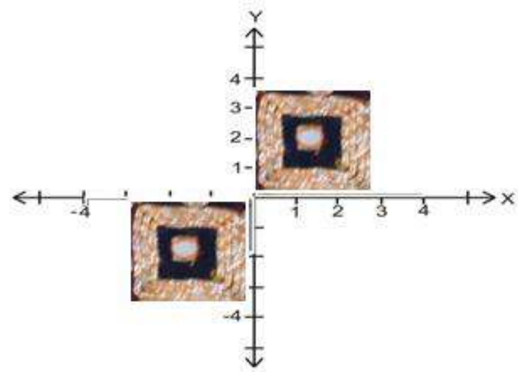


Figure 4: Rotation of Gajah Meghem motifs. The left figure was rotation on angle and the right figure was rotation on Cartesian coordinate

Reflection on Tapis Lampung motif

Given a line l and a point P, then, P' is a reflection image of P on the l if and only if $\overline{PP'}$ is perpendicular to l and $\overline{PM} = \overline{P'M}$, where M is the point of intersection of $\overline{PP'}$ and the l. In other words, P and P' are located on different sides of l but at equal distances from l. In this case, P' is said to be the mirror image of P and the l is said to be a line of reflection or an axis of symmetry. Reflection on l is usually denoted by S_l.

$$S_l(P) = \begin{cases} P, if\ P \in l \\ P',\ if\ P \notin \text{ and } l\ is\ the\ perpendicular\ bisector\ of\ \overline{PP'} \end{cases}$$

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Theorem: An isometry is a collineation that preserves betweenness, midpoints, segments, rays, triangles, angles, angle measure, and perpendicularity.

Consider the symmetries of the rectangle in Fig. 5. The axes of the plane are lines of symmetry for the rectangle, and the origin is a point of symmetry for the rectangle. Denoting the reflection in the $x-$ and y-axis by σ_h and σ_v, respectively, we have that $\sigma_h, \sigma_v, \sigma_o$, and l are symmetries for the rectangle. Note that l is a line of symmetry for any set of points. Since the image of the rectangle is known once which of A, B, C, D is an image of A is determined, the four lines are the only possible symmetries for the rectangle.

This is a geometric illustration of an elephant's transformation on a ship. A nongeometric motif is a motif applied to the elephant tapis. Elephant motif, human motivation, human motif for boat riding, and link motifs are all elements of the form. Application composition is taken from a plant and combined to make it attractive to animal, handler, and human motifs on board boats and chains. The main motif is the elephant animal motif, which stands directly between the motifs of the operator and the person. The above motif is a vessel filter motif with elements, such as bamboo shoots, single boats, handlers, and elephants. The motif of the ship is a ship with freight and elephants in terms of its characteristics in the woven tissue. Reflections show the shape of the elephant motif on the ship. The form of reflection can be guided.

Figure 5: Reflection on the y-axis in the left side, Siger motif and reflection in the right side

There are also filters due to reflection beside the above motif. The remaining elements are siger. The picture above shows two Siger Lampung motifs that are the result of the y-axis reflection, the results are similar in images, reflected on both the x- and y-axis. The result of the reflection. Filters with Tajuk Berayun motifs are also available, as shown in On Tapis Pucuk Rebung, the Tajuk Berayun motif is usually used. It is placed on the motif edge of the swinging canopy ornament. The swinging headers are placed side-by-side. It is obtained from young bamboo plants. The application of this form element has the significance of fertility because fertile natural effects exist. The bamboo-shooting motif is closely connected to the social (value) and religious systems. This motif also depicts the relationship between humans and God, and people and the environment. Tapis Tajuk Berayun motifs (Fig. 6) are used for wedding, graduation, circumcision, and many

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others ceremonies. Geometrically, the Tajuk Berayun motif illustrates reflections. This is another motif that can illustrate a geometrical reflection.

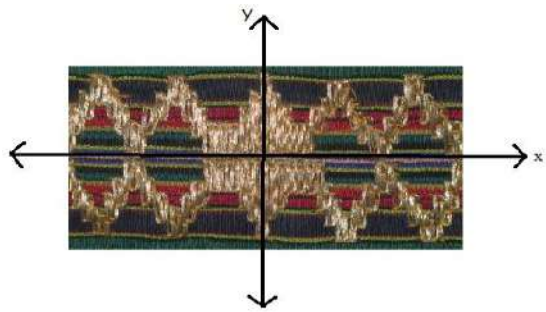

Figure 6: Tajuk berayun motif and reflection

Dilatation on Tapis Lampung

A transformation f is said to be a collineation if and only if the image of any line l under f is a line. In other words, for any point $P \in l$, the image $f(P) \in f(l)$. Furthermore, f is a dilatation if only if the image of any line l under f is a line parallel to l. That is, $f(l) \parallel l$ whenever f is colleneation, then f is said to be a dilatation.

Theorem: A dilatation is a translation or a dilatation

To show that there is a similarity in taking one triangle onto any similar triangle, suppose $\Delta ABC \approx \Delta A'B'C'$, as shown in Fig. 16. Let δ be the stretch about A such that $\delta(B) = E$ with $AE = A'B'$. With $F = \delta(C)$, then $\Delta AEF \cong \Delta A'B'C'$ by ASA. Since there is isometry β such that $\beta(A) = A'$, $\beta(E) = B$, and $\beta(F) = C'$, then $\beta\delta$ is a similarity taking $A, B, and\ C$ to $A', B' and\ C'$, respectively. If α a is similarity taking $A, B, and\ C$ to $A', B' and\ C'$, respectively, then $\alpha^{-1}(\beta\delta)$ fixes the noncollinear points and must be the identity. Therefore, $\alpha = \beta\delta$.

Dilation (multiplication) is a transformation that moves a geometry point, which depends on the dilation center and factor (scale). Thus, shades in a dilated geometry vary in size (small or big). The motif for Jung Sarat, for instance, is the motif for Mato Kibaw. The following motif can consider an extension. To achieve an attractive shape, the motif is enlarged. For the form shown in Fig. 7, the motifs are presented in part. The motif below can partially (separately) be considered as a group of Mato Kibaw motifs, originating from a square building with a white dot of fine zinc sheets at its center. The motifs below are of different sizes. If extended, this form produces a dilation or multiplication with a constant k to a partial shape, as shown in Fig. 18, which is considered a result of the positive real number k.

Mathematically, if k is a dilated factor, it applies to the following relationship. As a result, the shape of the Mato Kibaw motif is a dilated form of the center point of $O(0,0)$ by mapping.

$$[O, k]: P(x, y) \to P'(kx, ky)$$

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The matrix of the equations is given as

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} k & 0 \\ 0 & k \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix}.$$

Based on the analysis, another motif, a form of dilation or multiplication, can be displayed.

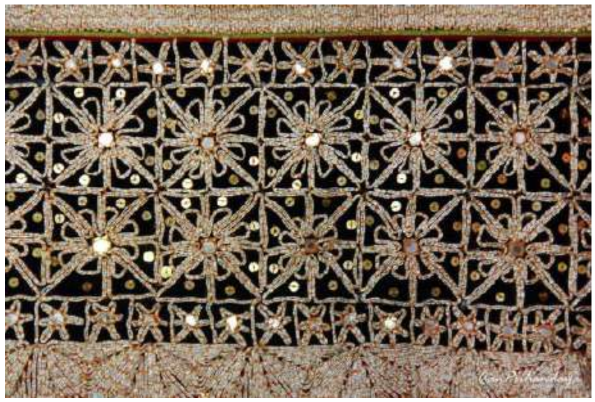

Figure 7: Flaura motif (Mato Kibaw)

METHOD

Participants

Participants were 157 secondary school students' (56% female), ages 12 to 14 years (*M* = 13.9; *SD* = .87). All students came from private and public school.

Procedure

An ethnographic approach was employed in this study (Gobo & Marciniak, 2011), aiming to provide an in-depth description and analysis of culture through intensive and prospective fieldwork research on culture (Huff et al., 2020; Person et al., 2013). This research focused on exploring culture while incorporating elements of Tapis Lampung as a symbol of users in a given culture. It gives insight into users' thoughts and actions, as well as the sights and sounds that they encounter during their activities. It clarifies the culture and symbolization of ethnomathematics. The framework stages are listed in Table 1.

Generic Question	Initial Answer	Critical Construct	Mastery Activity
Where should it look?	In the activities of making Tapis Lampung where there are mathematical practices	Culture	Interviewing indigenes who have the knowledge of Tapis Lampung or those who create Tapis motifs in Lampung.

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	in it.		
How is it to look?	Investigating and exploring Tapis motif of the Lampung people concerning mathematics concept.	Alternative thinking and prior-knowledge	Determine what ideas are included in the making of Tapis Lampung in relation to mathematical concepts.
What is it?	Evidence (The outcomes of alternative thinking in the previous procedure)	Philosophical mathematics	Identifying the characteristics in the process of Tapis Lampung
What does it mean?	Significant outcomes of mathematics and culture.	Anthropolog y	Describe the relationship between the two mathematical knowledge and cultural systems. Describe the mathematical concepts in the activity of making Tapis Lampung for the Lampung people.

Table 1: Design of the Ethnomathematics research

Instruments

The instruments was about figural on the tapis patterns in the context of ethnomathematics. The ethnomathematical test items for testing creative thinking in mathematics. The figural test is about picture construction. This means that the participant starts with a fundamental shape and builds on it to make a picture (J. C. Kaufman et al., 2008). Scores are assigned based on classified responses that include elaborations score. Each response is further considered for its elaborateness and given either two or one points. Below is an example of figural test an ethnomathematics content in the table 2. Furthermore, the results of the items were presented in the table 3.

Questions	Picture
The pictures are part of Tapis Lampung with geometry motifs. a. Make a list of any flat shapes that you find in the Tapis Lampung motif! b. Draw any pictures from your findings using at least one flat shape that you found in number a. You can combine 2 or 3 or more flat shapes to create a unique image. Then name the image you have made.	

Table 2*:* An Example of Ethnomathematics-based Test

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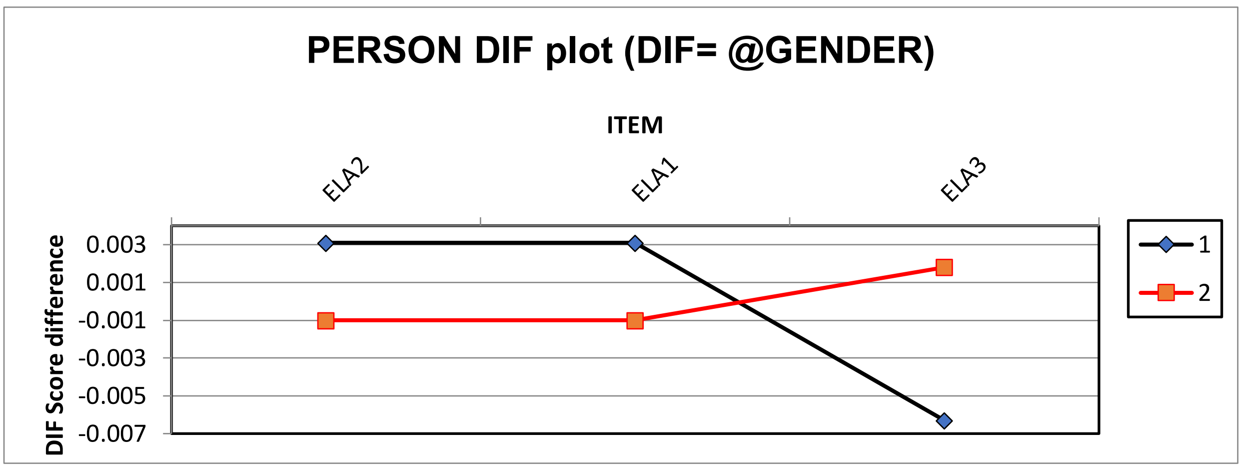
Item Measure	Test Group	
	Persons	Item
N	157	3
Measure	.53	.00
Mean	4.8	252.7
SD	.45	.68
SE	1.1	10.4
Mean Outfif MNSQ	.98	1.00
Mean Outfif SZTD	.05	-.23
Separation	.25	2.37
Reliability	.86	.85
Cronbach's Alpha	.86	

Table 3: The Summary of the Statistics Based on Pearson and Items

Based on Table 3, the reliability parameter in Rasch measurement for person and item are was .86 and .85, respectively. The statistics representing good reliability (more than 0.67) (Fisher, 2007). Furthermore, the Cronbach Alpha was 0.86. Rasch's measurements correspond to Outfit MNSQ in person ranging from 0.84 to 1.30 and Outfit SZTD ranging from -1.57 to 2.44. The item based on DIF is calculated for male (1) and female (2). There is no bias for item DIF has shown in the Figure 8.



Note: 1 = male; 2 = female; ELA1 = Item Elaboration no.1; ELA2 = Item Elaboration no.2; ELA3 = Item Elaboration no.3

Figure 8: The DIF item-based gender

Data Analysis

Data were collected through task and documentation. The objects observed include the steps in making Tapis Lampung, from the selection of tools to weaving the Tapis Lampung. As part of the documentation in this study, photographs of the task results by students of Tapis Lampung weaves were taken. To investigate the relationship between Tapis Lampung motifs and mathematical

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concepts, data were analyzed using Winstep software for Rasch measurement. This research is limited to the rules for determining the couple's matchmaking.

RESULTS

First, the 2-score items were examined using the Winstep format, one that compares the crossover, equal probability points "thresholds point'' using parameters of the partial credit model (Figure 9). The category probability curves of two items are demonstrated in Figure 9 (item 1 and item 3). The category probability curves indicate that items were like item 3 that equal to thresholds point. Therefore, the category probability has measure relative to item difficulty like item 1.

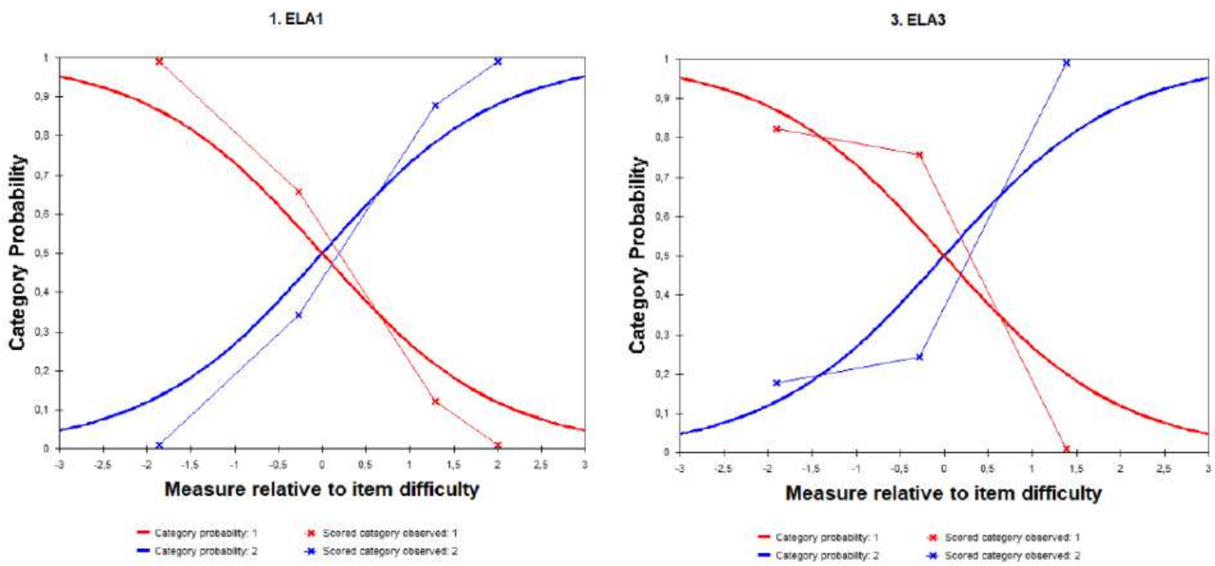

Figure 9: Category probability curves of the items 1 and 3.

Analysis of student answer patterns on creative thinking in mathematics in the context of Ethnomathematics has already presented. Further analysis was conducted to see how the pattern of answers of students with high statistical mathematical creative thinking (MCT) abilities, namely students with code 23MSMP and 116MSMP. The pattern of student answers can be seen in Table 4.

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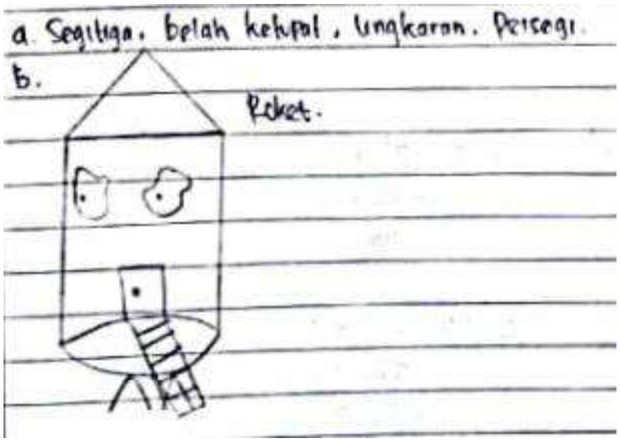
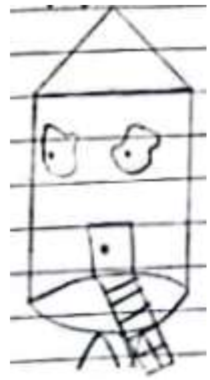
	**a. Triangle, rhombus, circle, square** **b. Rocket** 
	**a. Triangle, rhombus, and heksagonal** **b.** 

Table 4: Students' Answer of Tapis Pattern

Based on students' answers to the code 23MSMP on test number 3, it could be seen that the students' extracted information about the questions. The students were listed of the Tapis pattern in four shapes: triangle, rhombus, circle, and square. Additionally, students can draw pictures using shapes that were seen on the pattern. The picture name is rocket. In contrast, students' answer with code 116MSMP was only 3 kinds of the shapes, triangle, rhombus, and hexagonal, respectively. Then, can draw the angry bird picture.

Multiple Analysis

The regression test is satisfied if the covariate and dependent variable have a linear relationship. The results of multiple regression for the analysis as below in Table 5. Based on Table 5, we can see that the table describes the variance percentage explained by the included independent variables. The statistics results have explained that the independent variables can explain 2.9% of variance in the dependent variable. The total variance explained is 2.9% if we consider only the independent variables that significantly contribute to the regression model, $R^2 = .29$, $p = .21$. That can expect of item test number 3 not seems to exert the strongest elaboration, on the other hand may have an impact on the developmental level of learning creativity. It is also influenced by

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ethnic students' which task characteristics may explain. Regarding the coefficients analysis, the ethnic score (t = 1.12, p < .001), is the significant explanatory variables. Whereas, the schooltype (t =1.9, *p* = .06), and living place (t = -56, p = .58) does not have a significant contribution to the regression model.

Independent variables	*r*	*ß*	*r·ß·*100	*p*
Ethnic	.07	.09	.69	<.001
School type	.14	.16	2.31	.06
Living Place	.02	-.05	-.001	.58
Total variance explained			2.89	

Table 5: Results of multiple regression analysis for score no.3 as a dependent variable

Differential Item Functioning (DIS) based Gender

The DIF analysis confirmed that students with cross ethnic had fixed pattern of answer. This can be seen in the table 10 about DIF Measures. The students' have score different items in the own ethnic. In other words, the results of the DIF analysis in figure 10 conclude that although students have supportive demographic factors, such as gender, ethnic (i.e., Lampung, Java, Sundanese, Manado, Batak, Bugis, Munang, and others) in accordance with the given ethnomathematics-based test, they do not provide benefits for students in improving learning outcomes, especially those closely related to improving students' creative thinking in mathematics ability. However, it cannot be omitted that students' initial mathematical abilities also have their own role to support the development of other mathematical abilities.

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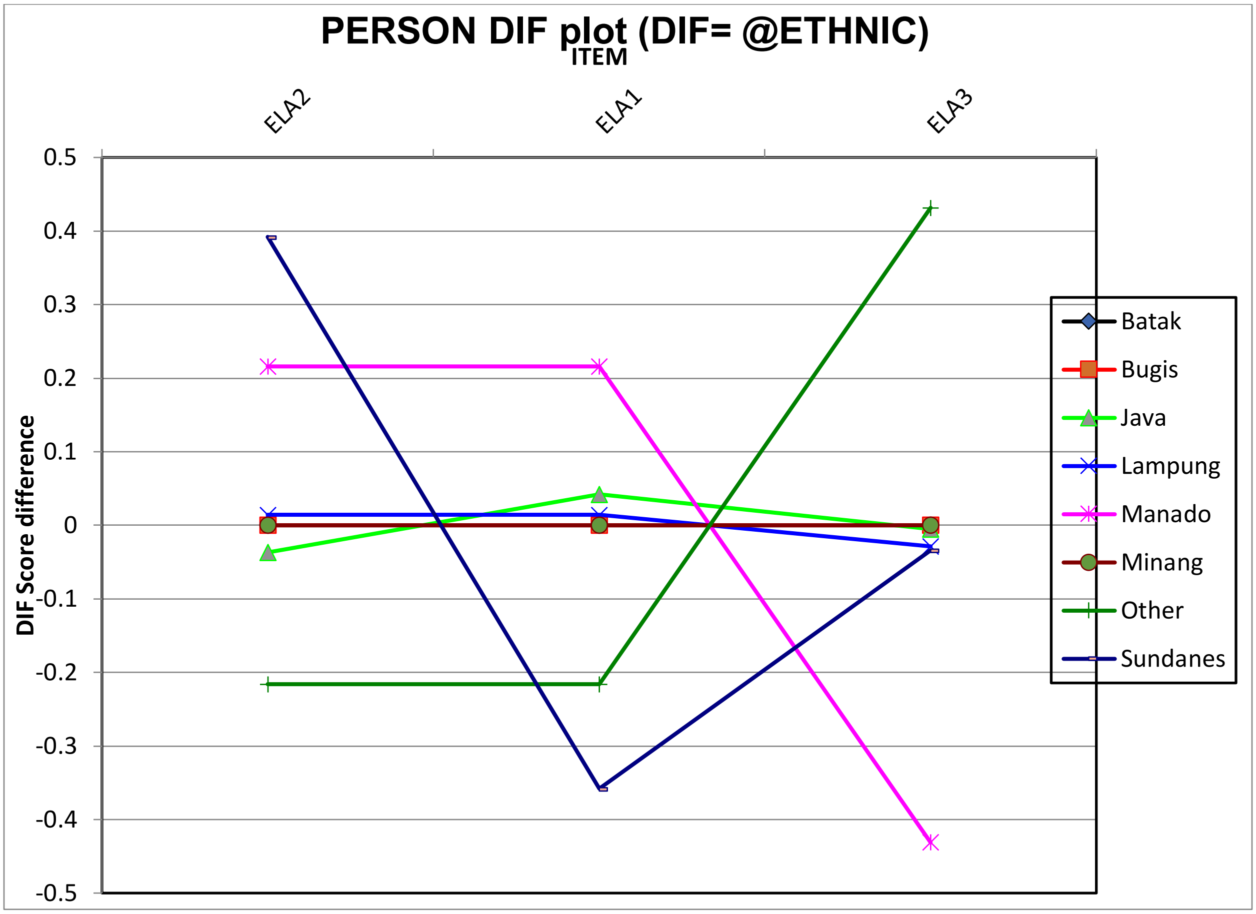

Figure 10: Person IF Students Answer on the Tapis Pattern Based Ethnic

DISCUSSION

Regarding the students answer, they can imagine to drawing the picture related to their own experienced. The picture based on the geometry pattern in the ethnomathematical context. The context has similar with the literature review about transformation geometry. Some examples of transformation geometry applications in the Tapis Lampung pattern are provided. The patterns on filtering motifs can have sacred values, social stratification, history and understanding, creativity, inclusiveness, and economic value (Matthews, 2018). For sacred values, traditional weaving cloth often indicates pure Lampung people in traditional ceremonies. The sacred value sources are motifs containing symbolic philosophical implications, such as constructions. Tapis woven fabric is regarded as a cloth with high symbolic value by the indigenes of Lampung. One of them symbolizes purity, which can protect the wearer from all external dirt. It is typically used in traditional and religious ceremonies to represent sacred values and functions. Ship decoration, for example, is a prominent feature of Lampung traditional tapis woven fabric. Ship shapes and colors

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also have different meanings. Red ship motifs represent sacredness and relationship with the upper world, whereas blue ship motifs indicate a relationship with the profane underworld. The third world is the middle, which includes humans and their natural environment, fauna, and flora (Nurdin & Damayanti, 2019).

For social stratification, traditional fabrics, usually owned by the local community, are maintained by indigenous Lampung families. Each cloth has a function, significance, and social status, such that some clothes are only allowed to be used by certain groups according to the social status of the ethnic groups. Tapis woven cloth is also an indicator of the social status of an individual (Isbandiyah & Supriyanto, 2019). Thus, a person's social status is known by looking at the woven tissue of the people by tapis. Members of the Lampung community wear tapis in traditional ceremonies, and each cultural group has different patterns and motifs of tapis. The patterns and motifs depend on the ceremony's purpose, and the tapis' patterns describe the users' position in the Lampung society's social hierarchy.

In the results, we found that the answer of students' creative thinking has different for each other. While they can answer the easy and difficulty of the item. We investigate in more detail using regression test to see whether independent variables (i.e., ethnic, school type, and living place) has effect on the creative thinking. Statistically, we found that only 29% of the creative thinking in mathematics contribute to the independent variables. Moreover, 73% was explained by other variables. Additionally, the item test was about figural on the tapis patterns in the context of ethnomathematics which can be seen that the figural covering of elaboration in more detail are fluency, flexibility, and the strategic retrieval and manipulation of knowledge may be among the more fundamental cognitive processes underlying g and divergent thinking (Beaty & Silvia, 2012; S. B. Kaufman et al., 2016). These skills appear to be more essential for mathematical creativity, which requires the application of reasoning and proofing ideation to an existing rational system and problem-solving (Huda et al., 2020). Practically, creative thinking in mathematics is needed to develop students' abilities. It can be understood by focusing on the responses of problem-solving students with out-of-the-ordinary thought processes and examining divergent production by determining the criteria of results (Haylock, 1997; Suherman & Vidákovich, 2022).

CONCLUSION

The Rasch Model analysis is important in checking for possible biases in student response patterns based on demographic factors. Rasch's analysis made it possible to further explore biases on demographic factors other than students' creative thinking in mathematics, gender, ethnicity, and student background. Other factors such as the level of affective factors and socio-cultural factors such as giving different results, can be explored further using the Rasch Model analysis by providing optimal analysis and students' results.

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This study giving problems with ethnomathematics contexts was proven to help students' understanding to the problem presented. Tapis Lampung may be expressed by translations, rotations, reflections, and dilations as a geometrical example of transformation. The results of this study will help teachers prepare the most appropriate strategy for improving the mathematical concepts and students' skills, especially in local cultures. This will aid in effective teaching, learning, and assessment of mathematics. However, there is a need for further studies on the empirical use of geometry learning in mathematics.

This research has limited findings, where the ethnomathematics context presented uses the cultural context and tapis pattern in Lampung, Indonesia, and the number of the research subject is also small. Therefore, further research will continue by paying attention to the demographic-focused factors used and the existence of socio-cultural factors so that the findings obtained can provide significant results.

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

(Suherman & Vidákovich, 2024b)

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

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ABSTRACT

Several studies have investigated the relationship between attitude, ethnicity, and mathematical creative thinking among secondary school students. Nonetheless, there is a lack of information regarding how ethnicity serves as a mediator in the correlation between attitude towards mathematics and mathematical creative thinking. To address this gap, the current study employed a descriptive correlational structural equation model to examine a hypothetical model. A survey was conducted among 896 secondary school students, consisting of 415 males and 481 females. Descriptive and correlational data analysis was performed using SPSS and Mplus. Ethnicity/culture and attitude significantly promoted creativity in mathematics, suggesting that an increase in ethnicity leads to a better attitude toward mathematics and higher mathematical creative thinking. Additionally, a positive relationship was observed between attitude toward mathematics and mathematical creative thinking, indicating that students who have positive attitude are more likely to perform creative thinking. Mathematical creative thinking increased as attitude and ethnicity increased. Overall, the correlation between attitude and ethnicity was significantly impacted by the promotion of critical thinking skills in mathematics. These findings are beneficial for mathematics educators in designing more effective courses that align with 21st century educational trends.

1. Introduction

Mathematics is well-known in both traditional and non-traditional societal cultural activities (Kelly, 2019). Thus, these endeavors encompass notions of ethnomathematics or cultural mathematical concepts and recognize the significance of creative thinking (CT) in realizing that every culture (ethnic identity) and corresponding attitudes entail distinctive approaches and intricate justifications to comprehend and alter their respective realities. Mathematics assessment tool incorporates both realistic and cultural aspects, namely ethnomathematics within the framework of mathematical creative thinking (MCT). A previous research found that attitude (J. Liu et al., 2021) and culture (Rouland et al., 2014) are the factor influencing CT.

The significance of mathematics education as an indispensable facet of a comprehensive education has been acknowledged for quite some time (Adler, 2017), as it imparts students with essential competencies and information vital to contemporary society (English & Halford, 2012). Despite this, many students struggle with mathematics (Xin, 2019), developing negative attitudes toward the subject that can have lasting impacts on their academic and personal lives (Aguilera-Hermida, 2020). On the contrary, pupils who

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have a deeper understanding and respect for mathematics may demonstrate greater motivation to engage in creative ways of thinking and investigate mathematical concepts in unconventional ways (Matsko & Thomas, 2014). Furthermore, issues of ethnic identity can exacerbate these difficulties, with students from diverse backgrounds often facing additional challenges in accessing and engaging with mathematics (Franke et al., 2007). In other words, different cultural backgrounds can significantly shape the impact of factors such as age, gender, or environment on a child's creative cognitive abilities (Shah & Gustafsson, 2021).

The past few years have witnessed a surge in the interest towards MCT as a feasible remedy for these predicaments (Bart et al., 2015; Durnali et al., 2023; Puspitasari et al., 2018; Wannapiroon & Pimdee, 2022). In this line, it is important to recognize that MCT is crucial to addressing various challenges in the field. By developing this skill, students may be able to overcome a negative attitude toward mathematics (ATM) and engage more meaningfully with the subject (Taşkin & Sezer, 2022), while also promoting greater understanding and appreciation of diverse cultures and perspectives (Porter et al., 2022). Previous research has shown that a positive ATM is crucial for academic success (Berger et al., 2020), with negative attitudes linked to lower achievement (Barkatsas et al., 2009), decreased motivation (White et al., 2019), and lower participation in science, technology, engineering, and math fields (Butler-Barnes et al., 2021). In other words, attitude is more powerful and significantly associated with creative thinking skill variables (Basadur et al., 2000). Similarly, Sánchez et al. (2022) research revealed that certain participants articulated a link between students' attitudes and the formulation of activities, particularly in terms of fostering students' creativity. Additionally, research has suggested that students' attitude closely linked with their creative thinking abilities. Furthermore, research has demonstrated the importance of ethnic identity in shaping educational experiences, with students from diverse backgrounds facing additional challenges in accessing and engaging with mathematics (Zhao et al., 2005). Therefore, the specific relationship between ethnic identity and dialectical thinking demonstrates a positive association with creativity (Paletz & Peng, 2009). Alt et al. (2023) elucidated that concerning controlled variables related to student characteristics, ethnicity emerged as a significant factor in the creativity post-test. The researcher emphasized the importance of diverse attitudes (Hidayatullah & Csíkos, 2023) and considering the influence of cultural backgrounds (Mims et al., 2022) to stimulate creative thinking in the context of mathematics.

Although there has been some research on the role of positive ATM and cultural understanding in promoting positive MCT, the literature remains relatively limited. Furthermore, there has been little research on the specific relationship between MCT, ATM, and ethnic identity. This paper investigated the relationship between MCT, ATM, and ethnic identity. This would provide insights into the potential of MCT as promoting positive ATM and foster greater cultural understanding and appreciation. Our findings would have significant implications for mathematics education and diversity and inclusion initiatives, highlighting the importance of promoting MCT as a key component of a modern, equitable, and effective education system. The primary objectives of this study were to address the subsequent research inquiries:

1. To what extent do ATM and ethnic identity intersect with MCT?
2. What impacts do exogenous variables have on endogenous variables (ATM on ethnic identity, ATM on MCT, and ethnic identity on MCT)?
3. Is there any mediating effect of ethnic identity on the relationship between ATM and MCT?

2. Theoretical Background

2.1. MCT

The assessment of creativity through creative products has generally been centered on employing divergent production tests, such as those created by Guilford (1959) and Torrance (1966). A subject is provided with an issue with various solutions or a circumstance with multiple reactions, which is a common feature of such assessments. Students must learn critical thinking, and analysis abilities that can be used in many aspects of life. As they acquire the required mathematics in the framework of ethnomathematics, students build talents, enhanced creativity, and a solid set of research habits. This indicates that ethnomathematics refer to mathematical notions integrated with cultural practices and recognizes that peoples' cultures generate unique strategies and complex explanations to know and change their reality (Rosa & Orey, 2011). Ethnomathematics, encompassing diverse cultural perspectives and practices related to mathematics, provides a rich context for students to engage with mathematical concepts in varied real-life settings. This exposure to different cultural approaches fosters a deeper understanding and appreciation of mathematics (Meng & Liu, 2022), allowing students to perceive it as a dynamic and adaptable discipline.

MCT refers to the ability to approach mathematical problems in a flexible, innovative, and open-minded manner, using creativity and imagination to explore new solutions and perspectives (Kharisudin, 2022; Sadak et al., 2022; Sengil-Akar & Yetkin-Ozdemir, 2022). Creativity and CT are often associated with artistic endeavors, but they are also essential in problem-solving across various domains, including mathematics. MCT refers to the ability to generate original and innovative solutions to mathematical problems by thinking outside the box and employing non-traditional approaches (Munakata et al., 2021). It involves the ability to think outside the box, develop unique approaches to problem-solving, draw connections between seemingly unrelated concepts (Moore-Russo & Demler, 2018), the application of imagination, intuition, and divergent thinking to mathematical concepts and problems, and the development of new ideas, concepts, and solutions that are not constrained by conventional thinking (Beghetto & Kaufman, 2014).

Previous research has defined MCT as a multi-dimensional construct that encompasses several cognitive processes, including flexibility, originality, elaboration, and fluency. Suherman & Vidákovich (2022b) defined MCT refers to the proficiency of creating unique and innovative resolutions to mathematical problems by employing different strategies, procedures, and heuristics that involve flexible and divergent thinking. This definition emphasizes the importance of not only arriving at a correct solution, but also the process of generating new and original ideas and strategies. The authors noted that MCT involves several components, including fluency, flexibility, originality, and elaboration, and can be applied to a wide range of mathematical tasks and problems. Similarly, Daher et al. (2020) highlighted the role of intuition and divergent thinking in developing MCT skills.

Several theoretical frameworks have been proposed to explain creativity, including the componential theory of creativity by Amabile (2011) and the systems model of creativity by Fulton & Paton (2016). The componential theory suggests that creativity is influenced by three main components: domain-relevant skills, creativity-relevant processes, and task motivation. Meanwhile, the systems model proposes that creativity is a product of the interaction between the individual, the domain, and the field.

Szabo et al. (2020) presented a framework of MCT, which includes three dimensions: fluency and flexibility (the ability to generate a variety of ideas and approaches to a problem), originality and novelty (the ability to come up with unique and innovative solutions to a problem), and elaboration and transformation (the ability to develop and refine ideas by expanding on them and transforming them in new ways). These dimensions are interconnected and necessary for effective mathematical problem-solving and the development of 21st century skills. The framework emphasized the importance of fostering mathematical creativity in education to prepare students for future challenges and opportunities. Overall, these theoretical frameworks and previous studies suggest that creativity and CT are important components of mathematical problem-solving and that individuals who exhibit higher levels of creativity may be better equipped to engage in MCT.

2.2. Attitudes toward mathematics (ATM)

ATM refers to an individual's positive or negative feelings, beliefs, and perceptions about mathematics and its relevance and importance in their lives (Soni & Kumari, 2017). It includes components such as interest, confidence, enjoyment, motivation, and anxiety of the subject. ATM plays a significant role in students' academic achievement, persistence in mathematics, and future career choices (Sithole et al., 2017; Yildirim, 2017; Yu & Singh, 2018) and various factors such as teaching methods, classroom environment, cultural and social background, and personal experiences influence ATM. Measurement and improvement of attitude in mathematics are important goals in mathematics education (Lin et al., 2016). A framework proposed by Fennema & Sherman (1976) and Attitude Toward Mathematics Inventory (ATMI) (Tapia & Marsh, 2004) identified three (confidence, interest, and perceived usefulness) and four (confidence, value, enjoyment, and motivation) dimensions of ATM, respectively. and these dimensions are positively correlated with students' achievement in the subject (Tapia & Marsh, 2004).

Previous studies have indicated that students who possess a favorable attitude towards mathematics (ATM) exhibit higher academic achievement in the subject and demonstrate a greater likelihood of pursuing math-related disciplines and vocations (Ceci & Williams, 2010). Additionally, ATM has been shown to be impacted by variables including gender, ethnicity, and socioeconomic status (SES) (Forgasz et al., 2004). According to a study, there is a positive correlation between students' enthusiasm for mathematics and their involvement in the process of problem-solving and exploration of mathematical concepts (Schindler & Bakker, 2020). Hence, understanding of students' ATM is important for educators and researchers as it can help inform interventions and strategies to improve students' engagement and performance in the subject.

2.3. Ethnic identity

The examination of ethnic identity has been a topic of research due to its significance for identity formation and psychological wellbeing (Rivas-Drake et al., 2014). In an effort to produce a meaningful measure of ethnic identification, the Multigroup Ethnic Identity Measure, consisting of 14 items, was created by Phinney (1992), which analyzes three components of ethnic identity: positive ethnic attitudes and belonging, ethnic identity achievement, and ethnic behaviors. Existing research demonstrates that ethnic identity is directly correlated with significant outcome variables, such as individuals' coping techniques with prejudice.

There are a number of theoretical frameworks that have been used to study ethnic identity. One of the most influential models is the Social Identity Theory (Hogg, 2016), which suggests that an individual's sense of identity is shaped by their membership in social groups, such as gender, race, ethnicity, or religion. According to this theory, individuals form an identity in part through their comparison of their own group to other groups. Thus, ethnic identity may be strengthened by intergroup contact and comparison, as well as by factors such as shared cultural practices and values. Another theoretical framework that has been used to study ethnic identity is the Developmental Niche Theory (Rogoff, 2003), which suggests that an individual's development is shaped by the interplay between three environments: the physical environment, the social environment, and the cultural environment. According to this theory, ethnic identity may be strengthened by exposure to and participation in cultural practices and traditions, as well as by the support and guidance of parents and other family members.

Previous research has identified a number of factors that can influence the development and expression of ethnic identity (Richardson et al., 2015; Trimble, 2007; Umaña-Taylor et al., 2013; Williams & Lewis, 2021; Woo et al., 2020). These include age, gender, SES, cultural values, discrimination and prejudice, and intergroup contact. For example, research by Richardson et al. (2015) has shown that individuals who experience discrimination based on their ethnicity may have a stronger sense of ethnic identity as a way to cope with the negative experiences. One recent study by Umaña-Taylor et al. (2013) examined the relationship between family ethnic socialization and ethnic identity among Latino adolescents and explored whether this relationship was a family-driven, youth-driven, or reciprocal process. The results of the study showed that family ethnic socialization was positively associated with ethnic identity exploration and affirmation among Latino adolescents (Umaña-Taylor et al., 2013). In addition, the study found that the relationship between family ethnic socialization and ethnic identity was a reciprocal process, meaning that family ethnic socialization practices were both influenced by and influenced adolescents' ethnic identity development. In other words, adolescents who were more engaged in exploring and affirming their ethnic identity were more likely to receive family ethnic socialization practices that supported their ethnic identity, and these practices, in turn, further facilitated the adolescents' ethnic identity development.

A theoretical figure that has been used to conceptualize ethnic identity is the Ethnic Identity Development Model proposed by Phinney (1990). The model suggests that individuals move through three stages in the development of ethnic identity: (1) the unexamined stage, where individuals have little awareness of their ethnic identity; (2) the exploration stage, where individuals begin to explore their ethnic identity and what it means to them; and (3) the achieved stage, where individuals have a clear sense of their ethnic identity and are comfortable expressing it to others. The model also suggests that individuals may move back and forth between stages as they encounter new experiences and challenges related to their ethnic identity.

2.4. Relationship between attitude and creativity

ATM and MCT are closely linked, as students' attitudes and beliefs about mathematics can have a notable influence on their ability to engage in creative and innovative mathematical thinking (P.-H. Liu & Niess, 2006). Studies have demonstrated that students with positive ATM are more motivated, persistent, and likely to engage in creative problem-solving strategies (Higgins, 1997; Lubienski, 2000; Scherer & Gustafsson, 2015; Stipek, 2002). Positive attitudes can also lead increased self-efficacy (Poortvliet & Darnon, 2014), or confidence in one's ability to succeed in mathematics (Christensen & Knezek, 2020; Suryadi & Santoso, 2017), which in turn can support advanced and creative mathematical thinking (Mann, 2009). On the other hand, students who have negative ATM are more likely to avoid or disengage from mathematical tasks (Gunderson et al., 2012), leading to lower levels of motivation and fewer opportunities for CT (Hussein & Csíkos, 2023). Negative attitudes can also contribute to feelings of anxiety or self-doubt, which can interfere with the cognitive processes involved in CT (Amin et al., 2023). A possible reason for this disparity is that students who exhibit a positive ATM are more inclined to partake in MCT activities (Bevan & Capraro, 2021). In other words, students who enjoy and value mathematics may be more motivated to think creatively and explore mathematical ideas in novel ways (Matsko & Thomas, 2014), and those who engage in MCT activities may develop a greater appreciation for the subject. Similarly, a study by Yoon et al. (2015) found that students' attitude was significantly changed correlated with their creativity in learning programs. Furthermore, Existing research, links ATM to creativity (De-La-Peña et al., 2021), mathematical achievement (Pásztor et al., 2015), and mathematical problem-solving (Cooper et al., 2018). In summary, the relationship between ATM and MCT is important and become more useful for students. While positive attitudes can support and enhance CT, negative attitudes can hinder it. Hence, our foundation is to explore the relationship between ATM and students' MCT.

2.5. Relationship between attitude and ethnicity

The relationship between ethnic identity and ATM is an important area of research in education. Studies have suggested a relationship between students' ethnic identity and their ATM. A study by Butty (2001) found that Black and Hispanic students who receive in mathematics classes has an effect on their mathematics achievement and students' ATM. Another study by Townsend & Belgrave (2000) shown that attitude is predictor for students racial identity. Verdín & Godwin (2018) found that Latino students who participated in a mathematics program that incorporated elements of their cultural background had higher levels of mathematics self-efficacy and a stronger sense of ethnic identity. Therefore, there is an opportunities linked between positive attitude and different ethnicities in education (Byrd & Legette, 2022).

Overall, the relationship between ATM and ethnicity is important, and is influenced by a range of cultural and social factors. While students from minority ethnic groups are more likely to have negative ATM, interventions aimed at improving attitudes toward the subject can benefit students from diverse backgrounds. It is critical to recognize that ethnic identity is a complex and multifaceted construct that is influenced by a range of factors including cultural and societal norms, family background, and individual experiences. ATM can also be influenced by diverse factors, including teaching practices, curriculum, and personal factors (self-efficacy and motivation).

2.6. Relationship between creativity and ethnicity

The relationship between MCT/creativity and ethnic identity has been explored in recent studies. The study by Kozlowski & Si (2019) explored the potential of mathematical creativity as a tool for fostering equity in mathematics education. The authors argued that traditional approaches to mathematics education often favor certain forms of knowledge and ways of thinking, resulting in inequitable outcomes for students from diverse backgrounds. They remarked that emphasizing mathematical creativity can help to challenge these inequities and create a more inclusive and equitable learning environment. By emphasizing flexible and imaginative thinking, teachers can create a more inclusive and engaging learning environment that values and recognizes the diverse backgrounds and experiences of all students. Paletz & Peng (2009) examined the relationship between naive dialectical thinking (the ability to perceive and integrate contradictory information), ethnicity, and creativity. The researchers discovered that respondents who indicated elevated levels of naive dialectical thinking achieved higher scores on measures of creativity and Asian participants scored higher on measures of naive dialectical thinking compared to European American participants. However, they did not find a significant relationship between ethnicity and creativity scores after controlling for dialectical thinking, suggesting that dialectical thinking is a cognitive process that contributes to creativity, and that cultural differences in dialectical thinking may partially explain differences in creativity between ethnic groups.

The relationship between cultural identity and academic achievement (i.e., mathematical creativity) among Latino youth students was explored by Martinez-Fuentes et al. (2021). The authors found that students who reported stronger cultural identity engaged in more creative and innovative mathematical problem-solving strategies and suggested that cultural identity provides a sense of purpose and meaning and supports more intrinsic motivation and engagement in mathematical problem-solving.

Overall, these studies suggest a positive relationship between MCT/creativity and ethnic identity. Incorporating cultural traditions and values into the mathematics curriculum may help to promote a stronger sense of identity and belonging, which can support more innovative and creative problem-solving approaches.

2.7. *Ethnicity as a mediator between attitude and creativity*

Bandura & Walters (1977) theory underscores how individuals learn from their environment, including cultural influences. Ethnicity represents the cultural context shaping beliefs and attitudes (Umaña-Taylor et al., 2014), including those toward subjects like mathematics. As per Social Learning Theory, people observe, imitate, and learn from behaviors and attitudes within their cultural setting (Bandura, 1969). In math, diverse ethnic backgrounds can impact experiences with CT (Chua, 2018). This cultural influence mediates attitudes toward math and creative potential. Ethnicity thus mediates between attitude and creative thinking in math, shaping perceptions. Cultural attitudes that encourage or discourage risk-taking and unconventional thinking affect one's willingness to engage in creative problem-solving (Al-Mamary & Alshallaqi, 2022). If a culture values creative thinking in math, individuals may develop higher creative abilities, whereas discouragement may impact one's motivation to solve creatively.

In regard to the previous study, students' attitude has a direct relationship between their ethnicity (Rinnooy Kan et al., 2023; Yli-Panula et al., 2022) and creativity (Han & Suh, 2023; Jiatong et al., 2021; Ruiz-Palomino & Zoghbi-Manrique-de-Lara, 2020). When students exhibit a positive and strong attitude towards their ethnicity, they tend to demonstrate higher engagement in CT within the field of mathematics (Uekawa et al., 2007). Similarly, Orakci & Durnali (2023) proposed that CT in mathematics can predict attitude toward in mathematics. Additionally, Naiman et al. (2023) discovered that ethnicity serves as a predictor of attitude. In essence on the observed correlations among attitude towards mathematics, ethnicity, and creativity, this study postulates that ethnic identity may serve as a mediator in the relationship between attitude towards mathematics and MCT. Therefore, our model has displayed in Fig. 1.

2.8. *Study context*

In Indonesia, mathematics education is recognized as a crucial component of the education system, with the government investing significant resources in improving mathematics teaching and learning. However, students in Indonesia often struggle with mathematics and require improvement in their attitudes toward the subject. Furthermore, Indonesia is a diverse country, with over 1,300 ethnic groups, and there is growing recognition of the importance of promoting inclusivity and diversity in education. However, ethnic identity remains an important aspect of many Indonesians' lives, influencing their attitudes and behavior.

Further, CT and attitude are also important concepts in Indonesia's educational system. CT is emphasized as an important skill that students should develop because it is necessary for innovation and problem-solving, which are crucial for the country's development. To promote CT, Indonesian schools often encourage students to engage in activities such as brainstorming, group discussions, and project-based learning. Attitude is also considered important in Indonesia's educational system. A positive attitude toward learning is believed to be necessary for academic success. Therefore, Indonesian schools place emphasis on cultivating positive attitudes toward learning, particularly in subjects such as mathematics, science, and language. This is achieved through various methods such as creating engaging and interactive learning environments, providing positive feedback to students, and encouraging them to set goals and strive toward achieving them.

3. Materials and Methods

3.1. *Participants*

The study randomly selected 896 students from secondary schools in Lampung province, Indonesia. We selected 27 classes randomly chosen from a total of seven schools, focusing on grades 7^{th} through 9^{th} in Lampung. Data were collected online using *a google form*. All participants provided informed consent prior to their participation in the study.

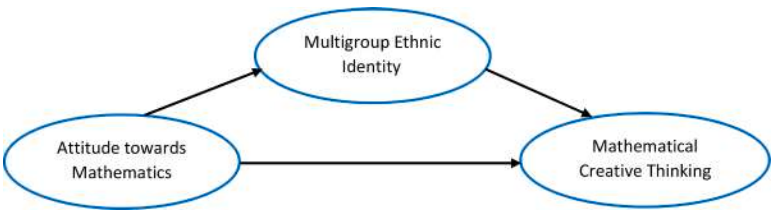

Fig. 1. Conceptual model.

Table 1 explain the demographic characteristics of the students. Of the 896 participants, 415 were males with a mean age of 13.24 ±1.04 while 481 were females, with a mean age of 13.43±1.11. The mean age of all participants was 13.34±1.08.

3.2. Instruments

This research adapted three several instruments to examine ethnic/cultural identity: (1) the mathematical creative thinking based Ethnomathematics test (MCTTBE), (2) the questionnaire on attitudes toward mathematics inventory for secondary education (ATMSE), and (3) the multigroup ethnic identity inventory (MEI2).

The MCTTBE is a 20-item instrument that was developed by Suherman and Vidákovich (2022c) in the context of *Tapis Lampung* as an ethnomathematics nuanced. The test has both figural and verbal components and the items cover fluency, flexibility, originality, and elaboration. The figural assessment consisted of two tasks: picture construction, which involved creating an image by adding onto a basic shape, and picture completion, which required the participant to finish an incomplete drawing and provide it with a title. The verbal test was also carried out in this study. For example, guessing required a participant to list possible causes for pictured action, product improvement necessitated the participant to enhance an image, the task of modification was given, while the task of unusual uses required the participant to generate multiple potential applications for an everyday object (J. C. Kaufman et al., 2008). Scores were assigned based on classified responses. The highest scores for fluency and flexibility were 5. Originality was scored according to percentages: above 3% = 0, above 2% and below 3% = 1, above 1% and below 2% = 2, and below 1% = 3. Elaboration was assigned either 1 or 2 scores. The fit indices, Infit mean square (MNSQ) and Outfit MNSQ of the MCTTBE item average, were determined to be 1.01 and 0.99, respectively. Cronbach's Alpha coefficient was 0.76 and the raw variance explained by measurements was 61.4%, which exceeded 20%.

ATMSE is a 26-item questionnaire that was also developed by Suherman and Vidákovich (2022a). Six items was used to measure self-perception of mathematics ("I am really good at math"), six items measured the value of mathematics ("I feel confident in my abilities to solve mathematics problems"), six items measured enjoyment of mathematics ("The subject taught in mathematics classes is very interesting"), and eight items measured perceived mathematics achievement ("I am sure I will be successful in math class"). The items were measured on a five-point scale (1 = *strongly disagree*, 2 = *disagree*, 3 = *neither agree nor disagree*, 4 = agree, and 5 = *strongly agree)* and students were asked to indicate their agreement with each statement by selecting from these options. The tests of reliability (consistency reliability using Cronbach alpha (α) and composite reliability using McDonald's omega (ω)) for the four scales ranged between 0.79 and 0.89. Specifically, the self-perception of mathematics subscale showed the highest reliability, scoring at Crb$\alpha = 0.79$ and $\omega = 0.79$. Similarly, the value of mathematics subscale also exhibited high reliability, with a Crb$\alpha = 0.79$ and $\omega = 0.79$. Moreover, both enjoyment of mathematics (Crb$\alpha = 0.89$; $\omega = 0.89$) and perceived mathematics achievement (Crb$\alpha = 0.87$; $\omega = 0.87$) demonstrated strong reliability. This instrument has valid in the Indonesian context.

The MEI2 questionnaire was adapted from Phinney (1992). The 19-item tool assessed students' knowledge of traditional clothing and motifs, cultural identity, and the association between culture and academics, namely, affirmation belonging (5 items: "I am very proud of my ethnic group and its achievements") and"), ethnic identity achievement (5 items: "I've spent time researching my own ethnic group's history, traditions, and customs"), and ethnic belonging (9 items: "I enjoy preserving the traditions of my ethnic group's heritage"). This was also rated on a 5-point scale, ranging from 1 (strongly disagree) to 5 (strongly agree). The reliability values for the three subscales ranged between 0.64 and 0.85. In regard to each subscale, the highest reliability was observed in the affirmation and belonging subscale, registering at Crb$\alpha = 0.76$ and $\omega = 0.76$. Likewise, the ethnic belonging subscale showed commendable reliability levels, recording Crb$\alpha = 0.85$ and $\omega = 0.83$. Additionally, ethnic identity achievement demonstrated acceptable Cronbach's alpha and omega coefficients at Crb$\alpha = 0.69$ and $\omega = 0.64$. Hence, the instruments are viable to assess ethnic identity.

Table 1
Characteristic of Participants.

Demographics		Frequency	Percentage (%)
Gender	Female	481	53.7
	Male	415	46.3
Grade	7th	306	34.2
	8th	292	32.6
	9th	298	33.3
School Place	Private	449	50.1
	Public	447	49.9
Living Place	City	460	51.3
	District	436	48.7
Ethnicity	Batak	57	6.4
	Bugis	25	2.8
	Java	395	44.1
	Lampung	131	14.6
	Manado	34	3.8
	Minang	23	2.6
	Others	47	5.2
	Palembang	24	2.7
	Sundanese	160	17.9

Table 2
Correlation coefficient, standard deviation, and mean.

	M	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. **MCT**	49.84	12.00	1													
1. Flu	16.45	3.97	.857**	1												
1. FLe	16.97	6.21	.926**	.671**	1											
1. EL	6.40	1.28	.696**	.538**	.547**	1										
1. OR	10.03	2.47	.788**	.589**	.618**	.620**	1									
1. **ATT**	95.79	16.23	.098**	.107**	.085*	.038	.072*	1								
1. SP	21.42	5.38	.066*	.079*	.055	.020	.046	.903**	1							
1. VM	23.51	3.07	.079*	.084*	.060	.029	.084*	.596**	.371**	1						
1. EM	29.43	5.93	.109**	.104**	.103**	.047	.077*	.936**	.796**	.523**	1					
1. PM	21.43	4.67	.074*	.092**	.062	.028	.042	.854**	.729**	.320**	.720**	1				
1. **ETH**	69.14	8.48	.081*	.063	.096**	.056	.021	.157**	.050	.189**	.164**	.156**	1			
1. AB	19.32	2.73	.069*	.038	.083*	.060	.032	.013	-.076*	.167**	.023	-.006	.750**	1		
1. EA	17.97	2.55	.068*	.046	.081*	.046	.028	.128**	.049	.170**	.117**	.128**	.842**	.577**	1	
1. EB	31.85	4.77	.068*	.066*	.079*	.041	.003	.204**	.106**	.150**	.216**	.213**	.898**	.452**	.631**	1

$^{**}p < 0.01$; $^{*}p < 0.05$; N = 896; **1. MCT**: Mathematical creative thinking, 2. Flue: Fluency, 3. Fle: Flexibility, 4. EL: Elaboration, 5. OR: Originality, **6. ATT**: Attitude, 7. SP: Self-perceive of mathematics, 8. VM: Value of mathematics, 9. EM: Enjoyment of mathematics, 10. PM: Perceived mathematics achievement, **11. ETH:** Ethnic, 12. AB: Affirmation belonging, 13. EA: Ethnic identity achievement, 14. EB: Ethnic belonging.

3.3. Data collection procedure

The study received approval from the Institutional Review Board of the Doctoral School of Education, University of Szeged, Hungary, which followed ethical guidelines set by the institution. Additionally, informed consent was obtained from all participants who agreed to take part in the study. To conduct the study, we sought permission from the school principals in order to distribute the questionnaires and tests. In each school's online test, analytical processes were implemented. The survey was deployed online via a google form test, and a link was sent to the students and their teachers via email or social media application. Under the guidance of their teachers, the participants responded to the test within 120 min, used 40 min to fill out the questionnaire, and their responses were delivered via the link. The data were recorded anonymously and privately and will be available for data analysis.

3.4. Data analysis

The data was analyzed using SPSS version 26 and Mplus version 8. The data were analyzed for the item's internal consistency with Cronbach alpha, construct validity with confirmatory factor analysis, and item's validity with Rasch analysis. We also performed a correlation analysis to explore the relationship between MCT and subtest of MCTTBE and between MCT, attitude, and ethnic identity.

4. Results

4.1. Association between MCT, ATM, and ethnic identity

Table 2 shows relationship between the variables. In Table 2, MCT ($M = 49.84$, $SD = 12.00$), ATM ($M = 95.79$, $SD = 16.23$), and ethnic identity ($M = 69.14$, $SD = 8.48$) were rated as "agree." There was a positive correlation between MCT and attitude ($r = 0.098$; $p < 0.01$), MCT and ethnic identity ($r = 0.081$; $p < 0.05$), attitude and MCT ($r = 0.157$; $p < 0.01$).

4.2. Overall effects and structural paths prior to the inclusion of the mediator variable

Table 3 presents the results of the structural paths analysis of the exogenous variables (attitude and ethnic identity) on the endogenous variable (MCT) in this study. The total effects of attitude on MCT ($\beta = 0.54$, $SE = 0.03$, $CR = 22.37$, $p < 0.001$) and ethnic identity ($\beta = 0.55$, $SE = 0.02$, $CR = 25.93$, $p < 0.001$) were both positive and significant, indicating that a positive ATM and a positive ethnic identity are associated with higher MCT. The total effect of ethnic identity on MCT ($\beta = 0.24$, $SE = 0.03$, $CR = 8.78$, $p < 0.001$) was also positive and significant, suggesting that having a positive ethnic identity is related to higher MCT. The R^2 value indicates that the exogenous variables explain 29.4% of the variance in MCT and the SE and CR values suggest that the results are robust and reliable. These results show that ATM was a significant predictor of both MCT and ethnic identity; a one unit increase in attitude resulted in a corresponding increase in MCT and ethnic identity by 0.54 and 0.55 units, respectively. Similarly, ethnic identity significantly predicted MCT; a one unit increase in ethnic identity led to an increase in MCT by 0.24 units. Overall, these findings suggest that ATM and ethnic identity are significant factors in the development of MCT.

4.3. The structural routes and direct effects, after the inclusion of the mediator variable

Covariance-based structural equation modeling (CB-SEM) was employed to examine the connection between attitude and MCT, where ethnicity as a mediator, are presented in Fig. 2. The goodness-of-fit indices for the path model are as follows: [$\chi^2(55) = 4195.92$, $p < 0.001$, RMSEA = 0.077, CFI = 0.948, TLI = 0.930, and SRMR = 0.044]. These results suggest that the proposed model is a good fit for the data.

Based on the model in Fig 2, ATM had a significant and positive direct effect on MCT ($\beta = 0.10$, $p < 0.05$), and ethnic identity ($\beta = 0.07$, $p < 0.001$). Ethnic identity also had a positive direct effect on MCT, but this was not statistically significant ($\beta = 0.15$, $p > 0.05$). In addition, there is any effect of attitude on MCT will be fully mediated through ethnicity. In this study, ATM indirectly influenced MCT through the mediating effect of ethnic identity [β (.15) x β (.07)] = .011, $p < 0.001$.

The regression correlation coefficients between ATM and MCT significantly decreased after the mediator variable, ethnic identity, was incorporated into the model, as presented in Tables 3 and 4 and Fig. 2. Furthermore, the mediated effect of ethnic identity on the association between ATM and MCT was statistically significant ($p < .05$). Thus, ethnicity played a crucial role in mediating the relationship between ATM and MCT.

Table 3
Structural paths and total effects leading up to a mediator variable.

	Exogenous variables	Structural Paths	Endogenous variables	β	R^2	SE	CR	p
Total effects	Attitude	→	MCT	0.54	0.49	0.03	22.37	< 0.001
	Attitude	→	Ethnics	0.55	0.29	0.02	25.93	< 0.001
	Ethnics	→	MCT	0.24		0.03	8.78	< 0.001

"β = Estimate; R^2 = Square Multiple Correlation; SE = Standard Error, CR = Critical Ratio"

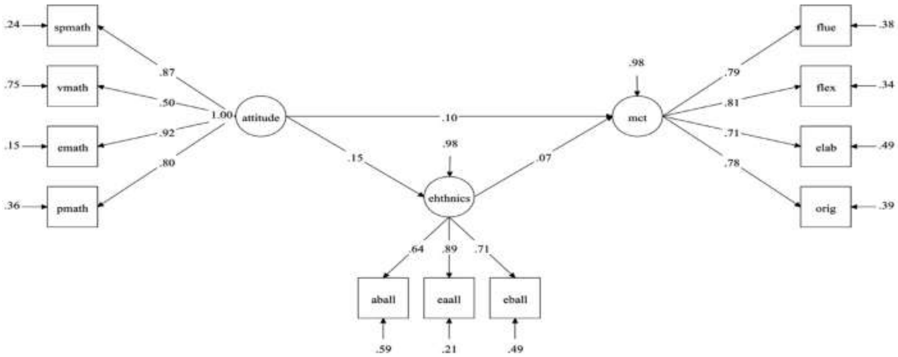

Fig. 2. A path diagram was utilized to display the standardized estimates of the model's goodness of fit.

Table 4
The direct effects and structural routes after adding a mediator variable.

	Exogenous variables	Structural Paths	Endogenous variables	β	R^2	SE	CR	p
Direct effects	Attitude	→	MCT	0.10	0.01	0.04	2.53	< 0.05
	Attitude	→	Ethnics	0.15	0.02	0.04	3.79	< 0.001
	Ethnics	→	MCT	0.07	-	0.04	1.66	$> .05$

β = Estimate; R^2 = Square Multiple Correlation; SE = Standard Error, CR = Critical Ratio

5. Discussion

The research findings showed that there was a notable and positive association between ATM, MCT, and ethnic identity, suggesting that having a positive attitude towards the subject could result in increased academic success and a more robust feeling of ethnic identity. Students with positive attitudes were likely to benefit more from the influence of both MCT and ethnic identity in their academic and personal endeavors. Thus, it can be inferred that cultivating a positive ATM could potentially have a positive impact on academic performance and personal identity. It is known that attitude plays a crucial role in regulating achievement and preventing distraction from minor issues. Previous studies have shown that a positive attitude toward learning and the task at hand can enhance focus on the primary objective, enabling individuals to work more efficiently toward achieving their desired outcomes (Huang et al., 2022; Tseng et al., 2013). By maintaining a positive attitude toward the main goal, individuals can free up mental capacity to strive for novel and inventive methods of attaining success, for example, in final examinations (Nja et al., 2022). Furthermore, research has shown that a positive attitude can lead to greater persistence in the face of challenges and setbacks, which is a key factor in achieving success (Wong & Fry, 2013). Therefore, it is important to cultivate a positive attitude toward learning and achievement to maximize performance and achieve success.

This study showed that CT can be enhanced through education, particularly in the field of mathematics, which can stimulate innovative ideas and actions. This is consistent with a previous research by (Hu et al., 2016). As education is an interdisciplinary field, there are many ways to achieve successful learning outcomes. Attitudinal change and elimination of CT barriers can help individuals develop multiple solutions to problems (Sowden et al., 2015). The present study highlights the importance of promoting a positive attitude and CT in educational context, as it can significantly influence students' success in problem-solving tasks.

The outcomes of the path analysis indicated that MCT was significantly predicted by ethnic identity. This is in line with previous studies (Bogilović et al., 2017; S. B. Kaufman et al., 2016; Saad et al., 2013). Social environment and cultural values influence the types of creative activities that individuals engage in. This study also supports findings that people who had multicultural social networks had a higher level of idea flow and creativity and were more likely to engage in creative problem-solving and generate more innovative ideas compared to those who had monocultural social networks. Hence, this study provides valuable insights into how culture, including multiculturalism, influences creativity and innovation and highlights the need to consider cultural factors when developing strategies to promote creativity in different cultural contexts.

In addition, ethnic identity mediated the relationship between ATM and MCT. This parallels previous studies (Jackson & Wilson, 2012; Laurence et al., 2018; Verdín & Godwin, 2018). Ethnicity may act as a mediator between attitude and mathematical creative thinking due to the cultural context and values associated with an individual's ethnic identity. Attitude shapes how one perceives and engages with mathematics, and these perceptions may be influenced by cultural beliefs or values tied to ethnicity, thereby impacting mathematical creative thinking. This finding can be explained in terms of Indonesia's unique cultural context, which is known for its multicultural environment in which a variety of ethnic groups such as Batak, Lampung, Javanese, Manado, and Mining coexist. Indonesian students prioritize academic performance to secure future career opportunities (Anwar et al., 2021; Bukodi et al., 2008; Hermino & Arifin, 2020; Maskur et al., 2022). Although they are highly motivated to learn mathematics (Shin et al., 2018), which indicates a positive ATM, this motivation may be influenced by external pressure from parents, teachers, relatives, and peers, which can have a negative impact on their overall wellbeing. Instead of exerting excessive pressure on students, schools and families should focus on inspiring them to learn and pursue their interests. Furthermore, parents and teachers should encourage students to pursue their talents and interests within the curriculum to improve their CT in mathematics.

6. Limitations and Future Research

Firstly, while measuring novel-idea flow was useful for some research questions, it did not fully capture the flow of ideas between individuals or how attitude and ethnicity influenced MCT. While the mediator variable, ethnic identity, led to a significant decrease in the correlation between attitude and MCT, the method relied on participants to select the ideas to report, which may have been influenced by recall and social desirability biases (Maxwell & Cole, 2007; Van Vo & Csapó, 2023).

Secondly, this was a cross-sectional study among only secondary school students. Self-reports as indicators of MCT performance are subject to bias, and with a small sample size, path models were only carried out within the marginal model for each cohort, which could affect the path analysis results. Hence, caution should be exercised when generalizing the results of this study. This underscores the need for large-scale investigations in the future.

Lastly, the study focused on the relationship between attitudes, ethnicity, and MCT, and did not consider other potential predictors of MCT (age, gender, and SES). Consequently, future research could investigate other mediator variables that could help to explain the relationship between ethnicity, attitude, and MCT. In addition, further research could explore the role of other factors such as educational background, cultural differences, and personality traits, in the development of MCT. Moreover, interventions could be designed to improve ATM and promote a positive ethnic identity among students, which could lead to improved MCT abilities.

Despite these limitations, the present study served as a foundation for further research into the content and origins of idea flow in educational settings. Future research could build on this methodology to improve the accuracy of idea-reporting measurements.

7. Conclusion

This study utilized path analyses and a cross-sectional approach to provide empirical evidence on how attitude and ethnicity can facilitate the generation of new ideas and improve students' performance in MCT. The findings revealed that ethnicity and attitude are significant factors in promoting creativity in mathematics, suggesting that having a positive ATM and a positive ethnic identity are crucial elements in the development of MCT. These findings would help mathematics educators to promote a positive ATM among students through stimulating and meaningful activities that enable students to explore mathematical concepts in a creative and interactive manner. While this study offers important information regarding the factors that influence the development of MCT, further investigation is required to comprehend the complex interaction among these variables. This can assist educators to design more effective teaching strategies that promote MCT among their students.

CRediT authorship contribution statement

Suherman Suherman: Conceptualization, Writing – original draft, Formal analysis, Methodology, Writing – review & editing, Visualization. **Tibor Vidákovich:** Supervision, Funding acquisition, Writing – review & editing.

Declaration of Competing Interest

There are no conflicts of interest to declare.

Data availability

Data will be made available on request.

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

(Suherman & Vidákovich, 2024a)

Mathematical Creative Thinking-Ethnomathematics based Test: Role of Attitude toward Mathematics, Creative Style, Ethnic Identity, and Parents' Educational Level

Pensamiento creativo matemático - prueba basada en la etnomatemática: rol de la actitud hacia las matemáticas, estilo creativo, identidad étnica y nivel educativo de los padres

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Resumen
El pensamiento creativo desempeña un papel crucial en el éxito académico en matemáticas, influenciado por diversos factores. Sin embargo, el impacto combinado de la educación de los padres, la identidad étnica, la actitud hacia las matemáticas y el estilo creativo en el pensamiento creativo matemático en el contexto de la etnomatemática no ha sido examinado de manera exhaustiva. En este estudio transversal, exploramos estas relaciones entre 896 estudiantes de secundaria seleccionados al azar de cinco escuelas públicas y privadas que completaron una prueba basada en etnomatemática de pensamiento creativo matemático (MCT) y cuestionarios. Los participantes tenían una edad promedio de 13.34 + 1.08 años, y más de la mitad eran hombres (53.7%). Los resultados mostraron que una actitud positiva hacia las matemáticas se relacionaba con niveles más altos de fluidez, flexibilidad y originalidad en el pensamiento creativo, mientras que una sólida identidad étnica se asociaba con una mayor flexibilidad. Aunque el estilo creativo y la educación de los padres tenían una correlación negativa con la creatividad en general, esta relación se volvía positiva al examinarla en diferentes niveles de grado. Curiosamente, la actitud hacia las matemáticas actuaba como mediadora, influyendo en el impacto de la formación educativa de los padres en la creatividad de los estudiantes. Este estudio contribuye a nuestra comprensión de la naturaleza multifacetica del pensamiento creativo matemático, ofreciendo conocimientos para mejorar la educación matemática en la era digital al reconocer la importancia del apoyo parental, la identidad étnica y las actitudes para fomentar la creatividad.
Palabras clave: estilo creativo, identidad étnica, etnomatemática, pensamiento creativo matemático, actitud hacia las matemáticas, educación de los padres.

Abstract
Creative thinking plays a crucial role in academic success in mathematics, influenced by various factors. However, the combined impact of parental education, ethnic identity, attitude towards mathematics, and creative style on mathematical creative thinking within the context of ethnomathematics has not been extensively examined. In this cross-sectional study, we explored these relationships among 896 secondary students randomly chosen from five public and private schools who completed MCT-ethnomathematics based test and questionnaires. The participants had an average age of 13.34 $\pm$ 1.08 years, with males comprising more than half (53.7%). The results showed that a positive attitude towards mathematics was linked to higher levels of fluency, flexibility, and originality in creative

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thinking, while a strong ethnic identity was associated with increased flexibility. Although creative style and parental education had a negative correlation with overall creativity, this relationship turned positive when examined across various grade levels. Interestingly, attitude towards mathematics acted as a mediator, influencing the impact of parental educational background on students' creativity. This study contributes to our understanding of the multifaceted nature of mathematical creative thinking, offering insights into enhancing mathematics education in the digital age by recognizing the significance of parental support, ethnic identity, and attitudes in fostering creativity.
Keywords: creative style, ethnic identity, ethnomathematics, mathematical creative thinking, attitude toward mathematics, parental education.

1. Introduction

Exploring creative thinking (CT) is crucial for students' learning experience and academic achievement in mathematics (Kozlowski et al., 2019). To achieve this, incorporating visual culture in education (Grodoski, 2016) and ethnomathematics (Orey & Rosa, 2007; Rosa & Orey, 2015), which acknowledges the cultural dimensions of mathematics, is vital. Moreover, research has highlighted the relationship between mathematical creative thinking (MCT) and students' overall competence and sense of identity within their cultural environment (Hongjia et al., 2018). Hence, MCT is not only an academic pursuit but also a means of strengthening students' affiliation with their ethnicity and culture (Soler Pastor et al., 2022; Tidikis et al., 2018). Despite these insights, the factors influencing student creativity, particularly in mathematics, remain unclear (Liu et al., 2021; Power, 2015; RN Wang & Chang, 2022; Wu et al., 2022). Understanding these factors, especially within the context of mathematics and culture (i.e., ethnomathematics), becomes crucial in devising effective educational strategies and fostering students' intellectual growth. It refers to the culture offers a natural means for students to access a framework for conceptual understanding in mathematics (Harding-DeKam, 2014). Furthermore, attitude plays a crucial role in shaping students' mathematical learning experiences and outcomes, and its impact on MCT has garnered significant attention in scientific research. Recent research by Kurdal & Kaplan (2023) has shown a significant positive correlation between students' metacognitive awareness (i.e., thinking process) and their attitude toward mathematics (ATM). Additionaly, studies indicate that parental education level (PED) is a predictor of mathematics achievement (Hidayatullah & Csíkos, 2023), and creative style is predictive of creativity (Wechsler et al., 2012). While several studies have explored the relationship between MCT and individual factors like PED, ethnic identity, attitude toward mathematics (ATM), and creative style (CST), there exists a research gap regarding their combined impact on MCT. To address this gap, our study aims to examine how these factors interact and influence students' MCT abilities across various grade levels.

2. Literature Review

MCT and Ethnomathematics

MCT has been a subject of growing interest and has received significant research attention (Liu et al., 2021; Power, 2015; Suherman & Vidákovich, 2022b; R.-N. Wang & Chang, 2022; Wu et al., 2022). These factors include ethnomathematics, parents' educational level, ATM, ethnic identity, and creative style. Ethnomathematics enhances students' understanding and appreciation by linking mathematical concepts to real-world contexts and diverse cultural practices (Orey & Rosa, 2007; Rosa & Orey, 2015). The connection between MCT and ethnomathematics lies in the idea that studying and understanding different cultural mathematical practices can stimulate and improve MCT. When individuals are exposed to various mathematical ideas and problem solving methods from various cultural contexts, it can broaden their perspectives and encourage them to think creatively about mathematical concepts (D'Ambrosio & Rosa, 2017; Rosa & Orey, 2016; Suherman & Vidakovich, 2022a).

Role of Parents' Educational Level

Parents' educational level considerably shapes students' academic achievement and educational outcomes and serves as a strong predictor of their involvement in their children's education (Davis-Kean et al., 2021), as well as their ability to provide a supportive learning environment at home (Lehrl et al., 2020). Moreover, parental education plays a crucial role in influencing children's interaction in educational attainment (Gil-Hernández, 2019; Mönkediek & Diewald, 2022), cognitive development (Danovitch, 2019), CT development (C. Tang et al., 2022; Zhao & Yang, 2021), and overall academic success (Tazouti & Jarlégan, 2019). Studies on the influence of ethnic identity on MCT have demonstrated that cultural context plays an important role in shaping the expression of creativity and its development among people in different regions (Cabra & Guerrero, 2022; Karwowski, 2016; Rudowicz, 2003; M. Tang et al., 2018; Torrance, 1974; Zheng et al., 2023).

Creative Styles and Their Contribution to MCT

Creative style refers to individual differences in how creative tasks are approached and engaged (Nori et al., 2018). There was a prevailing belief that CT abilities were limited to a small group of exceptionally talented individuals with unique problem solving and creative skills (Wang et al., 2017). However, recent studies have recognized that creativity can be developed and nurtured in all students through close interactions and supportive environments (Behnamnia et al., 2020; Kim et al., 2016; Renzulli & Reis, 2021). Studies have also shown that creative style influences creativity and that a diverse range of creative styles contribute to innovative CT in various contexts (Chen et al., 2015; Rodet, 2021) and influence approaches to problem solving and academic and career achievement (Ee et al., 2007; Mkpanang, 2016; White & Shah, 2011). These previous studies explored the relationship between MCT and these factors separately; however, there exists a research gap regarding their combined impact on MCT. Moreover, the specific association between parents' educational level and changes in CT in the context of mathematics is unclear. Hence, this study explored the influence of ATM, ethnic identity, parental education, and creative style on MCT among secondary school students. We hypothesized that these variables would have a positive correlation with MCT. Understanding these factors, especially within cultural contexts, is crucial in developing effective educational strategies and fostering students' intellectual growth.

Present Study

The present study, conducted in the context of secondary education in Indonesia, aims to delve into the impact of the MTC-ethnomathematics based test (MCTBE) on students' MCT. This impact is explored with regard to various factors previously mentioned, such as parental educational level, ethnic identity, attitude towards mathematics, and creative style. The rationale for this investigation is grounded in the evidence compiled from a comprehensive literature review. As previously discussed, there is a growing body of research emphasizing the significance of these factors in shaping students' MCT abilities. However, the combined and interactive effects of these factors, particularly in the context of ethnomathematics, have not been extensively explored. Therefore, the current study seeks to bridge this research gap and provide a more comprehensive understanding of how these factors collectively influence students' MCT within the specific educational landscape of Indonesia's secondary schools.

In line with our research objectives, we have formulated the following research questions (RQ) to guide our investigation:

1. (RQ1) How can students' performance on the MTC-ethnomathematics based test (MCTBE) be effectively assessed?
2. (RQ2) What is the collective impact of attitude towards mathematics (ATM), CST, ethnic identity, and PED level on students' performance in the MCTBE?

3. Method

Participants and Procedure

The research involved 896 students who were in grades 7 to 9 and attended both private and public secondary schools in Lampung province, Indonesia. The students were randomly selected and informed consent was obtained from them prior to their participation. The study was carried out in accordance with the Declaration of Helsinki and was approved by the Institutional Review Board of the Doctoral School of Education, University of Szeged (Approval number 6/2023). Confidentiality was maintained, and participants were informed of their right to refuse or withdraw participation anytime during the study without consequence. Students took approximately 120 min to complete the instruments under the supervision of both their teacher and assistant teacher.

Table 1
Participants socio-demographic characteristics

Characteristics	*N*	Percentage (%)	Mean age (years)
Grade			
7	306	34.2	12.21
8	292	32.6	13.41
9	298	33.3	14.43
Gender			
Girl	481	53.7	13.43
Boy	415	46.3	13.24
Ethnic			
Batak	57	6.4	12.91
Bugis	25	2.8	12.76
Java	411	45.9	13.27
Lampung	158	17.6	13.85
Manado	51	5.7	12.76
Minang	35	3.9	13.51
Others	47	5.2	12.98
Palembang	25	2.8	13.44
Sundanese	87	9.7	13.62

Characteristics	*N*	Percentage (%)	Mean age (years)
Type School			
Private	449	50.1	13.28
Public	447	49.4	13.40

Table 1 presents the characteristics of the participants. Their mean age was 13.34 ± 1.08 years and more than half (53.7%) were males. Table 2 presents their parents' educational levels. Forty-six percent of the participants were from the Javanese ethnic group (45.9%), Lampung (17.6), while Bugis and Palembang were only 2.8%.

Table 2
Parents' highest level of education

Grade	Mother's Education Level			Father's Education Level		
	I (%)	II (%)	III (%)	I (%)	II (%)	III (%)
7	0	59.5	40.5	0.3	60.8	38.9
8	0	20.3	79.7	1.0	21.3	77.7
9	8.4	25.2	66.4	13.8	17.1	69.1

Note: I: education without experience, did not complete grade 6; II: primary education, secondary education, high school education; III: higher education (diploma, bachelor, master and doctorate).

Instruments

MCTBE

To assess MCT, we incorporated 20 items from the Tapis Lampung framework, which carries ethnomathematics nuances (Fig. 1). Tapis Lampung serves as a manifestation of mathematical ideas, making it apt to be regarded as a mathematical concept within this context. This categorization is justified by the complex geometric patterns, symmetry, and the incorporation of mathematical principles in its design (Suherman & Vidakovich, 2022a). Tapis Lampung, originating from Indonesia's Lampung province, is rich in cultural and historical significance. Its intricate geometric patterns form the basis for assessing students' Mathematical Creative Thinking (MCT). These patterns engage students in recognizing and manipulating mathematical elements, connecting academic learning with their cultural experiences, particularly in the context of buying and selling activities that are central to Lampung culture. This approach blends math and culture within ethnomathematics, promoting a holistic understanding that extends beyond the classroom, making Tapis Lampung an ideal tool for evaluating MCT.

The items were designed to cover two distinct subtests: the figural and verbal components. In the figural subtest, students were presented with visual representations or diagrams of mathematical concepts and were required to analyze and interpret the figures to demonstrate their CT skills in solving mathematical problems. Moreover, the verbal subtest assessed students' ability to apply MCT through writing and to use clear and logical communication to articulate mathematical ideas, justify their solutions, and evaluate mathematical arguments. The fit of the items was conducted in a previous study using rapid measurement validation (Suherman & Vidakovich, 2022b). The fit indices for the average MCTBE item, including Infit mean square (MNSQ) and Outfit MNSQ, were 1.01 and 0.99, respectively, and the Cronbach's alpha (α) coefficient was 0.76.

Figure 1
An example of the MCTBE item test

No.1. Following is the Tapis Lampung pattern. You can see the triangle pattern in this motif. Make five different pictures from them, based on the pattern you see in the motif. Give a title for each image.

ATM

We developed a set of 26 items to assess ATM. These items were classified into four subscales: self-perception of mathematics, value of mathematics, enjoyment of mathematics, and perceived mathematics achievement. These subscales were adapted from the work of Suherman & Vidákovach (2022). Reliability tests for the four scales, which included consistency reliability using Cronbach's α and composite reliability using McDonald's omega (ω), yielded values ranging from 0.79 to 0.89. The items were measured on a five-point Likert scale (1 = strongly disagree and 5 = strongly agree). Students were asked to indicate their level of agreement with each statement by selecting one of the five response options.

Multigroup ethnic identity inventory (MEI2)

Ethical identity was also measured on a five-point Likert scale (1 = strongly disagree and 5 = strongly agree) using a questionnaire that was adapted from Phinney (1992). The questionnaire had 19 items that were categorized into three subscales: affirmation of belonging, achievement of ethnic identity, and ethnic belonging. The measure of internal consistency to determine the reliability of the three subscales yielded Cronbach's α coefficient ranging from 0.64 to 0.85.

Creative style inventory (CSQ)

This questionnaire assesses the perspectives and techniques individuals employ to foster creativity in their endeavors (Kumar et al., 1997). The questionnaire was adapted from Kumar et al. (1997) into eight subtests with 57 items: creativity capacity, belief in unconscious, use of techniques, use of other people, final product orientation, environmental control/behavioral self-regulation, superstition, and use of sense. The Cronbach's α coefficient for the eight subtests ranged from 0.64 to 0.82. The summary of ATM, MEI2, and CSQ are presented in the table 3.

Table 3
Summary of the validity and reliability.

Variables	CFI	TLI	RMSEA	SRMR	α
ATM	0.92	0.91	0.05	0.06	0.85
MEI	0.93	0.91	0.05	0.05	0.73
CSQ	0.94	0.92	0.04	0.05	0.76

Background questionnaire

Information on the parents' highest level of education (PED) was obtained from the students and was categorized into seven, according to the Indonesian education system (1-no formal education, 2-primary education, 3-secondary education, 4-high school, 5-bachelor's, 6-master's, and 7-doctoral).

Overall, the Cronbach's α values obtained for the ATM, MEI2, CSQ, and PED questionnaires were $\alpha = 0.85$, $\alpha = 0.73$, $\alpha = 0.76$, and $\alpha = 0.78$, respectively, indicating an acceptable reliability.

Data Analysis

The first step involved in analyzing the test instruments was to assess their validity. For reliability estimates, we utilized Cronbach's α as an internal consistency indicator using JASP version 0.16.3 (J. Team, 2022). Statistical distribution and correlation analysis was performed using SPSS version 26 while R version 4.2.2 (R. C. Team, 2022) with pirate plots was used to visualize the participants' performance at different grade levels. Path analysis was performed using MPlus version 8 (Muthén & Muthén, 2017) to assess the model's fit. For model evaluation, we considered four main index criteria recommended by Hu & Bentler (1999): comparative fit index (CFI), Tucker Lewis index (TLI), root mean square error of approximation (RMSEA), and standardized root mean squared residual (SRMR). They suggested cutoff criteria close to 0.95 for TLI and CFI, and < 0.05 for RMSEA. In this study, we used maximum likelihood parameter estimates.

4. Results

We used descriptive statistics to examine the correlations between variables (see Table 6). Table 6 shows the descriptive statistics and correlations among variables. There were significant positive correlations (p <.01) between the MCTBE subtests: fluency-flexibility (r = .671), fluency-elaboration (r = .538), fluency-originality (r = .589), flexibility-elaboration (r = .547), flexibility-originality (r = .618), and elaboration-originality (r = .620). ATM was positively related to fluency (r = .107, p <.01), flexibility (r = .085, p <.05), and originality (r = .072, p <.05), and elaboration (r = .038, p <.05). MEI2 had a significant positive correlation with flexibility (r = .096, p < .01), then a positive correlation with other MCTBE subtests. There were negative correlation between MCTBE subtest with CSQ: fluency-CSQ (r = -.013, p > .01) and elaboration-CSQ (r = -.041, p > .01). FE was positively related to fluency (r = .009, p <.01) and flexibility (r = -.002, p <.01). Surprisingly, there was linear relationship between MCTBE subtests (elaboration) and ME (r = .002, p <.01).

Pirate plots were used to visualize the participants' performance by grade level (Fig. 2) and the responses of the model of students at different grade levels for subtest no.1 (Fig. 3). The 9th graders had the highest mean (M_{score}) and standard deviation (SD) fluency subtest scores (16.63 ± 3.77), followed by the 7th graders (16.43 ± 4.13) and the 8th graders (16.27 ± 3.99) (Fig. 2a). Although the 8th graders had a lower mean flexibility score (16.66 ± 6.21) than the 9th graders (17.25 ± 6.20), they were highly proficient and completed the MCTBE subtests (Fig. 2b). For the originality subtest (Fig. 2c), grade 7 had the highest mean score (M = 10.16 ± 2.57), followed by grade 9 (10.13 ± 2.34) and grade 8 (9.78 ± 2.49). This was similar to the elaboration subtest (Fig. 2d), with the 7th graders achieving the highest mean score (6.48 ± 1.29), followed by the 9th graders (6.39 ± 1.28) and 8th grades (6.33 ± 1.29). The detail is in the table 5.

Table 5
Students performance by grade.

Grade	Frequency	Fluency	Flexibility	Elaboration	Originality
7	M_{score}	16.43	16.99	6.48	10.16
	SD	4.13	6.23	1.29	2.57
8	M_{score}	16.27	16.66	6.33	9.78
	SD	3.99	6.21	1.29	2.49
9	M_{score}	16.63	17.25	6.39	10.13
	SD	3.77	6.20	1.28	2.34

We examined the predictive role of exploratory variables (ATM, MEI2, CST, FE, and ME) on MCTBE scores. A path model was calculated for all grade levels and the model's fit was highly satisfactory [$\chi^2(3) = 5.568$, CFI = .995, TLI = .977, SRMR = .015, RMSEA = .031 (90% CI = .000–.071)]. MCTBE score was significantly associated with ATM (β = .087) and MEI2 (β = .068) (p <.05), but not with CST (β = .029, p = .51), ME (β = .003, p = .92), and FE (−.032, p = .46).

By grade level (Fig. 4), the model's fit was adequate for the 7th grade [$\chi^2(3) = 5.438$, CFI = .991, TLI = .956, SRMR = .024, RMSEA = 0.052 (90% CI: 0.000 - 0.120)]. In seventh grade, ATM (β = .183), MEI2 (β = .071), and CST (β = .044) had positive relationships (p <.05) with MCTBE, while FE (β = −.067, p = .91) and ME (β = −.007; p = 0.41) had negative relationships. FE and ME had a positive indirect influence on CST and ATM, which in turn influenced MCTBE, respectively (β = .725, β = 0.014; p <.05). In eighth grade, MCTBE had a positive association with ATM (β = .002), MEI2 (β = .016), and CST (β = .124) (p <.05), but a negative association with FE (β = −.030, p = .45) and ME (β = -.044; p = 0.67). FE and ME had a positive indirect influence on CST and ATM, which in turn influenced MCTBE, respectively (β = .577, β = 0.066; p <.05).

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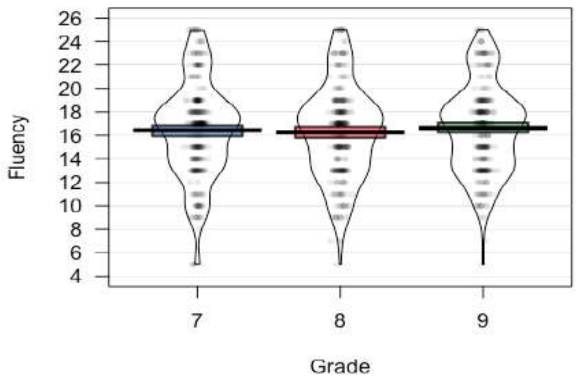
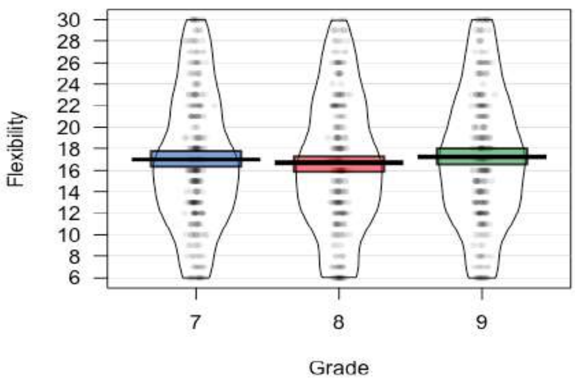
Figure 2

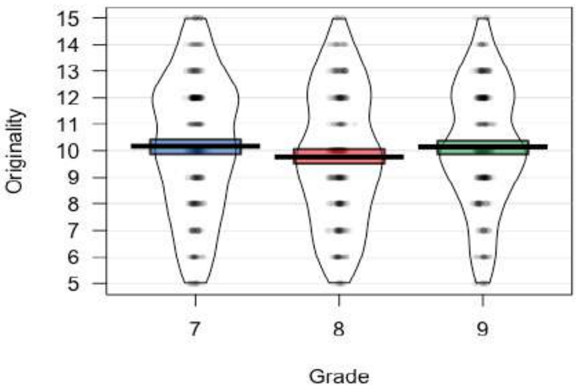
Student performance by grade levels across the four creative thinking tests: a) fluency, b) flexibility, c) originality, and d) elaboration.



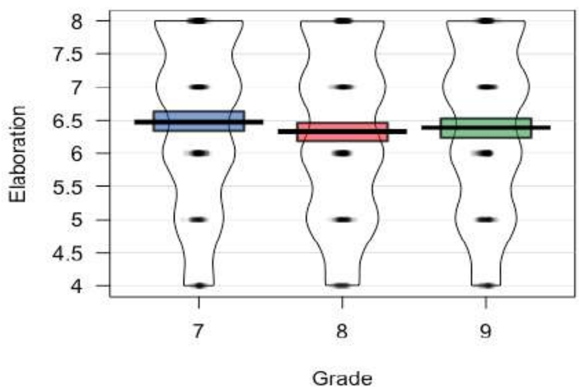
a) Fluency



b) Flexibility



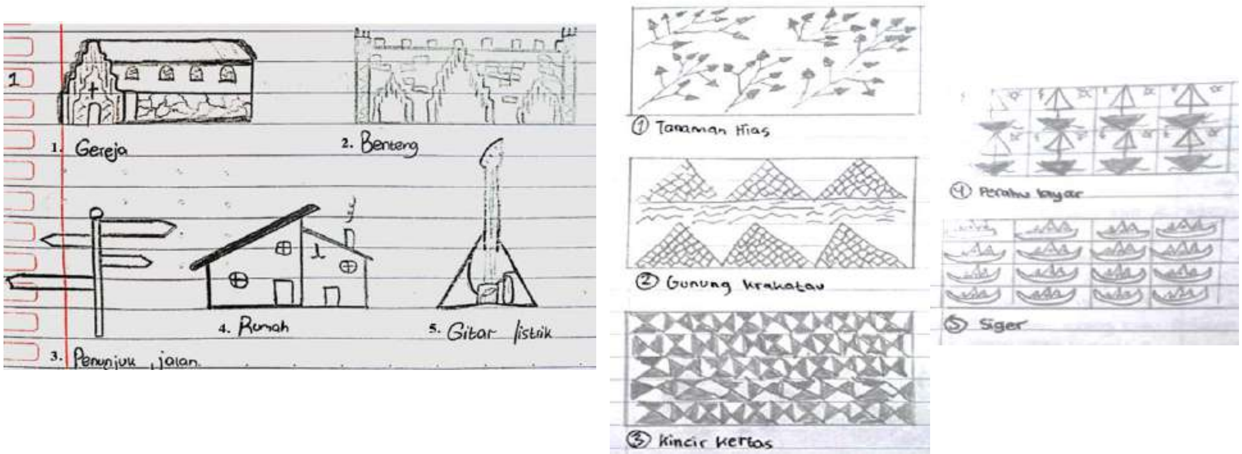
c) Originality



d) Elaboration

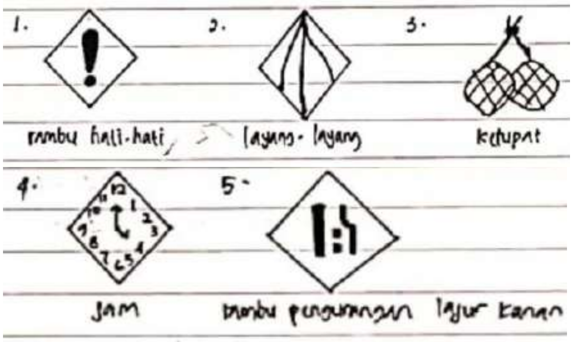
In ninth grade, MEI2 ($\beta = .217$, $p < .05$) and FE ($\beta = 041$, $p < .05$) exhibited a positive direct effect in relation to MCTBE. However, ATM and CST had a negative effect on MCTBE. Overall, fathers' education had a positive effect on their children's MCTBE achievement. Specifically, FE positively contributed to MCTBE achievement ($\beta = .041$, $p <.05$). MEI2 also had a positive influence on MCTBE ($\beta = .217$, $p <.05$). Furthermore, ME had a direct positive effect on MCTBE achievement in relation to CST and ATM, respectively ($\beta = .002$, $\beta = .00001$, $p >.05$).

Figure 3
Pattern of students' responses in the flexibility subtest by grade levels.



a) Grade 7 (1 = church; 2 = fortress; 3 = signpost; 4 = house; 5 = classical guitar)

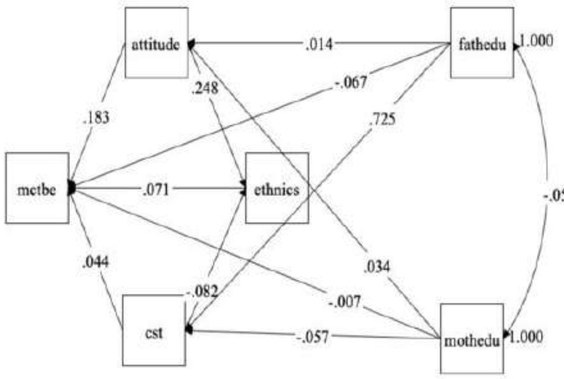
b) Grade 8 (1 = ornamental plants; 2 = Krakatoa Mountain; 3 = paper windmill; 4 = traditional boat; 5 = siger) (traditional headdress)



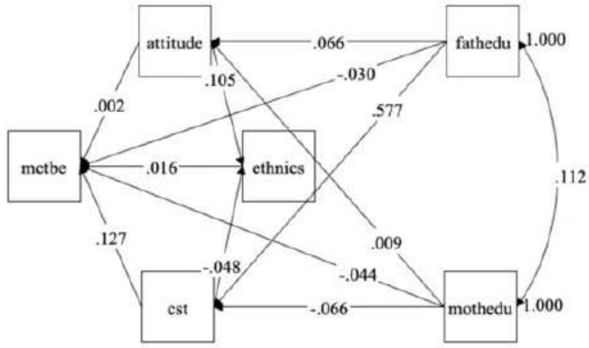
c) Grade 9 (1 = warning sign; 2 = Kite; 3 = "ketupat"/Diamond-shaped rice cake; 4 = Clock; 5 = Right Lane Ends)

Figure 4

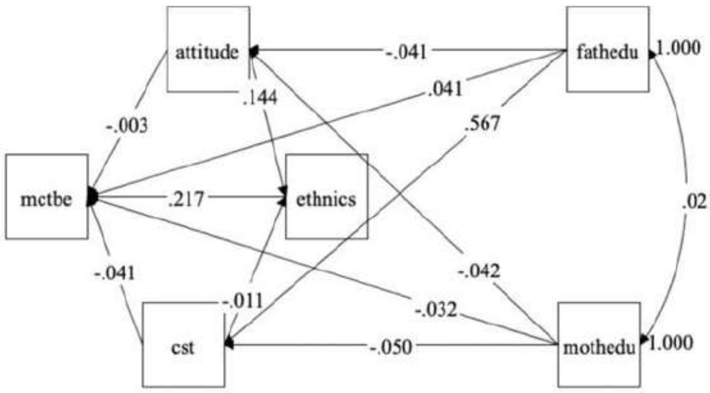
Path models for each grade with standardized values to predict MCTBE: ethnic identity (ethnics), attitude toward mathematics (attitude), creative style test (CSQ), mother's education (mothedu), father's education (fathedu), mathematics creative thinking-based ethnomathematics test (mctbe).



a). 7th grade ($\chi^2(3)$ = 5.438, *CFI* = .991, *TLI* = .956, *SRMR* = .024, RMSEA = 0.052 (90% CI: 0.000–0.120) R^2 = .047)



b). 8th grade ($\chi^2(3)$ = 6.623, *CFI* = .970, *TLI* = .858, *SRMR* = .027, RMSEA = 0.064, (90% CI = 0.000 - 0.132), R^2 = .015)



c). 9th grade ($\chi^2(3)$ = 6.243, *CFI* = .975, *TLI* = .884, *SRMR* = .024, RMSEA = 0.060, 90% CI = 0.000–0.128), R^2 = .049)

Table 6
Result of model analisis.

Measurement model	Grade 7th			Grade 8th			Grade 9th		
	β_0	*S.E.*	*p*	β_0	*S.E.*	*p*	β_0	*S.E.*	*p*
Ethnics → MCTBE	0.071	0.058	< 0.05	0.016	0.059	> 0.05	0.217	0.056	< 0.01
Attitude → MCTBE	0.183	0.057	< 0.01	0.002	0.059	> 0.05	-0.003	0.057	> 0.05
CST → MCTBE	0.044	0.082	> 0.05	0.127	0.071	< 0.05	-0.041	0.059	> 0.05
Mothedu → MCTBE	-0.007	0.057	> 0.05	-0.044	0.059	> 0.05	-0.032	0.057	> 0.05
Fathedu → MCTBE	-0.034	0.081	> 0.05	-.033	0.072	> 0.05	0.041	0.069	> 0.05
Mothedu → Attitude	0.014	0.057	> 0.05	0.066	0.059	> 0.05	-0.041	0.058	> 0.05
Fathedu → Attitude	0.034	0.057	> 0.05	0.009	0.059	> 0.05	-0.042	0.058	> 0.05
Attitude → Ethnics	0.248	0.054	< 0.01	0.105	0.058	> 0.05	0.144	0.057	< 0.05
CST → Ethnics	-0.082	0.055	> 0.05	-0.048	0.058	> 0.05	-0.011	0.057	> 0.05
Mothedu → CST	0.725	0.027	< 0.01	0.577	0.040	< 0.01	0.567	0.039	< 0.01
Fathedu → CST	-0.057	0.039	> 0.05	-0.066	0.048	> 0.05	-0.050	0.048	> 0.05
Fathedu ↔ Mothedu	-0.052	0.057	> 0.05	0.112	0.058	< 0.05	0.021	0.058	> 0.05

Note: Ethnics = Ethnic identity; CST = creative style test; mothedu =mother's education; fathedu = father's education; MCTBE = mathematics creative thinking-based ethnomathematics test; β_0 = standardized coefficient; S.E. = standard error.

Table 7
Descriptive statistics and correlations among variables.

	Mean	SD	1	2	3	4	5	6	7	8	9	10
1. MCTBE	49.84	11.99	1	.857**	.926**	.696**	.788**	.098**	.081*	-.004	.007	-.014
2. Fluency	16.45	3.97		1	.671**	.538**	.589**	.107**	.063	-.013	.009	-.013
3. Flexibility	16.97	6.21			1	.547**	.618**	.085*	.096**	.005	.022	-.009
4. Elaboration	6.40	1.28				1	.620**	.038	.056	-.041	-.017	.002
5. Originality	10.03	2.48					1	.072*	.021	.007	-.028	-.025
6. ATM	95.79	16.23						1	.157**	-.073*	.006	-.005
7. MEI2	69.14	8.48							1	.006	-.019	.005
8. CSQ	80.29	9.68								1	-.049	.010
9. FE	5.07	1.75									1	.645**
10. ME	5.00	1.58										1

Note. N = 896, MCTBE = Mathematics Creative Thinking based Ethnomathematics test, ATM = Attitude towards Mathematics, MEI2 = Multigroup Ethnic Identity Inventory, CSQ = Creative Style Questionnaire, FE = Father Education, ME = Mother Education. ** $p < 0.01$, * $p < 0.05$.

5. Discussion

This study was conducted to better understand the roles of ATM, MEI2, parental education level, and CST in MCTBE. Our findings showed significant correlations between the MCTBE subtests, indicating that they are interrelated. This parallels a previous report that different aspects of CT are inextricably linked with parents education (Pugsley & Acar, 2020), innovative style of creativity (Ramos & Puccio, 2014), and cultural backgrounds have been identified as conducive to nurturing creativity (Luria et al., 2016). Interestingly, people with strong cognitive shift skills and higher intelligence scores are more likely to demonstrate creativity, particularly in terms of producing a greater quantity of ideas, showing flexibility, generating original and unique creative solutions (Pan & Yu, 2018), and able to formulate real solutions (Farida et al., 2022). Studies have highlighted the importance of attitude in fostering CT (Shalley & Gilson, 2004). In this study, ATM had a positive relationship with fluency, flexibility, and originality, but a negative relationship with elaboration, suggesting that students with a positive ATM are more fluent, flexible, and original in their MCT but struggle with elaboration. MEI2 had a positive correlation with flexibility but a negative correlation with other MCTBE subtests. This indicates that students with a strong ethnic identity are more adaptable in their CT, but may not excel in other aspects of CT. This finding is consistent the study by Al-Suleiman (2009) which demonstrated the influence of cultural factors on CT. Surprisingly, the MCTBE subtests did not show significant correlations with CSQ, FE and ME, indicating that creativity ability, environmental control / behavior self-regulation, and family educational level do not have a direct impact on specific aspects of MCT. This contradicts previous research that have suggested that creative style and socioeconomic status are important in promoting CT (Castillo-Vergara et al., 2018; Liang et al., 2022; M.-Z. Wang et al., 2017).

Pirate plots have been shown to be effective in displaying scores distribution and identifying patterns in data (Van Vo & Csapó, 2023). This study used pirate plots to visualize variations in MCTBE scores by grade level. The results revealed interesting patterns in the students' performance at different grade levels in the MCTBE fluency, flexibility, originality, and elaboration subtests. In the fluency subtest, the mean scores of students from grades 7 to 9 showed a gradual decrease, with the lowest mean score observed in the 9^{th} grade. This indicates that as students' progress to higher grade levels, their fluency in CT decline. Similarly, in the originality subtest, the mean scores of students from grades 7 to 9 showed a slight decrease, indicating a possible decrease in their ability to generate original and innovative ideas as they advance in grade levels. Eighth graders achieved a lower score than ninth graders in the flexibility subtest, suggesting that students in eighth grade may have faced some challenges in their CT flexibility, but they were able to overcome these challenges and perform better in ninth grade. The elaboration subtest displayed relatively consistent mean scores across all grade levels, with a slight difference between the seventh and ninth grades. This indicates that students' ability to elaborate and develop their ideas remain relatively stable as they progress through different grade levels. Our finding on the MCTBE subtests is consistent with that of Cheung et al. (2003), which demonstrated that creative potential in college students varied across different years levels, with some aspects of creativity declining in verbal fluency and flexibility as students progressed to higher grades.
Overall, the path model analysis in this study was a good fit and by grades, the model's fit was adequate for the 7th grade, indicating that the selected variables accounted well

for the variance in MCTBE scores. Children and adolescents go through various developmental stages. Grade 7 students may be at a stage where they are more open to influences on their attitudes and creativity. Older students in grades 8 and 9 might be going through stages that emphasize other aspects of development or have already formed more stable attitudes. This outcome supports the findings of Gralewski et al. (2016) who also observed a decline in creative thinking during adolescence, specifically in the Test of Creative Thinking- Drawing Production, which measures figural creativity. The decrease in creativity scores between grade 8 and grade 9 can be attributed to the transition from lower grades (grade 8) to higher grades (grade 9) (Hemdan & Kazem, 2019), where students might begin to adopt more convergent thinking, particularly in applied science or context-based curricula. The process of identity formation during early adolescence, involving the adaptation to social norms and rules, may have a detrimental effect on creative thinking (Hemdan & Kazem, 2019). Furthermore, the rapid developmental changes in the brain, which emphasize a reduction in mathematical concepts, could also be a contributing factor. The results imply that teachers in secondary school, especially in higher-level classes, there should be a focus on promoting activities that encourage divergent thinking in addition to fostering intellectual abilities and academic achievement.

Our findings on significant positive association of ATM and MEI2 with MCTBE scores show that the ability to generate new and favorable original ideas (Davadas & Lay, 2017) and the willingness to explore and take risks in thinking (Grodoski, 2016) are important factors that contribute to higher CT abilities in students. Good attitude is significantly associated with divergent thinking in terms of CT (Basadur et al., 2000), and ethnicity as a moderator of creativity (Paletz & Peng, 2009) and creative style (Ülger & Morsünbül, 2016) are associated with producing original ideas. The positive relationship of ATM, MEI2, and creative style with MCTBE score among 7th and 8th graders in the current study suggests that idea generation, exploratory thinking, and creative style are important factors that contribute to higher CT abilities in students at this grade level.

FE and ME had a negative influence on MCTBE in the 7th and 8th graders, indicating that field dependence and memory efficiency may hinder students CT abilities. One possible explanation for this finding is the disparity between parents educational background and the teaching approach used in MCTBE. Parents with higher levels of education often prefer traditional and formal teaching methods (Li, 2006) that prioritize rote learning and support traditional modes of assessment like standardized testing (Harris, 2015). However, MCTBE encourages creativity, exploration, and the application of mathematics in real-life contexts, which may be unfamiliar and undervalued by parents with limited exposure to such approaches (Jay et al., 2018). Furthermore, some parents may feel unconfident or excluded from supporting their children because they do not understand the modern approaches to teaching mathematics (McMullen & de Abreu, 2011).

The indirect positive influence of FE and ME on MCTBE through their effects on ATM and CST in 7th and 8th graders imply that they indirectly impact CT abilities through their influence on idea generation and creative style. Conversely, ATM and CST had a negative effect on MCTBE in 9th graders, indicating that idea generation and creative style may not be as strong in predicting CT abilities at this grade level. However, fathers' education had a positive impact on their children's MCTBE achievement. This contributes to the growing body of knowledge on the role of family background in creativity, underscores the importance of parental participation and support and provides valuable information for educators and parents to promote positive mathematics learning experiences for children (Retanal et al., 2021). Additionally, the family environment and educational level indirectly contribute to students' cognitive strategies for learning mathematics (Lehrl et al., 2020), which in turn influence their performance in MCT.

6. Limitations and Future Research

This study had some limitations. First, it was a cross-sectional design; hence, a cause and effect relationship could not be established. However, the design offers valuable insights into the developmental trajectory of CT abilities. Second, the study was conducted among a relatively small sample of students of certain grade levels, which may limit the generalizability of the findings to other populations. Third, the study focused solely on MCT and its relationship with attitude, ethnic identity, creative style, and parental education, but did not explore other subjects and potential factors, such as teacher influence, school type, and school climate. Fourth, the study relied on self-report measures, which is subject to response bias and social desirability effects.

While this study provides valuable information on the relationships between ATM, ethnic identity, creative style, parental education, and MCT abilities, it also identifies areas for future research. First, longitudinal designs, diverse samples, and multiple methods (performance-based tasks and divergent thinking tasks) that would help to gain a more comprehensive and nuanced understanding of how the complex interplay of these factors shape MCT among students in different contexts should be explored. Second, observational or behavioral measures would provide more objective assessment of CT abilities. Lastly, exploring CT in various subjects, such as science, language arts, and arts, could shed light on the transferability of CT skills and their application in different academic areas.

7. Conclusions

This study explored the relationship between ATM, ethnic identity, creative style, parents' education, and MCTBE and highlighted the complex interplay of these variables on CT among students of different grade levels. Furthermore, people with strong cognitive shift skills and higher intelligence scores were more likely to be creative, particularly in terms of producing a greater amount of ideas, showing flexibility, and generating original and unique creative solutions. Thus, it demonstrates that idea generation, exploratory thinking, and creative style are important factors in fostering CT abilities. To summarize, the finding of this study pointed out that a positive ATM was associated with greater fluency, flexibility, and originality in CT, but had a negative relationship with elaboration. Similarly, students with a strong ethnic identity showed greater flexibility in creative thinking, while not excelling in other aspects of CT. Interestingly, the MCTBE subtest did not show significant correlations with creative style and parental education for exploration. This suggests that these factors may not have a direct impact on specific aspects of CT in the context of mathematics. Path model analysis showed that ATM and ethnic identity had significant positive associations with MCTBE scores, implying that the ability to generate new and original ideas and the willingness to explore and take risks in thinking were important factors contributing to higher CT abilities in students. In particular, father education positively impacted their children's MCTBE achievement, emphasising the role of parental involvement and support in promoting positive maths learning experiences. It also underscores the importance of improving ATM, embracing cultural sensitivity, promoting parental involvement and support, integrating CT into the curriculum, training teachers, and fostering collaboration between policymakers and researchers in nurturing MCT and enhancing overall educational outcomes in the Indonesian digital society.

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

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

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ABSTRACT

In the field of education, research has consistently emphasized mathematical creative thinking as a crucial component of 21st-century skills. Thus, this cross-sectional study examines the predictors of such thinking by specifically focusing on the roles of perceived creativity, creative self-efficacy, and computational thinking. The participants consisted of 896 secondary school students (52.9 % female; 47.1 % male) in Indonesia who were asked to complete a series of online questionnaires and tests. For analysis, structural equation modeling was employed, demonstrating satisfactory construct validity and instrument reliability. Based on the results, there was a positive association between computational thinking and mathematical creative thinking. In addition, perceived creativity had a positive impact on mathematical creative thinking, whereas creative self-efficacy showed a negative association. As for the empirical model, it revealed that computational thinking plays a mediating role, connecting perceived creativity and creative self-efficacy to mathematical creative thinking. The findings suggest that incorporating these skills and related variables into the mathematics curriculums in schools is essential for preparing students for success in the 21st century.

1. Introduction

In the ever-evolving landscape of education, mathematical creative thinking (MCT) has transcended traditional boundaries, emerging as a vital skill applicable across diverse disciplines such as mathematics and music (Azaryahu et al., 2023), art (Sharma & Kumar 2023), engineering (Zhan et al., 2023), and science (Yang et al., 2022). Specifically, MCT surpasses routine problem-solving, serving as a catalyst for both critical thinking and innovation. This paradigm shift acknowledges that future challenges will demand that individuals are capable of navigating various complexities and offering innovative perspectives. In this regard, the cultivation of MCT becomes a collaborative endeavor and an essential part of the complete process of advanced mathematical thinking (Schoevers et al., 2020), not only preparing students for mathematical intricacies, but also for real-world challenges spanning the fields of science, technology, and engineering. Beyond such academic pursuits, MCT equips individuals with the tools to confidently confront the unknown and formulate innovative solutions that transcend conventional boundaries. Aligned with this perspective, researchers, such

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as Treffinger et al. (2012) and Alt et al. (2023), have emphasized the growing importance of preparing for a future marked by uncertainty.

Based on previous research, integrating perceived creativity (PC), creative self-efficacy (CS), and computational thinking (CT) can enhance the depth and logic of MCT (Huang et al., 2020; Israel-Fishelson & Hershkovitz, 2022; Kreitler & Casakin, 2009). Specifically, PC is a dimension in which individuals perceive and harness their creative potential, fostering a mindset that is open to innovative possibilities (Laguía et al., 2019). As for CS, it is the belief in one's ability to effectively apply creative skills, building the necessary confidence for unconventional problem-solving (Puente-Díaz, 2016). Regarding CT, it is a vital skill that is not only relevant to students pursuing computer science or mathematics, but also to individuals navigating the challenges of the 21st century (Li et al., 2020) and can be utilized to address various problems that do not necessarily involve programming (Román-González et al., 2018).

Previous studies have also revealed the positive impact of CS on creative thinking (Huang et al., 2020) and academic performance (Liu et al., 2017; Puente-Díaz & Cavazos-Arroyo, 2017b), suggesting that students who are confident in their creative abilities tend to exhibit better academic performance. Similarly, CT has been highlighted as a crucial link between computational prowess and creative thinking, emphasizing the interconnectedness of logical and creative processes (Doleck et al., 2017). Meanwhile, PC has been linked to creative thinking (Proudfoot et al., 2015), implying that students who perceive themselves as creative are more likely to think creatively in the mathematics context. Altogether, these elements not only enrich the landscape of MCT, but also underscore its relevance in preparing individuals for multi-faceted challenges in our ever-changing world.

Even though prior research has focused on the various facets of PC, CS, and CT in regard to students' innovative 21st-century skills, the interconnected variables have yet to be fully identified. For example, previous studies have explored the positive correlation between high PC and enhanced CT in mathematical tasks, while other investigations have highlighted the role of CS in fostering students' problem-solving skills. However, understanding how these elements intersect and influence MCT remains a complex issue. Therefore, this cross-sectional study examines the predictors of MCT by specifically focusing on the roles of PC, CS, and CT among a sample of secondary students in Indonesia.

2. Theoretical frameworks

2.1. Mathematical creative thinking (MCT)

MCT has been defined as a multi-faceted cognitive process that is essential in problem-solving across various domains such as mathematics (Suherman & Vidákovich, 2024b). It also involves the ability to approach mathematical challenges with innovation, originality, and flexibility, including the capacity to explore unconventional solutions, connect disparate concepts, explore new solutions, and formulate novel approaches to mathematical reasoning (Kharisudin, 2022; Sadak et al., 2022; Sengil-Akar & Yetkin-Ozdemir, 2022).

In general, individuals with strong MCT skills have the ability to navigate complex problem spaces and recognize patterns/relationships that may elude more rigid problem-solving approaches (Suherman & Vidákovich, 2022). This dynamic cognitive skill set is particularly crucial in the 21st century, in which complex problem-solving and innovative thinking are valued across various disciplines. As classrooms prepare students for the complexities of the modern world, the cultivation of MCT becomes instrumental in nurturing a generation of learners who are not only proficient in mathematics, but also adept at applying such knowledge in innovative and unexpected ways (Ariba & Luneta, 2018).

Previous research has also underscored the importance of MCT in fostering deeper mathematical understanding and real-world applicability (Leikin & Pitta-Pantazi, 2013; Schoevers et al., 2019; Sriraman, 2009). For example, Leikin and Pitta-Pantazi (2013) focused on the role of creative thinking in mathematics education, emphasizing its contribution to students' conceptual understanding and problem-solving skills. Moreover, Sriraman (2009) explored the intersection between creativity and mathematical problem-solving, highlighting the need to nurture creative thinking in order to enhance mathematical proficiency. As the educational landscape evolves to meet the demands of our rapidly changing world, cultivating MCT and understanding its underlying components have become key goals for educators and researchers.

2.2. Computational thinking (CT) and MCT

The significance of creativity and CT in education has garnered attention from various researchers, leading to a growing trend in their adaptation across school curriculums (Angeli et al., 2016; Wing, 2006). Currently, many educational institutions are reshaping their computer science programs to emphasize core concepts/principles. In this regard, CT (as a new essential skill for navigating the complexities of the 21st century) is being increasingly acknowledged for its pivotal role in preparing students for a technologically driven world characterized by constant advancements. According to Aho (2012), CT involves the cognitive processes of framing problems in ways in which their solutions can be expressed through computational steps and algorithms. In academic contexts, CT not only entails understanding and using computational concepts, but also cultivates essential skills such as logical reasoning, problem-solving, and decomposing complex issues into manageable components (Belmar 2022).

Research on the intricate relationship between creativity and CT has also underscored the need for a comprehensive understanding of this concept, prompting the use of empirical and objective approaches for both constructs (Hershkovitz et al., 2019; Israel-Fishelson et al., 2021). For instance, Doleck et al. (2017) explored the correlation between creativity (which is inherent in CT) and academic achievement, and found that students endowed with creative skills can adeptly complete CT-related tasks, resulting in commendable academic performance. Knochel and Patton (2015) asserted that introducing creativity in programming (as a facet of CT) can enhance students' creative design outcomes, while other studies indicated that the creative potential unlocked by programming environments can serve as a catalyst for effective learning (Knobelsdorf & Romeike, 2008; Roque et al., 2016). Given the body of research supporting the association between CT and creative thinking in the mathematics context, we present the following hypothesis:

H1: CT is positively correlated with students' MCT.

2.3. *Perceived creativity (PC) and MCT*

PC has been defined as an individual's self-belief and self-efficacy regarding his/her creative potential (Karwowski et al., 2018; Lau et al., 2004; Pretz & Nelson, 2017), which is influenced by various factors such as identity (Karwowski, 2016) and creative thinking in mathematics (Suherman & Vidákovich, 2024a). PC not only has a significant impact on an individual's creative performance and problem-solving skills, but is also closely related to the concept of creative mindsets, which refers to perceived sources of creativity as well as perceived stability versus changeability of creativity (Lau et al., 2004). Thus, understanding and fostering PC is essential for developing an individual's creative potential and meeting the challenges of an ever-evolving world.

According to previous research, PC is expected to positively correlate with creative thinking (Alt et al., 2023; Goncalo et al., 2010). In this regard, Groeneveld et al. (2023) qualitatively explored the differences in PC between undergraduate and graduate students, and found disparities in how creativity is perceived at these educational levels. Notably, they acknowledged a limitation (i.e., insufficient data) of drawing a definitive conclusion on the evolution of students' views on creativity as they progress through their education. In a related study, Li et al. (2017) found a positive correlation between perceived reward for creativity and creative performance. They also suggested that when individuals perceive rewards for creativity conducive to achieving personal objectives (especially in terms of enhancing creative thinking skills), it triggers positive emotions. Consequently, individuals are more likely to experience satisfaction and derive enjoyment from their creative endeavors. Likewise, Goncalo et al. (2010) demonstrated the positive impact of PC on creative evaluation, implying that such creativity plays a crucial role in fostering creative thinking, particularly in the mathematics context. Hence, we present the following hypothesis:

H2: PC positively contributes to students' MCT.

2.4. *Creative self-efficacy (CS) and MCT*

The concept of CS is rooted in self-efficacy theory, which asserts that an individual's belief in his/her own capabilities profoundly influences his/her performance. According to Bandura (1997), maintaining innovativeness necessitates a steadfast belief in one's efficacy, especially when engaging in creative pursuits that demand prolonged time and effort. In such scenarios, particularly when progress is frustratingly slow, outcomes are uncertain, and products face social devaluation (due to their incongruence with established norms), an unwavering sense of efficacy becomes crucial. In other words, it is not merely the possession of skills that matters, but rather the confidence in applying these skills in certain situations (Bandura, 1997).

In this context, CS refers to an individual's belief in his/her ability to produce innovative outcomes (Kumar et al., 2022). Within the educational domain, self-efficacy has been linked to enhanced academic performance (Hidayatullah & Csíkos, 2023; Mou, 2024; Zimmerman & Kitsantas, 2005), since students with a high level of self-efficacy tend to invest more attention/effort in achieving their objectives and actively seeking solutions from diverse perspectives (Gan et al., 2023; Schunk & Mullen, 2012). Conversely, those with a low level of self-efficacy tend to lack the confidence to formulate innovative solutions, assuming that the answers are already known. In this regard, CS emerges as a pivotal factor that motivates students to take action and develop innovative ideas.

Previous studies have also revealed a robust connection between students' CS and MCT (Haase et al., 2018; Pretz & Nelson, 2017; Puente-Díaz & Cavazos-Arroyo, 2017a). Specifically, exposure to complex experiences tends to bolster an individual's confidence in his/her creative abilities and foster a higher appreciation for creativity (Puente-Diaz et al., 2020). Moreover, empirical investigations have consistently shown a positive correlation between CS and various indicators of creative thinking (Karwowski et al., 2018; Liu et al., 2024). This underscores that students' confidence in their ability to formulate creative solutions is intricately linked to their creative thinking prowess. Thus, we present the following hypothesis:

H3: CS positively predicts students' MCT.

2.5. *Mediating role of computational thinking (CT)*

Since CT serves as a foundational mediating element in our study, it is crucial to delve deeper into its role, considering its significance in shaping the relationships between key variables (Guggemos, 2021; Zhang & Wong, 2023). Meanwhile, CT, characterized by problem-solving skills and algorithmic approaches (Tsai et al., 2021), plays a pivotal role in mediating the complex interplay between PC, CS, and MCT. Hence, by determining how CT acts as a mediator, we can reveal the intricate dynamics that contribute to enhanced creative abilities in the mathematics context.

According to self-cognitive theory (DiGiuseppe et al., 2016), CT is a cognitive tool that individuals employ to understand and navigate complex problem-solving situations. This theory also posits that an individual's self-efficacy beliefs, cognitive processes, and problem-solving strategies intertwine to influence their approach to CT-related tasks. In the context of our study, the lens of this theory allows us to examine how individuals (based on their PC and CS) engage in CT when dealing with creative mathematical challenges. Therefore, we present the following hypothesis:

H4: CT positively mediates the association between PC, CS, and MCT.

3. Method

3.1. Participants

The participants in this study consisted of 896 secondary school students (52.9 % female; 47.1 % male), representing both public and private schools in Lampung Province, Indonesia. The cross-sectional study (Pandis, 2014) and students were selected through stratified random sampling (Nguyen et al., 2021) and sourced from diverse districts and villages, encompassing various ethnic backgrounds such as Javanese, Lampung, Sundanese, Manado, Padang, among others.

This study received approval from the Institutional Review Board of the University of Szeged, ensuring compliance with ethical standards. All of the students provided their informed consent before participating in the study. The demographic characteristics of the participants are presented in Table 1.

3.2. Instruments

Perceived creativity: In order to assess the students' PC and the conviction that creativity constitutes a significant aspect of their self-descriptions, we employed a six-item questionnaire developed by Karwowski et al. (2018, 2022). The responses were based on a five-point Likert scale, ranging from 1 (definitely not) to 5 (definitely yes). Sample statements included: "I am sure I can deal with problems requiring creative thinking" and "Being a creative person is important to me." Cronbach's alphas for these statements ranged from 0.80 to 0.96. We also evaluated the reliability and validity of this scale.

Creative self-efficacy: To assess the CS of the students, we employed a six-item questionnaire developed by Karwowski (2012). Examples of the items included: "I know I can efficiently solve complicated problems"; "I trust my creative abilities"; "Compared to my friends, I am distinguished by my imagination and ingenuity"; "Many times, I have proven that I can cope with difficult situations"; "I am sure I can deal with problems requiring creative thinking"; and "I am good at proposing original solutions to problems." The responses were based on a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). The original version of this scale demonstrated internal consistency with a coefficient of 0.81. We also assessed the validity and reliability of this scale.

Computational thinking: To evaluate the CT of the students, we employed a five-item questionnaire developed by Korkmaz et al. (2017). The responses were based on a five-point Likert-type scale, ranging from 1 (never) to 5 (always). Examples of the items included: "I believe that I can solve the problems that may occur when I encounter a new situation"; "I like solving problems related to group projects together with my friends in cooperative learning"; and "I think that I have a special interest in mathematical processes." Again, we assessed the reliability and validity of the instrument.

Mathematical creative thinking. By integrating elements of ethnomathematics (e.g., the Tapis pattern) (Suherman & Vidákovich, 2022), which explores the cultural, social, and historical dimensions of mathematics, the MCT-based ethnomathematics test (MCTBE) aims to provide a more culturally relevant and inclusive approach to assessing mathematical proficiency. In this regard, the test items are designed to incorporate cultural nuances, traditional practices, and indigenous knowledge systems, allowing students to engage with mathematical concepts in familiar contexts. This test, developed by Suherman & Vidákovich, 2024a, included 20 items related to fluency, flexibility, elaboration, and originality. The responses were allocated according to the categorized answers. For example, a rating of 5 represented the highest scores for fluency and flexibility. Meanwhile, the scores for originality were determined by percentages. For instance, scores above 3 % received a value of 0, scores above 2 % but below 3 % received a score of 1, scores above 1 % but below 2 % were assigned a score of 2, and scores below 1 % were given a score of 3. As for elaboration, the scores were either 1 or 2. Again, we calculated the reliability and validity of the instrument.

Table 1
Demographic characteristics of the participants.

Demography		Frequency	Percentage (%)
Gender	Female	474	52.9
	Male	422	47.1
Grade	7	306	34.2
	8	292	32.6
	9	298	33.3
School Type	Private	447	49.9
	Public	449	50.1
Place	City	457	51.0
	Disctrict	439	49.0
Ethnics	Batak	57	6.4
	Bugis	25	2.8
	Java	413	46.1
	Lampung	156	17.4
	Manado	51	5.7
	Minang	35	3.9
	Others	45	5.0
	Palembang	27	3.0
	Sundanese	87	9.7

$N = 896$; mean age = 13.32, SD = 1.084.

3.3. Data analysis

In this study, our initial data analysis encompassed descriptive statistics and zero-order correlations. Specifically, we explored innovative behavior, CS, class interactions, perceived competence, and academic achievements by using structural equation modeling (SEM). However, it was important to first assess the construct validity and reliability of our instruments through confirmatory factor analysis (CFA). Based on the SEM (using SmartPLS Version 4 software), several model fit indices were employed, including comparative fit indices (CFI), Tucker-Lewis indices (TLI), the root mean square error of approximation (RMSEA), and the standardized root mean square residual (SRMR). As for the recommended thresholds for evaluating the fit indices, they are CFI $\geq$ 0.90, TLI $\geq$ 0.90, SRMR from 0 to 0.1, and RMSEA $\leq$ 0.06 (Hu & Bentler, 1999).

The convergent and discriminant validity of the instruments in this study were also assessed. Regarding convergent validity, measured by the coefficient of the average variance extracted (AVE), it should be higher than 0.5 (Hair et al., 2019). As for discriminant validity, it was evaluated according to the root of the average variance extracted (AVE) and the heterotrait-monotrait (HTMT) criterion. In this case, when the root of the AVE exceeds the correlations between the factors, it fulfills the discriminant validity criterion (Hair et al., 2019). In order to examine the reliability of the instruments, composite reliability (CR) and Cronbach's alpha were employed. We also evaluated the validity and reliability of the MCTBE by using Winstep software (Linacre, 2012). Finally, the coefficient of determination (R^2) and significant prediction were assessed to examine the proposed hypotheses, while R software was used to generate visual representations of the relationships between the variables in the scales, elucidating the students' performances.

4. Results

4.1. Internal reliability and convergence validity of the questionnaires

Table 2 provides a comprehensive overview of the loading factors, construct reliability, and validity of the key variables in this study. Based on the findings, CS exhibits robust outer loadings ranging from 0.65 to 0.72, indicating a solid connection between the latent construct and its observed indicators. In addition, Cronbach's alpha for CS is 0.78, suggesting internal consistency within the items; the composite reliability (CR) for CS is 0.84, surpassing the recommended threshold of 0.7; and AVE is 0.47, meeting the minimum criterion. Similarly, CT displays substantial outer loadings (0.63 to 0.71) and satisfactory reliability (Cronbach's alpha = 0.72, CR = 0.81, AVE = 0.47). As for PC, it exhibits a good outer loading range (0.58 to 0.72), with high reliability (Cronbach's alpha = 0.74) and excellent validity (CR = 0.81, AVE = 0.66). Even though the AVE is below the threshold, the CR has a value above 0.60 (Fornell & Larcker, 1981). These results underscore the reliability and validity of the instruments and provide a solid foundation for subsequent analyses.

4.2. Discriminant validity

A test for discriminant validity was conducted to determine whether latent factors manifest significant distinctions from one another (Hair Jr. et al., 2021). For this assessment, we used the HTMT ratio, a methodology advocated by Henseler et al. (2015). As shown in Table 3, the values range from 0.06 to 0.81 and are <0.90 (Hair et al., 2010; Henseler et al., 2015), confirming the presence of discriminant validity in this study.

Table 2
Loading factors, construct reliability, and validity.

Variables		Outer loading	Cronbach's alpha	CR	AVE
Creative self-efficacy			.78	.84	.47
	CS1	.65			
	CS2	.69			
	CS3	.67			
	CS4	.70			
	CS5	.67			
	CS6	.72			
Computational thinking			.72	.81	.47
	CT1	.68			
	CT2	.69			
	CT3	.63			
	CT4	.69			
	CT5	.71			
Perceived Creativity			.74	.81	.66
	PC1	.58			
	PC2	.61			
	PC3	.65			
	PC4	.72			
	PC5	.71			
	PC6	.62			

4.3. Validity of the MTC-based ethnomathematics test (MCTBE)

Table 4 provides a comprehensive summary of the Rasch analysis conducted to evaluate the efficacy of the MCTBE. This test includes 20 items distributed across four key subtexts: fluency, flexibility, originality, and elaboration.

In general, an ideal fit to the Rasch model is denoted by a mean square residual (MNSQ) value of 1.0. In this study, the average person outfit MNSQ values varied between 0.56 and 1.13, while the average person infit MNSQ values ranged from 0.38 to 1.02, signifying a commendable adherence to the Rasch model. For the item outfit and infit MNSQ values (in which a value of 1.0 signals a flawless fit), the mean item outfit MNSQ values ranged from 1.14 to 4.28, while the mean item infit MNSQ values ranged from 0.97 to 1.01. Moreover, the precision of the measurements based on person and item separation revealed distinctions in ability and item difficulty stratification. Specifically, the person separation values ranged from 1.06 to 2.57, while the item separation values ranged from 6.83 to 52.28, indicating various levels of measurement accuracy across the subtexts and items.

Table 4 also elucidates unidimensionality, a measure of how well a test captures a singular underlying construct. In this case, the raw variance by measure values (representing the unexplained variance after Rasch model adjustment) ranged from 42.11 % to 93.3 %, surpassing the 20 % threshold (Chan et al., 2021) and affirming reasonable unidimensionality in the subtexts and overall test in this study.

4.4. Reliability of the MCTBE

In a Rasch analysis, evaluating reliability involves various criteria such as person and item reliability (Fisher, 2007; Linacre, 2022). Similarly, Cronbach's alpha assesses the internal consistency of participants' responses, by specifically focusing on the reliability of person raw scores (Sekaran & Bougie, 2003). In addition, the person reliability index evaluates the consistency in the placement of individuals when presented with another set of items measuring the same construct as the initial test. This evaluation is sample-specific and examines the reproducibility of person placements (Bond & Fox, 2015).

In the present study, Cronbach's alpha for person reliability was within the range of 0.63–0.87, indicating a commendable reliability of the test in measuring the students' abilities. The reliability coefficients for the item scores were notably high. Specifically, they ranged from 0.98 to 1.00, signifying a consistent measurement across the subtexts in the MCTBE. The outfit mean square fit statistics of the instrument are shown in Fig. 1.

4.5. Descriptive statistics

Table 5 presents the descriptive statistics and normality of the variables in this study. First, the MCTBE exhibits an average score (M) of 12.46 with a standard deviation (SD) of 2.999, indicating a moderate level of variability. Additionally, the skewness value of 0.048 suggests a nearly symmetrical distribution, whereas the negative kurtosis (−0.428) indicates a slightly flatter distribution than the normal curve. Second, the mean score for CT is 3.62 with a low SD of 0.532, reflecting relatively consistent scores among the students. In this case, the skewness and kurtosis values (0.185 and −0.015, respectively) indicate a slightly positively skewed and approximate normal distribution. Third, CS includes a mean score of 3.48 and a SD of 0.560, highlighting a moderate level of variability. Meanwhile, the skewness of 0.401 suggests a moderately positively skewed distribution, whereas the kurtosis of 0.136 indicates a distribution that peaks slightly more than the normal curve. Finally, PC includes an average score of 3.62 with an SD of 0.484, indicating consistent scores. As for the skewness (0.399) and kurtosis (−0.116) values, they suggest a nearly symmetrical and slightly flatter distribution. Overall, these statistics provide insights into the tendency, variability, and distribution shape of the variables in this study. Table 6 presents the correlations among the components of these variables.

4.6. SEM analysis

SEM analysis was performed to examine the hypotheses in this study. According to Fig. 2, which summarizes the standardized relationships among the variables, the fit indices are as follows: Chi-square = 3160.914, df = 163, $p < .001$; CFI = 0.91; TLI = 0.94; RMSEA = 0.04; and SRMR = 0.06. As discussed earlier, the recommended thresholds for CFI and TLI are > 0.90, whereas for the RMSEA and SRMR, they should be <0.08 (Hu & Bentler, 1999; Kwong-Kay Wong, 2013; Meyers et al., 2016). The findings indicate that the model has acceptable fit, meeting the suggested criteria for the CFI, TLI, RMSEA, and SRMR.

Regarding the coefficient determination, MCT is influenced by CT, PC, and CS at a rate of 0.04 % ($R^2 = 0.004$). Similarly, CS is accounted for by PC at 39.7 % ($R^2 = 0.397$), while CT is explained by PC and CS, contributing to 46.6 % ($R^2 = 0.466$). With respect to the path coefficients, CS exhibits a direct positive association with PC ($\beta = 0.630, p < .001$) and CT ($\beta = 0.571, p < .001$). Moreover, CS

Table 3
Discriminant validity-HTMT.

	CS	CT	MCTBE	PC
CS	–			
CT	.81	–		
MCTBE	.07	.06	–	
PC	.76	.65	.06	–

Table 4
Summarizing the assessment of the MCTBE through Rasch analysis.

Measurements	Subtest				Test
	Fluency	Flexibility	Originality	Elaboration	MCTBE
Number of items	5	6	5	4	20
Mean					
Person outfit MNSQ	0.56	1.13	0.99	0.99	1.04
Person-infit MNSQ	0.38	1.00	0.98	0.98	1.02
item MNSQ outfit MNSQ	4.28	1.14	0.99	0.99	1.04
item infit MNSQ	0.70	0.97	0.99	1.00	1.01
Separation of people	2.08	1.66	1.42	1.06	2.57
Item Separation	52.28	15.54	11.37	6.83	22.18
Unidimensionality Raw Variance by Measure	93.3 %	57.2 %	46.9 %	42.11 %	

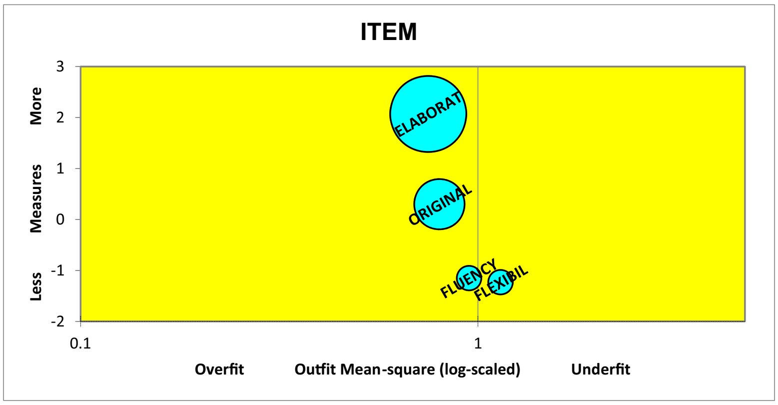

Fig. 1. Bubble chart for the outfit mean square fit statistics of the instrument.

Table 5
Descriptive statistics and normality of the variables.

Variables	M	SD	Skewness	Kurtosis
MCT-based ethnomathematics test	12.46	2.999	.048	−0.428
Computational thinking	3.62	.532	.185	−0.015
Creative self-efficacy	3.48	.560	.401	.136
Perceived Creativity	3.62	.484	.399	−0.116

is negatively associated with MCT ($\beta = -.097$, $p > .05$), whereas PC has a positive association with CT and MCT ($\beta = 0.159$, $p \langle .001$; and $\beta = 0.036$, $p \rangle .05$, respectively).

Table 7 presents the indirect and direct effects of the variables. In order to assess how CT acts as a mediator in the connection between MCT, CS, and PC, bootstrapping was employed with 5000 iterations.

Based on the findings, the mediation role of CT is positively associated with MCT ($\beta = 0.057$, $p > .05$). Similarly, the indirect effects of the four variables are positive ($\beta = 0.021$, $p > .05$), as well as the correlations between PC, CS, and CT ($\beta = 0.360$, $p < .001$).

4.7. Students' performance

Density plots are a type of data visualization that can help reveal the distribution of data points (Cui & Liu, 2021), which can be useful for understanding different patterns and trends in students' performance (see Fig. 3). A summary of the students' performance among the variables is presented in Table 8.

Table 8 provides a detailed overview of the students' performance in CT, CS, PC, and the MCTBE. The M and SD values are presented for different categories, including gender, grade, school type, place, and ethnicity. First, based on gender, the female students exhibit mean scores of 3.60 (CT), 3.49 (CS), 3.61 (PC), and 12.64 (MCTBE), with slight variations among the male students. Second, regarding grade, the 9th-grade students have the highest mean scores for CT, CS, and PC, while the 8th-grade students have the highest mean scores in the MCTBE. Third, as for school type, private schools have slightly higher performance than public schools across all categories. Fourth, according to location, the students from urban areas generally demonstrate higher mean scores, notably in CT, PC, and the MCTBE, compared to the students from districts. Finally, concerning ethnicity, there are distinct patterns such as the Batak students showing high variability in the MCTBE and the Minang students exhibiting lower MCTBE mean scores.

Table 6
Correlations among the components of the variables.

	CT1	CT2	CT3	CT4	CT5	CS1	CS2	CS3	CS4	CS5	CS6	PC1	PC2	PC3	PC4	PC5	PC6	FLU	FLE	ELB	ORG
CT1	1																				
CT2	.291**	1																			
CT3	.266**	.273**	1																		
CT4	.304**	.285**	.433**	1																	
CT5	.298**	.330**	.417**	.490**	1																
CS1	.280**	.263**	.165**	.221**	.232**	1															
CS2	.861**	.275**	.223**	.283**	.297**	.366**	1														
CS3	.282**	.823**	.212**	.268**	.322**	.331**	.358**	1													
CS4	.256**	.253**	.197**	.276**	.217**	.314**	.302**	.300**	1												
CS5	.267**	.191**	.203**	.188**	.231**	.280**	.307**	.239**	.552**	1											
CS6	.239**	.241**	.229**	.290**	.265**	.341**	.299**	.279**	.603**	.644**	1										
PC1	.157**	.226**	0,059	.105**	.184**	.252**	.184**	.256**	.147**	.085*	.113**	1									
PC2	.132**	.241**	.086*	.109**	.156**	.248**	.175**	.278**	.201**	.102**	.170**	.582**	1								
PC3	.152**	.260**	.075*	.147**	.157**	.318**	.214**	.320**	.212**	.154**	.182**	.577**	.600**	1							
PC4	.276**	.318**	.255**	.318**	.320**	.311**	.345**	.406**	.344**	.293**	.352**	.223**	.206**	.280**	1						
PC5	.269**	.281**	.264**	.293**	.304**	.362**	.340**	.341**	.363**	.325**	.362**	.156**	.222**	.231**	.481**	1					
PC6	.266**	.226**	.265**	.209**	.311**	.377**	.347**	.341**	.187**	.194**	.159**	.183**	.185**	.206**	.313**	.379**	1				
FLU	−0,040	.071*	0,004	0,021	−0,003	−0,042	−0,065	0,017	0,005	0,029	0,027	0,019	0,019	0,009	0,036	−0,004	−0,038	1			
FLE	−0,055	.080*	0,013	0,038	−0,004	−0,036	−0,058	0,017	−0,006	0,018	0,041	0,007	0,031	−0,025	0,045	0,018	0,002	.671**	1		
ELB	−0.066*	0,054	0,008	0,011	−0,008	−0,059	−0.088**	−0,019	−0,016	−0,025	0,007	0,008	0,013	0,017	0,013	−0,007	−0.075*	.538**	.547**	1	
ORG	−0,024	.066*	0,001	0,005	−0,002	−0,036	−0,026	0,022	0,020	0,033	.077*	−0,007	0,043	0,023	0,043	0,023	−0,056	.589**	.618**	.620**	1

**. $p < .01$; *. $p < .05$. FLU = Fluency; FLE = Flexibility; ELB = Elaboration; ORG = Originality.

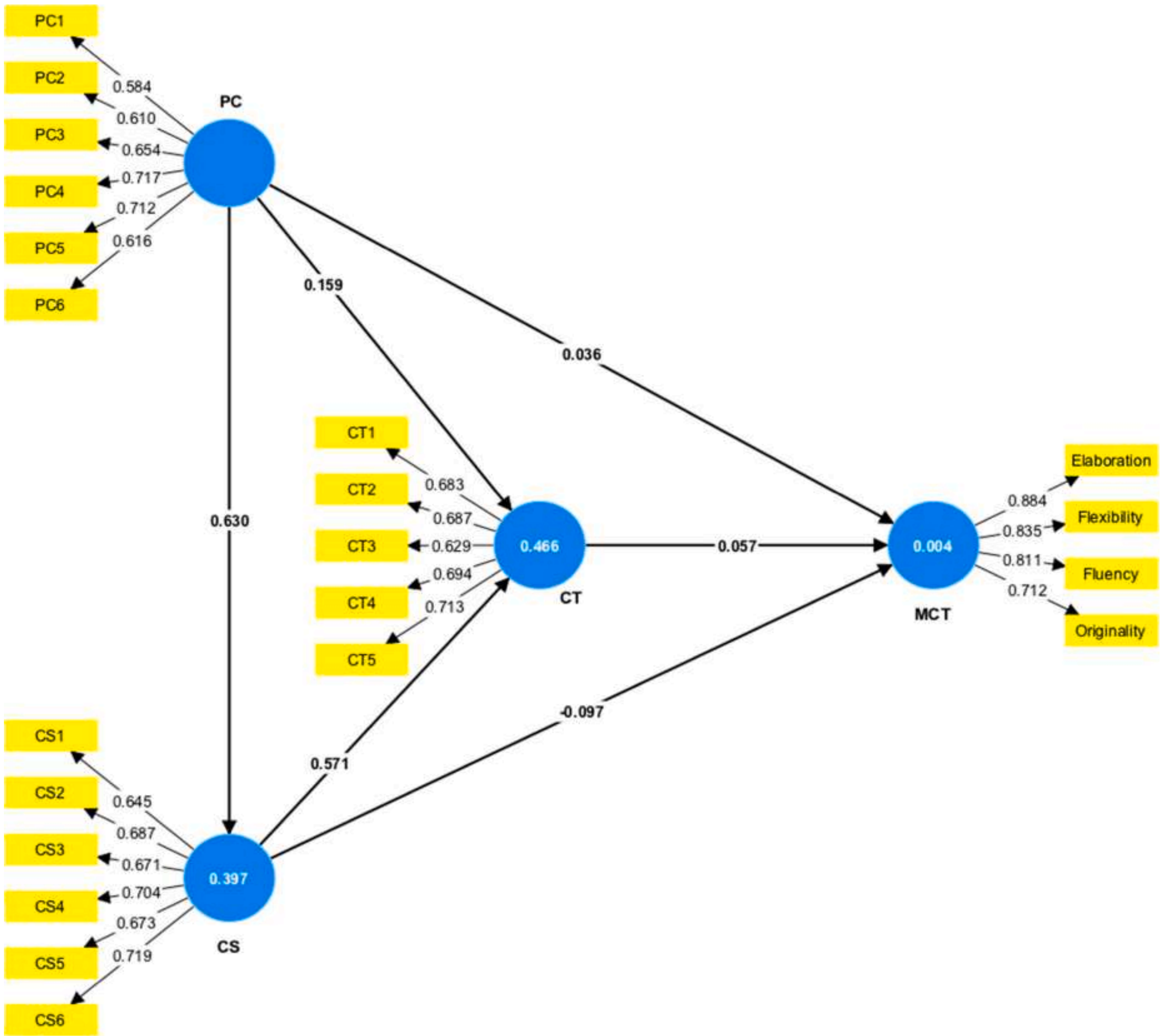

Fig. 2. Standardized relationships among the variables. Notes: Mathematical creative thinking (MCT); Computational thinking (CT); Creative self-efficacy (CS); and perceived creativity (PC).

Table 7
Total indirect and direct effects of the variables.

Path model	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P-values
CS -> CT	.571	.572	.029	19.618	<0.001
CS -> MCT	−0.097	−0.081	.082	1.178	>0.05
CT -> MCT	.057	.052	.059	.973	>0.05
PC -> CS	.630	.632	.022	28.819	<0.001
PC -> CT	.159	.159	.032	4.943	<0.001
PC -> MCT	.036	.034	.051	.699	>0.05
PC -> CS -> MCT	−0.061	−0.051	.052	1.174	>0.05
PC -> CT -> MCT	.009	.008	.010	.931	>0.05
CS -> CT -> MCT	.033	.030	.034	.971	>0.05
PC -> CS -> CT	.360	.362	.021	17.463	<0.001
PC -> CS -> CT -> MCT	.021	.019	.021	.969	>0.05

5. Discussion

The purpose of this study was to determine the extent to which students' MCT is influenced by PC, CS, and CT. Our finding that CT is positively associated with MCT aligns with previous research. For example, Doleck et al. (2017), Knobelsdorf and Romeike (2008), and

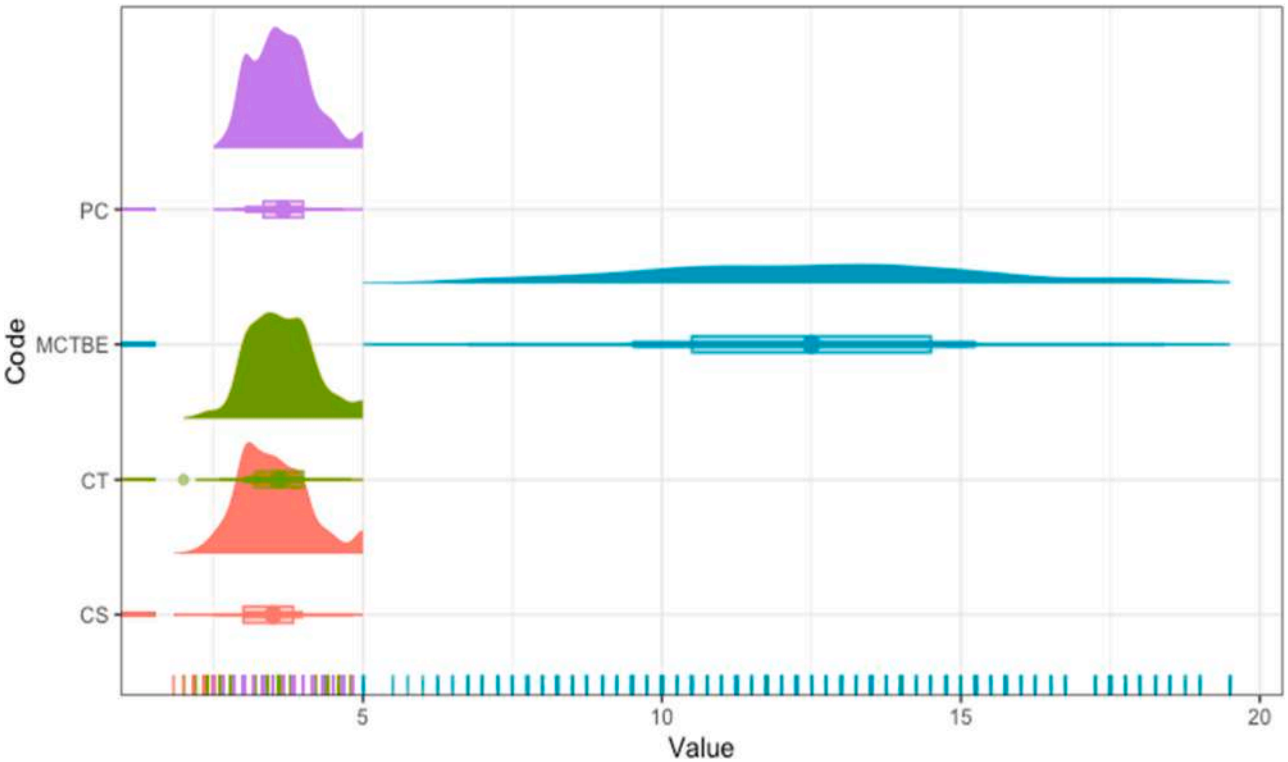

Fig. 3. Density plot of the students' performance.

Table 8
Summary of the students' performance among the variables.

Category	CT		CS		PC		MCTBE	
	M	SD	M	SD	M	SD	M	SD
Gender								
Female	3.60	.54	3.49	.57	3.61	.49	12.64	2.98
Male	3.64	.52	3.47	.55	3.62	.48	12.26	3.01
Grade								
7th	3.58	.55	3.51	.53	3.67	.48	12.51	3.01
8th	3.59	.51	3.45	.60	3.60	.49	12.26	3.03
9th	3.69	.53	3.49	.55	3.59	.49	12.60	2.89
School-type								
Private	3.64	.54	3.51	.59	3.69	.49	12.45	2.97
Public	3.60	.53	3.45	.52	3.55	.47	12.47	3.04
Place								
City	3.63	.55	4.48	.58	3.62	.49	12.66	3.12
District	3.60	.51	3.49	.54	3.62	.47	12.26	2.86
Ethnicity								
Batak	3.59	.51	3.34	.55	3.54	.52	14.16	3.55
Bugis	3.53	.55	3.41	.60	3.64	.42	12.53	3.14
Java	3.59	.55	3.48	.55	3.59	.46	12.39	2.99
Lampung	3.69	.51	3.53	.54	3.68	.54	12.23	2.96
Manado	3.48	.39	3.48	.49	3.62	.45	12.22	3.16
Minang	3.66	4.5	3.51	.48	3.60	.46	12.77	2.59
Others	3.64	.61	3.44	.70	3.68	.55	12.76	2.65
Palembang	3.73	.53	3.75	.73	3.80	.53	12.28	2.65
Sundanese	3.69	.52	3.45	.56	3.61	.49	11.99	2.72

Knochel and Patton (2015) consistently demonstrated the significant role of PC in fostering creative thinking, not only in general contexts, but also in specific mathematical tasks. These studies also indicated that individuals who perceive themselves as creative are more likely to exhibit creative thinking skills, including mathematical problem-solving. In practical terms, teachers can implement pedagogical approaches that go beyond traditional problem-solving methods. In this regard, encouraging students to approach mathematical challenges with an open mind, explore alternative solutions, and view mistakes as opportunities for learning can further strengthen the link between PC and MCT.

We also found that PC positively contributes to students' MCT. This finding resonates with the research of Groeneveld et al. (2023), Li et al. (2017), and Goncalo et al. (2010), which consistently highlighted the connection between individuals who perceive themselves as creative and their ability to engage in creative thinking processes. In the context of mathematics, where creative problem-solving has been increasingly recognized as a valuable skill that promotes creative thinking (Puccio et al., 2023), fostering PC has become a significant goal of education (Langley, 2018). This indicates that creating a classroom environment that values diverse approaches to problem-solving (Supriadi et al., 2024) and emphasizes the importance of creativity in mathematics can help shape positive self-perceptions among students.

Conversely, we found that CS is negatively associated with MCT. This outcome aligns with Redifer et al. (2021), who indicated that heightened cognitive load can adversely influence creative thinking performance. They also found that the interplay between CS and performance feedback on creative thinking is partly mediated by cognitive load. In essence, individuals who perceive themselves as less adept at creatively solving mathematical problems (as indicated by low CS) tend to demonstrate elevated levels of MCT (Bicer et al., 2020; Snyder et al., 2021). In order to address this issue, teachers can implement strategies that mitigate cognitive load such as providing constructive feedback and creating a supportive atmosphere that boosts students' confidence in their mathematical and creative problem-solving skills.

Surprisingly, we found that CT positively mediates the association between PC, CS, and MCT. This finding is in line with Youjun and Xiaomei (2022), who found that CT plays a fundamental role in mediating individuals' regulation of their thinking patterns. In addition, previous research has suggested that CT is essential for problem-solving (Yadav et al., 2016), building abstract conceptualizations (Shute et al., 2017), and fostering creativity across various fields, including mathematics (Nordby et al., 2022; Soboleva et al., 2021). In sum, CT is indeed a key component in enhancing creative thinking abilities and promoting successful learning outcomes in mathematics education, paving the way for more effective and holistic learning experiences.

Finally, concerning the students' performance, we found that the female students outperformed the male students across all variables. A possible explanation for their superior performance could be attributed to differences in their learning styles and preferences (Al-Zohbi et al., 2023), as well as the effectiveness of teaching methods and curricular designs that resonate with them (Supriadi, Wan, & Suherman, 2024). Previous research has also suggested that females tend to exhibit higher levels of engagement in creative and computational activities because of varying cognitive approaches. Another aspect to consider is the influence of societal expectations and biases. However, if female students excel in these areas, then it may indicate a positive shift in societal attitudes toward embracing and empowering women in science, technology, engineering, and mathematics (STEM) fields and creative domains (Hughes et al., 2024). Thus, teachers and policymakers should reevaluate and potentially formulate educational strategies to ensure that they cater to the diverse needs and strengths of all students, regardless of gender.

6. Limitations and future research

Although this study offers valuable insights into the factors influencing MCT among a sample of secondary school students, it is important to acknowledge several limitations. First, the use of a cross-sectional design implies a correlational (rather than a causal) relationship between the variables. To enhance the robustness of our findings, future investigations should employ a longitudinal design. Second, a noteworthy limitation is the absence of control variables in this study. Hence, subsequent research should consider additional variables that might impact MCT such as socioeconomic status, parental education level, gender, and student behavior. Third, since we found a negative association between CS and MCT in our sample of secondary school students, future research should determine whether CS can make a positive contribution to MCT, especially in this demographic. Finally, this study only used a series of CT questionnaires to measure MCT. Therefore, future research should use an alternative approach that incorporates CT problem-solving tests in order to provide a more comprehensive and nuanced assessment of students' MCT skills.

7. Conclusions

Based on the findings in this study, there was a positive association between CT, PC, and MCT, but a negative association between CS and MCT. In addition, CT played a positive mediating role in the relationship between PC, CS, and MCT. These findings provide valuable insights into the complex interplay of these factors and their impact on students' creative thinking skills in mathematics. These implications also underscore the importance of a well-rounded mathematics education that incorporates CT, nurtures PC, and addresses CS in order to foster MCT among students. Overall, they align with the broader goals of preparing students for a future that will increasingly rely on computational skills and creative problem-solving.

CRediT authorship contribution statement

Suherman Suherman: Writing – original draft, Validation, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Tibor Vidákovich:** Writing – review & editing, Supervision, Investigation, Funding acquisition.

Declaration of competing interest

There are no conflicts of interest to declare.

Data availability

Data will be made available on request.

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CHAPTER III. DISCUSSION AND CONCLUSIONS

3.1. General Discussion and Conclusions

Research has extensively examined creative thinking, a crucial skill for the 21st century, widely applied across various domains. This study evaluated the mathematical creative thinking of Indonesian secondary school students and explored the factors that influence it. Due to the complexity involved in assessing mathematical creative thinking, there is a need for a review of appropriate assessment tools and frameworks for different mathematical creativity disciplines. However, comprehensive reviews are lacking, particularly in terms of diagnostic tools that can assess students' fluency and elaboration in thinking, but are unable to effectively measure creative thinking indicators specifically in mathematics (Hadar & Tirosh, 2019).

To answer RQs 1, a systematic review was conducted to evaluate the assessment of creative thinking in mathematics by identifying key discussions among researchers and uncovering existing research gaps, following the PRISMA guidelines. In study 1, the review included articles published between 2011 and 2021, revealing that most assessments of mathematical creative thinking were carried out at the secondary education level. This is important as research on creative thinking, especially in mathematics, encourages students to develop their skills and serves as a foundation for understanding other programs (Hsu et al., 2018). In terms of mathematical domains, the studies demonstrated a wide variety of materials used to assess creative thinking. Geometry and measurement were the most frequently assessed topics, followed by algebra, numbers, and probability/statistics, aligning with curricular standards and providing structured opportunities to evaluate creative thinking (Huizinga et al., 2014; Taylor, 2013). Open-ended tests emerged as the most commonly used method for assessing mathematical creative thinking, particularly at the secondary education level. These tests often feature open-ended questions that allow for multiple correct answers or diverse solution strategies. Notably, the review highlighted the integration of open-ended questions grounded in ethnomathematics, a promising approach to bridge cultural gaps in mathematics education. This approach helps address challenges many students face due to cultural conflicts between the contexts experienced at school and in their communities (Khalifa et al., 2016; Ogbu, 1992). However, while some studies reported the validity of these tools, a significant gap was found in detailed psychometric evaluations, such as reliability and construct validity. This indicates a need for further research to establish reliable, valid, and culturally adaptive tools for assessing mathematical creative thinking across various educational contexts. Future studies should focus on enhancing the psychometric properties of these assessment tools to ensure their effectiveness in measuring creative thinking in mathematics. This should involve cross-validation across diverse educational settings to improve the generalizability and fairness of these tools.

To address critical gaps and answering the RQs 2 in the assessment of mathematical competencies among Indonesian secondary school students, study 2 has developed and psychometrically validated two instruments: an ethnomathematics-based test to measure mathematical creative thinking (Suherman & Vidákovich, 2025) and a questionnaire to evaluate students' attitudes toward mathematics. Both tools were specifically designed for use within the Indonesian cultural and educational context, ensuring contextual relevance and practical applicability. Findings from the validation process confirm that the ethnomathematics-based test demonstrates strong construct validity and internal consistency across grades 7 to 9. More importantly, the test effectively identifies key components of mathematical creative thinking such as fluency, flexibility, and originality as evidenced by clear response patterns and consistent performance across student subgroups (Baer & Kaufman, 2008; Bart et al., 2015; Jungert et al., 2019; Matud et al., 2007). These outcomes underscore the test's utility as a diagnostic tool and affirm the feasibility of integrating ethnomathematical elements into formal assessments to enhance student engagement and cognitive expression. Similarly, the development and validation of the attitude-toward-mathematics questionnaire yielded robust psychometric results. Factor analysis confirmed a stable structure reflecting key affective dimensions, including enjoyment, confidence, and perceived value of mathematics. The instrument demonstrated high reliability and was sensitive to variations across gender and grade level, indicating its capacity to capture nuanced student perspectives. Unlike many existing international instruments (Aiken Jr & Dreger, 1961; Fennema & Sherman, 1976), which often require cultural adaptation, this tool was grounded in the Indonesian schooling experience, thereby improving relevance and interpretability of results. These findings contribute original evidence to the field, showing that student attitudes in the Indonesian context can be measured with both precision and cultural sensitivity. This validation is essential to ensuring the tool's applicability in diverse cultural settings, not just within the Indonesian context. This study contributes to addressing the lack of reliable and valid instruments for measuring students' attitudes toward mathematics in Indonesia, offering a robust tool for future research and application in this context.

For the exploration of RQs 3, the integration of local culture into the assessment of students' mathematical creative thinking can be explored through ethnomathematics, which has proven to be a transformative tool in bridging the gap between local knowledge and formal mathematics (Peni & Baba, 2019). In study 3, I found that the Tapis Lampung pattern offers a concrete example of how cultural elements can be incorporated into mathematics education. Tapis, a traditional item of women's clothing from Lampung, features geometric patterns with strong contours made from various line elements such as straight lines, curves, zigzags, and spirals. These patterns are not only culturally significant but also provide an opportunity to explore mathematical concepts such as geometric shapes, transformations (rotation, translation, reflection, and dilation), and symmetry in the classroom (Suherman & Vidakovich, 2022). Incorporating Tapis Lampung's geometric patterns into mathematics assessments can encourage students to apply their cultural knowledge to solve formal mathematical problems, fostering both creativity and deeper understanding. While the challenge remains in effectively implementing such cultural geometry models in classrooms, their integration can highlight essential cultural considerations that enrich mathematical learning and problem-solving (Nasir et al., 2008). Furthermore, a regression analysis conducted in this study revealed that factors such as ethnicity, school type, and living place significantly influenced students' creative thinking responses. These results provide concrete evidence that cultural context plays a crucial role in shaping students' mathematical problem-solving abilities. This finding underscores the importance of considering local cultural contexts in mathematics assessments, as they can influence students' ability to engage with and solve mathematical problems. Thus, integrating local culture, as exemplified by the Tapis Lampung pattern, can enhance the teaching, learning, and assessment of mathematical creative thinking by making mathematics more relatable, engaging, and culturally relevant for students.

To answer RQs 4, study 4 explored the influence of positive attitudes and cultural understanding on enhancing mathematical creative thinking, however, the literature remains limited. Although these studies provide valuable insights, the factors that influence student creativity in mathematics are still not fully understood (Liu et al., 2021; Power, 2015; Wang & Chang, 2022; Wu et al., 2022). In response to this gap, research has highlighted the role of ethnicity as a mediator between attitude and mathematical creative thinking. The findings indicate that both attitude and ethnicity significantly influence mathematical creative thinking, consistent with prior research (Jackson & Wilson, 2012; Laurence et al., 2018; Verdín & Godwin, 2018). Students with positive attitudes benefit from enhanced mathematical creative thinking and ethnic identity, suggesting that fostering a positive attitude toward mathematics can contribute to academic success. Moreover, this study found that ethnic identity significantly predicted mathematical creative thinking, supporting earlier findings (Else-Quest et al., 2013; Sonnenschein & Galindo, 2015). Ethnicity mediates this relationship, as cultural values tied to ethnic identity shape students' academic experiences. This finding further emphasizes the need for culturally responsive teaching strategies that take students' ethnic backgrounds into account. Indonesia's multicultural environment, which includes diverse ethnic groups like Batak, Lampung, Javanese, Manado, and Minang, influences students' academic achievements. At the same time, a positive attitude toward mathematics plays a crucial role in enhancing mathematical creative thinking. A positive attitude helps maintain focus, regulate achievement, and supports persistence in overcoming challenges (Huang et al., 2022; Tseng et al., 2013). Thus, promoting a positive attitude toward mathematics can lead to improved mathematical creative thinking and greater overall success. While Indonesian students value academic success, particularly in mathematics (Shin et al., 2018), external pressures from parents, teachers, and peers may also impact their achievements.

Jumping out of the relationships among the factors influencing mathematical creative thinking, to answer RQs 5, this dissertation continued to explore the relationship between ethnicity, attitude, creative style, parents' education level, and mathematical creative thinking across different grade levels was explored in this study, acknowledging that students' creative thinking abilities can vary due to these factors. The findings revealed that mathematical creative thinking was influenced by these factors, in line with prior research that links parents' education to creative thinking (Pugsley & Acar, 2020), creative style (Ramos & Puccio, 2014), and cultural influences (Luria et al., 2016). Specifically, attitude toward mathematics was positively correlated with fluency, flexibility, and originality, but negatively correlated with elaboration. Ethnicity had a positive effect on flexibility but a negative effect on other aspects of mathematical creative thinking, suggesting that a strong cultural identity can enhance adaptability but may present challenges for other dimensions of creativity (Myers, 2016). The study highlights the dynamic interplay between cultural identity and academic creativity. These results are consistent with Al-Suleiman (2009) findings on the influence of cultural factors on creativity. The study also uncovered meaningful variations across grade levels. Among 7th graders, attitude toward mathematics and creative style positively influenced mathematical creative thinking, and parents' education indirectly supported students' creativity by fostering more positive attitudes toward mathematics. For 8th graders, attitude, ethnicity, and creative style were all positively associated with mathematical creative thinking, highlighting the importance of both internal motivation and cultural background during this developmental stage. In 9th grade, ethnicity and fathers' education contributed positively to mathematical creative thinking, while shifts in students' learning dynamics may have influenced the role of attitude and creative style. These findings suggest that idea generation, exploratory thinking, and creative dispositions are particularly valuable in fostering creativity among 7th and 8th graders. Additionally, the role of parental education appears nuanced, with its influence shaped by how it interacts with students' attitudes and the broader learning environment. This complexity highlights the need for educational approaches that balance structure with open-ended exploration, especially as students progress through different academic stages. Moreover, traditional methods that emphasize memorization and standardized assessments (Harris, 2015) may need to be complemented with more flexible, creativity-oriented strategies to fully support students' creative development in mathematics.

Answering RQs 6, study 6 delved into the factors influencing mathematical creative thinking, a crucial skill for the 21st century, by examining the roles of perceived creativity, creative self-efficacy, and computational thinking. These elements contribute to a deeper understanding of mathematical creative thinking and underscore its significance in preparing students to tackle complex, real-world challenges. In this study, I found that computational thinking acted as a mediator between perceived creativity and creative self-efficacy in fostering mathematical creative thinking. This supports previous research highlighting the role of computational thinking in enhancing creativity, both in general and in the context of mathematical problem-solving (Doleck et al., 2017; Knochel & Patton, 2015; Romero et al., 2017). Computational thinking was found to positively influence creativity, suggesting that shared cognitive processes are closely tied to mathematical ability and abstraction (Hsu et al., 2018). Furthermore, providing students with opportunities to solve open-ended mathematical problems was shown to enhance their achievement (Xu et al., 2022). In addition, the study revealed that perceived creativity positively influenced mathematical creative thinking, whereas creative self-efficacy did not. This aligns with previous studies (Groeneveld et al., 2023; Li et al., 2017), which highlight the connection between individuals' self-perception of creativity and their engagement in creative thinking processes. Many students, however, hold limited views of mathematical creativity and negative beliefs about their own ability to think creatively in mathematics (Bicer et al., 2020), often underestimating their creative potential and distinguishing mathematical creativity from other types of creative thinking (Beghetto et al., 2011). Regarding gender differences, the study found that Indonesian female students outperformed their male counterparts across all variables. This difference may be attributed to variations in learning styles and the alignment of teaching methods and curricula with students' needs. This suggests that gender may play a role in fostering mathematical creativity, warranting further investigation into how gender-responsive teaching methods could enhance creativity in mathematics. Previous research has suggested that females tend to engage more in creative and computational activities, possibly due to differences in cognitive approaches. Societal expectations and biases may also contribute. If female students continue to excel in these areas, it could signal a positive shift toward greater inclusion and empowerment of women in STEM and creative fields (Hughes et al., 2024).

The findings of this study also inform broader educational discussions surrounding the cultivation of 21st-century skills, particularly creativity, problem-solving, and adaptability. As education systems worldwide shift toward fostering these competencies, there is an increasing demand for assessment tools that can measure students' creative abilities in authentic, culturally relevant ways. The development and validation of an ethnomathematics-based test in this study address this need by offering a diagnostic tool that is not only psychometrically sound but also aligned with students' lived cultural experiences. This integration reflects global priorities, as outlined by frameworks such as the PISA, which has increasingly emphasized mathematical reasoning, real-world problem-solving, and creative thinking in its assessments. Indonesia's performance in international benchmarks like PISA has highlighted persistent challenges in students' higher order thinking skills, underscoring the urgency of educational reforms that go beyond rote memorization. The tools developed in this study support such reforms by promoting creative engagement with mathematics and validating students' diverse cognitive and cultural strengths. By connecting local cultural practices with global educational goals, this research demonstrates how culturally grounded assessments can play a transformative role in preparing students to thrive in a rapidly evolving, knowledge-driven world.

3.2. Implications

The theoretical and practical implications of this research are multifaceted and relevant to the fields of mathematics education. Mathematical creative thinking, assessed through an ethnomathematics-based test, is a crucial skill for students as outlined in Indonesia's 2013 mathematics curriculum (Ministry of Education, 2016). However, studies have highlighted low achievement levels and a lack of research in this area within Indonesia (Corebima et al., 2017; Ismawati et al., 2023). This study contributes to the field of assessment by presenting a practical ethnomathematics-based test and inventory for measuring mathematical creative thinking skills. Additionally, it provides insights into skill development, differences among students, and potential factors influencing these skills, particularly to enhance the achievement of Indonesian students.

The theoretical and practical implications of this research are multifaceted and especially significant within the context of mathematics education in Indonesia. Rooted in the 2013 national curriculum (K–13), which emphasizes critical and creative thinking (Ministry of Education, 2016), this study responds to an ongoing challenge: despite curriculum reforms, Indonesian students still tend to underperform in creative thinking assessments (Corebima et al., 2017; Ismawati et al., 2023). This research fills a vital gap by developing and validating an ethnomathematics-based assessment tool designed to capture students' mathematical creative thinking through culturally familiar tasks.

The systematic review of mathematical creative thinking assessment methods highlights the need for culturally sensitive and context-specific measurement tools (Koch et al., 2015). This finding suggests that a one-size-fits-all approach is inadequate for capturing the complexities of mathematical creative thinking across different cultural and educational settings. It emphasizes the need for teachers and researchers to adapt the assessment methods such as ethnomathematics based test to reflect the diverse backgrounds and learning environments of students. Including, (1) using open-ended essay tests to assess deeper aspects of mathematical creative thinking, (2) taking into account psychometric validity and cultural relevance when designing these assessments, and (3) incorporating ethnomathematics-based tests to better evaluate mathematical creativity. These findings offer valuable guidance for selecting or developing assessment tools that align with the Indonesian context, considering variations in the creative thinking curriculum.

The validation of the instrument underscores the importance of culturally adapting assessment tools (Hannula et al., 2016; Sidani et al., 2010). This has broader implications, suggesting that attitude measurement instruments should be tailored to the cultural context to ensure accurate results (Aquilina et al., 2024; Unfried et al., 2015). This practice is relevant not only in mathematics education but also in other fields (i.e., scince, technology, engineering) where attitudes and perceptions are assessed (Tseng et al., 2013; Tzeng et al., 2024). Additionally, the incorporation of ethnomathematics as a framework for exploring mathematical concepts through cultural patterns encourages educators to embrace cultural diversity and local knowledge (Wulandari et al., 2024). By integrating traditional cultural elements into mathematics education, teachers can create a more inclusive and engaging learning environment (Payadnya et al., 2024), potentially overcoming cultural barriers in the teaching of mathematics and to incorporate culturally responsive practices to support student success (Cobian et al., 2024). Furthermore, the results provide guidance for teachers in designing effective instructional strategies and assist policymakers in revising policies or curricula. This includes focusing on creative thinking activities for students in grades 7 to 9, especially for those in urban schools and during the knowledge acquisition phase, as this is when their skills are most likely to develop.

Moreover, the identification of various factors influencing students' mathematical creative thinking such as parental education, creativity style, ethnicity, perceived creativity, attitude, and computational thinking illustrates the complexity of the relationship between these factors and academic performance. These results can guide mathematics teachers in developing more personalized and effective teaching approaches that consider the diverse needs and backgrounds of their students (Cai & Wang, 2010; Tossavainen & Helenius, 2024). Teachers can create inclusive learning environments that foster creativity by integrating cultural awareness, encouraging positive attitudes towards math, and recognizing the importance of parental involvement. Teachers can also support students by persuading them of their potential in mathematics and offering opportunities to demonstrate their creative capabilities. To foster creativity in the classroom, teachers can go beyond general encouragement by implementing specific, research-informed practices. For instance, they can use open-ended problems that allow multiple solution paths, integrate culturally relevant examples that connect mathematics to students' lived experiences, and structure project-based learning activities that blend creativity with real-world applications. Encouraging group work that values different perspectives and offering reflection opportunities on creative processes can also enhance student engagement. Furthermore, recognizing the importance of parental involvement, schools can support home–school connections through initiatives like take-home creative tasks or family math nights. Direct instruction with these multifaceted influences, educators can create inclusive and stimulating learning environments that not only develop students' creative thinking but also support their overall academic success.

Additionally, the findings provide the implication that incorporating computational thinking and creative thinking into the curriculum can enhance students' critical thinking skills and help them connect mathematical concepts to real-world applications and innovation (Kong, 2016; Tsortanidou et al., 2019). This study also provides a useful framework for policymakers to ensure that curricula and assessments support the development of these skills, promoting a more holistic and forward-thinking approach to mathematics education (Rehman et al., 2024; Umami, 2018). Furthermore, professional development opportunities for teachers focused on creative teaching strategies and the integration of these factors into the classroom could lead to improved student outcomes and better preparation for the challenges of the 21st century (Herlinawati et al., 2024; Kim et al., 2019).

The model developed to explore the factors influencing mathematical creative thinking skills can be applied to similar studies in this area, as it proved to be statistically reliable and well-suited to the data analyzed. Moreover, the direct and indirect effects identified in the study offer valuable theoretical insights, filling gaps in previous research that overlooked the simultaneous consideration of all relevant factors (Gil-Hernández, 2019; Guggemos, 2021; Haase et al., 2018; Mönkediek & Diewald, 2022; Pretz & Nelson, 2017; Proudfoot et al., 2015; Rodet, 2021; Román-González et al., 2018; Zhang & Wong, 2023). From a practical standpoint, these findings help guide teachers in designing effective instructional strategies that focus on affective factors, especially within the Indonesian context. This can involve reinforcing mathematical concepts when students struggle with certain areas or introducing open-ended tasks to improve comprehension skills, which in turn enhance mathematical creativity performance. Additionally, providing financial support or resources to students from economically disadvantaged backgrounds could have a positive impact on their development of these skills.

One of the unique findings from the Indonesian context is the differentiated impact of ethnicity across grade levels. For example, while ethnicity had a positive influence on mathematical creative thinking in grade 9, it had a negative or neutral influence in earlier grades. This suggests that students' cultural identity may evolve as they progress through school, and its influence on creativity may become more positive with age or educational maturity. Another surprising finding is the consistently negative effect of parents' education levels on creative thinking particularly in younger grades which may be attributed to traditional expectations or pressure that emphasize academic conformity over creative exploration. These insights challenge common assumptions about the universal benefits of parental education and invite further research into how cultural expectations within families shape students' learning behaviors.

More broadly, the implications of this dissertation align with global shifts in education policy that emphasize the development of 21st-century skills, such as creativity, problem-solving, adaptability, and innovation. Mathematical creative thinking is central to these skills, yet remains underdeveloped in many education systems, particularly those like Indonesia that are still transitioning away from rote learning models. This is especially relevant in light of Indonesia's performance in international assessments like PISA, where students often score lower in creative thinking domains. Thus, emphasizing creative thinking in mathematics education through contextually relevant tools like ethnomathematics-based assessments this study supports a broader educational transformation. Such efforts are essential not only for improving assessment strategies but also for equipping students to thrive in a complex, fast-changing world. The findings underscore the urgent need for systemic reform in both curriculum and teacher training, emphasizing culturally responsive pedagogy and the nurturing of creative potential in all learners.

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APPENDIX A

ATTITUDE TOWARD MATHEMATICS QUESTIONNAIRE (ENGLISH VERSION)

General Information

1. Name ……………………………………………………………………
2. Gender : Male [ ] Female [ ]
3. Grade: 7 [ ] 8 [ ] 9 [ ]
4. Ethnicity:
   Java [ ] Lampung [ ] Batak [ ] Bugis [ ]
   Padang [ ] Sunda [ ] Betawi [ ] Others [ ]
5. Living place: City [ ] District [ ]
6. Type of school: Public [ ] Private [ ]
7. Mother Education Level
   Education Without Experience [ ] Did Not Complete Grade 6 [ ]
   Primary Education [ ] Secondary Education [ ]
   High School Education [ ] Higher Education (Diploma) [ ]
   Bachelor [ ] Master [ ] Doctorate [ ]
8. Father Education Level
   Education Without Experience [ ] Did Not Complete Grade 6 [ ]
   Primary Education [ ] Secondary Education [ ]
   High School Education [ ] Higher Education (Diploma) [ ]
   Bachelor [ ] Master [ ] Doctorate [ ]

The scale is as follows: 1 = Strongly Disagree, 2 = Disagree, 3 = Neither Agree nor Disagree, 4 = Agree, 5 = Strongly Agree. Kindly read each statement carefully and indicate the extent to which you agree. Thank you for your participation.

No	Statements
1	I am really good at math.
2	I understand math.
3	I can solve difficult math problems
4	Math is very hard for me.
5	Math is confusing to me.
6	I can tell if my answers in math make sense
7	Mathematics has contributed greatly to science and other fields of knowledge.
8	Mathematics is a very worthwhile and necessary subject.
9	An understanding of mathematics is needed by artists and writers as well as scientists.
10	Mathematics helps develop a person's mind and teaches him to think.
11	Mathematics is needed in designing practically everything.
12	Mathematics is needed in order to keep the world running.
13	When I have to do math homework, I do it with some joy.
14	If given the opportunity, I would choose elective courses related to mathematics.

No	Statements
15	The subject taught in mathematics classes is very interesting.
16	Mathematics is one of the most boring subjects.
17	I like mathematics.
18	Studying mathematics is dead boring.
19	I feel comfortable doing math problems.
20	Doing math is easy for me.
21	My friends think that I am successful at Maths.
22	I see myself as a successful student in Maths
23	I think I am a good student in Maths.
24	I am sure I will be successful in math class.
25	According to my friends, I am a successful student in mathematics.
26	I am sure that my teachers found me successful in math class.

APPENDIX B

ATTITUDE TOWARD MATHEMATICS QUESTIONNAIRE (INDONESIAN VERSION)

(1= sangat tidak setuju, 2 = tidak setuju, 3 = netral, 4 = setuju, 5 = sangat setuju)

No	Pernyataan
1	Saya sangat pandai dalam matematika.
2	Saya memahami matematika.
3	Saya bisa menyelesaikan masalah matematika yang sulit.
4	Matematika sangat sulit bagi saya.
5	Matematika membingungkan bagi saya.
6	Saya dapat mengetahui apakah jawaban saya dalam matematika masuk akal.
7	Matematika telah berkontribusi besar pada ilmu pengetahuan dan bidang pengetahuan lainnya.
8	Matematika adalah mata pelajaran yang sangat berharga dan diperlukan.
9	Pemahaman matematika dibutuhkan oleh seniman dan penulis, serta ilmuwan.
10	Matematika membantu mengembangkan pikiran seseorang dan mengajarkannya untuk berpikir.
11	Matematika diperlukan dalam merancang hampir segala sesuatu.
12	Matematika dibutuhkan agar dunia dapat terus berjalan.
13	Ketika saya harus mengerjakan PR matematika, saya melakukannya dengan sedikit rasa senang.
14	Jika diberi kesempatan, saya akan memilih mata kuliah pilihan yang berkaitan dengan matematika.
15	Topik yang diajarkan dalam kelas matematika sangat menarik.
16	Matematika adalah salah satu mata pelajaran yang paling membosankan.
17	Saya suka matematika.
18	Belajar matematika sangat membosankan.
19	Saya merasa nyaman mengerjakan soal-soal matematika.
20	Mengerjakan matematika mudah bagi saya.
21	Teman-teman saya berpikir bahwa saya berhasil dalam matematika.
22	Saya melihat diri saya sebagai siswa yang berhasil dalam matematika.
23	Saya berpikir bahwa saya adalah siswa yang baik dalam matematika.
24	Saya yakin saya akan berhasil di kelas matematika.
25	Menurut teman-teman saya, saya adalah siswa yang berhasil dalam matematika.
26	Saya yakin guru saya menganggap saya berhasil di kelas matematika.

APPENDIX C

MULTIGROUP ETHNIC IDENTITY INVENTORY (ENGLISH VERSION)

General Information

1. Name ……………………………………………………………………
2. Sex: Male [ ] Female [ ]
3. Grade: 7 [ ] 8 [ ] 9 [ ]
4. Ethnicity:
   Java [ ] Lampung [ ] Batak [ ] Bugis [ ]
   Padang [ ] Sunda [ ] Betawi [ ] Others [ ]
5. Living place: City [ ] District [ ]
6. Type of school: Public [ ] Private [ ]
7. Mother Education Level
   Education Without Experience [ ] Did Not Complete Grade 6 [ ]
   Primary Education [ ] Secondary Education [ ]
   High School Education [ ] Higher Education (Diploma) [ ]
   Bachelor [ ] Master [ ] Doctorate [ ]
8. Father Education Level
   Education Without Experience [ ] Did Not Complete Grade 6 [ ]
   Primary Education [ ] Secondary Education [ ]
   High School Education [ ] Higher Education (Diploma) [ ]
   Bachelor [ ] Master [ ] Doctorate [ ]

The scale is as follows: 1 = Strongly Disagree, 2 = Disagree, 3 = Neither Agree nor Disagree, 4 = Agree, 5 = Strongly Agree.

Kindly read each statement carefully and indicate the extent to which you agree. Thank you for your participation.

No	Statements
1	I am happy that I am a member of the group I belong to.
2	I have a strong sense of belonging to my own ethnic group.
3	I have a lot of pride in my ethnic group and its accomplishments.
4	I feel a strong atachment towards my own ethnic group.
5	I feel good about my culture or ethnic background.
6	I have spent time trying to find out more about my own ethnic group, such as its history, traditions, and customs.
7	I have a clear sense of my ethnic background and what it means for me.
8	I think a lot about how my life will be affected by my ethnic group membership.
9	I undesrtand pretty well what my ethnic group membership means to me, in term of how to relate to my own group and other groups.
10	In order to learn more about my ethnic background, I have often talked to other people about my ethnic group.
11	I like keeping the traditions of the heritage of my ethnic group.

No	Statements
12	The values of my ethnic groups determine my life.
13	In general, belonging to my ethnic group is an important part of my self-image.
14	The values of my ethnic groups are important for my judgment about what I have to do.
15	The cultural traditions of my ethnic group absolutely express me.
16	I know about being traditional fabric cloth, such as Tapis Lampung.
17	I know about being Tapis Lampung motif, such as Jung Sarat motif, Mountain Motif, Flaura and Fauna motif, Pucuk Rebung motif.
18	I know about the process of making Tapis Lampung
19	I know the values of Tapis Lampung, such as economyc, cultur, story.

APPENDIX D

MULTIGROUP ETHNIC IDENTITY INVENTORY (INDONESIAN VERSION)

(1= sangat tidak setuju, 2 = tidak setuju, 3 = netral, 4 = setuju, 5 = sangat setuju)

No	Statements
1	Saya senang menjadi bagian dari kelompok yang saya ikuti.
2	Saya memiliki rasa kebersamaan yang kuat dengan kelompok etnis saya sendiri.
3	Saya sangat bangga dengan kelompok etnis saya dan pencapaiannya.
4	Saya merasa memiliki ikatan yang kuat dengan kelompok etnis saya sendiri.
5	Saya merasa bangga dengan budaya atau latar belakang etnis saya.
6	Saya telah meluangkan waktu untuk mencari tahu lebih banyak tentang kelompok etnis saya sendiri, seperti sejarah, tradisi, dan adat istiadatnya.
7	Saya memiliki pemahaman yang jelas tentang latar belakang etnis saya dan apa artinya bagi saya.
8	Saya sering memikirkan bagaimana kehidupan saya dipengaruhi oleh keanggotaan dalam kelompok etnis saya.
9	Saya cukup memahami apa arti keanggotaan kelompok etnis saya bagi saya, terutama dalam hal bagaimana saya berhubungan dengan kelompok saya sendiri dan kelompok lainnya.
10	Untuk mempelajari lebih lanjut tentang latar belakang etnis saya, saya sering berbicara dengan orang lain tentang kelompok etnis saya.
11	Saya suka melestarikan tradisi warisan dari kelompok etnis saya.
12	Nilai-nilai dari kelompok etnis saya menentukan cara hidup saya.
13	Secara umum, menjadi bagian dari kelompok etnis saya adalah bagian penting dari citra diri saya.
14	Nilai-nilai dari kelompok etnis saya sangat memengaruhi penilaian saya tentang apa yang harus saya lakukan.
15	Tradisi budaya kelompok etnis saya benar-benar mewakili saya.
16	Saya tahu tentang kain tradisional, seperti Tapis Lampung.
17	Saya tahu tentang motif Tapis Lampung, seperti motif Jung Sarat, motif Gunung, motif Flora dan Fauna, serta motif Pucuk Rebung.
18	Saya tahu tentang proses pembuatan Tapis Lampung.
19	Saya memahami nilai-nilai Tapis Lampung, seperti nilai ekonomi, budaya, dan cerita.

APPENDIX E

THE CONSTRUCT OF AN ETHNOMATHEMATICAL BASED TEST

Content Domain Test	Creative Thinking Factors	Sources	Item Number	BT
Figural				
Picture Construction	Fluency	(Torrance, 2008)	1 and 2	C1, C3
	Flexibility	(Lee & Seo, 2003)	3 and 4	C1, C3
	Elaboration	(Barkley & Cruz, 2001)	5	C1, C2 C3
Picture Completion	Originality	(Torrance, 2008)	6 and 7	C1, C2 C3
	Flexibility	(TIMSS, 2003)	8	C1, C2 C3
	Elaboration	(Carter, 2008)	9	C1
Verbal				
Unusual Uses (Triangle)	Flexibility	(TIMSS, 2003)	10	C4, C5, C6
Unusual Uses (Square)	Fluency	(Rahman As'ari et al., 2017)	11	C4, C5, C6
Unusual Uses (Triangle)	Elaboration	(Subchan et al., 2018)	12	C4, C5, C6
Unusual Uses (Algebra/ Pattern)	Elaboration	(TIMSS, 2003)	13	C4, C5, C6
Unusual Uses: Geometry (Two and three-dimensional shapes)	Fluency	(TIMSS, 2003)	14	C4, C5, C6
	Fluency	Researcher	15	C2
	Flexibility	(Kemendikbud, 2017)	16	C4, C5, C6
	Flexibility	Researcher	18	C2
Product Improvement	Originality	(Munahefi et al., 2021)	17	C1, C2, C3
Guessing Causes and Consequences	Originality	(Subchan et al., 2018)	19	C5, C6
	Originality	Researcher	20	

Note: *C1: Remember; C2: Understand; C3: Apply; C4: Analyze; C5: Evaluate; C6: Create, BT: Bloom taxonomy.*

APPENDIX F

THE SCORING RUBRIC

Scores are assigned based on classified responses that include fluency, flexibility, creativity, and elaboration. The scores will modify by Lee & Seo (2003) for each scoring technique as follow:

1. Fluency

   How many right solutions exist for each response category. When a student correctly answers multiple questions in a category, the highest possible score is 5.

2. Flexibility

   How many unique categorical responses a student may provide. Students may write a maximum of 5 responses to a single problem. Thus, the maximum flexibility score is 5. For instance, if a student's comments are classified into 4 different categories, the flexibility score is 4.

3. Originality

   How original is an answer that no other pupils could think of. The originality score reflects the response's relative rarity. The following criteria are used to assess originality:

   a. The frequency is examined in terms of how many students gave the same type of response, classified by sub-level.

   a. The percentage of frequency to which the response type belongs is calculated.

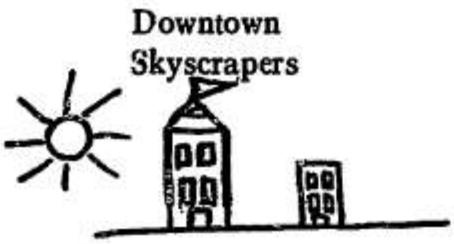
   b. The score is awarded according to the percentage of frequency as shown below.

      1) 3% above = 0
      2) 2% above – 3% below = 1
      3) 1% - 2% below = 2
      4) 1% below = 3

   b. The originality score has no upper limit

4. Elaboration

   Each response is further considered for its elaborateness and given either two or one points. If a subject describes in his response an object beyond its very minimum essentials (to convey what he has in mind), the response is scored two for elaborateness. For example score for elaboration:



Elaboration score = 2

Elaboration score = 1

APPENDIX G

MATHEMATICAL CREATIVE THINKING-ETHNOMATHEMATICS BASED TEST (ENGLISH VERSION)

General Information

1. Name ……………………………………………………………………
2. Sex: Male [ ] Female [ ]
3. Grade: 7 [ ] 8 [ ] 9 [ ]
4. Ethnicity:
   Java [ ] Lampung [ ] Batak [ ] Bugis [ ]
   Padang [ ] Sunda [ ] Betawi [ ] Others [ ]
5. Living place: City [ ] District [ ]
6. Type of school: Public [ ] Private [ ]
7. Mother Education Level
   Education Without Experience [ ] Did Not Complete Grade 6 [ ]
   Primary Education [ ] Secondary Education [ ]
   High School Education [ ] Higher Education (Diploma) [ ]
   Bachelor [ ] Master [ ] Doctorate [ ]
8. Father Education Level
   Education Without Experience [ ] Did Not Complete Grade 6 [ ]
   Primary Education [ ] Secondary Education [ ]
   High School Education [ ] Higher Education (Diploma) [ ]
   Bachelor [ ] Master [ ] Doctorate [ ]

Test Instrument

*The red is the key answers

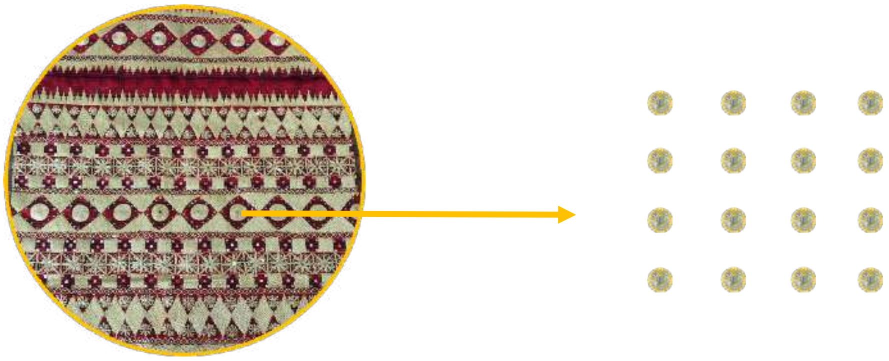
1. Below is Tapis Lampung pattern. You can see the triangle pattern in this motif. Make five different pictures out of them, based on the pattern you see in the motif. Give a title of each image.

Students can provide up to five different pictures, each with a title. The highest possible score is 5.

2. Below is Tapis Lampung with Ship Motif.
    a. Find the rhombus pattern on the Tapis Lampung motif!
    b. Based on your findings. Make five different images. You can draw anything from that rhombus shape. Make the diamond a part of any picture you make. Try to think of pictures no one else will think of. Add details to tell complete stories with your pictures.

Students can provide up to five different pictures, each with a title. The highest possible score is 5. There is no right or wrong here.

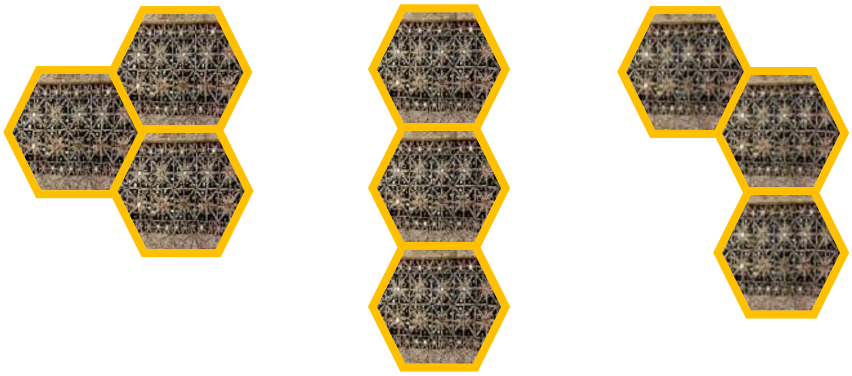
3. Below is Tapis Lampung pattern with a motif in the circle. As shown below, there are 16 dots arranged with 1 unit area spacing between them.



Draw lines between the dots to make as many figures as possible with 2 unit areas. If two or more figures are overlapped when turned around or over, they are considered identical. No figure should be split in two or have one point in common with another.

Students can provide as many as pattern. The highest possible score is 5. There is no right or wrong here.

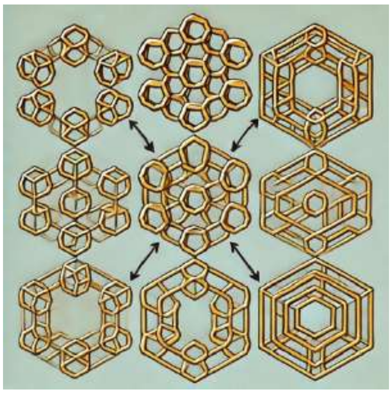
4. Below is Tapis Lampung with Flaura Motif (Mato Kibaw).
    a. Find and draw the regular hexagonal in the Tapis Lampung pattern!
    b. As shown in the example below, 3 sheets of paper in the shape of a regular hexagonal can be joined together along the sides in 3 ways.



 and  are considered identical

Then, make all drawings of how to join together 6 sheets of paper in the shape of a regular hexagon along the sides, as in the example above. If two or more figures are overlapped when turned around or over, they are considered identical.

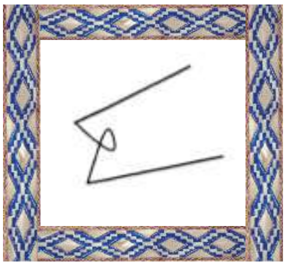
Students can provide as many as pattern. The highest possible score is 5.



5. The pictures are part of Tapis Lampung with geometry motifs.
   a. Make a list of any flat shapes that you find in the Tapis Lampung motif!
   b. Draw any pictures from your findings using at least one flat shape that you found in number a. You can combine 2 or 3 or more flat shapes to create a unique image. Then name the image you have made.

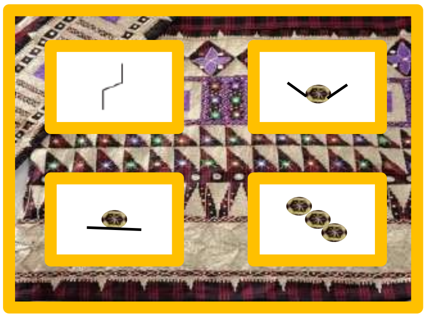
Students can provide as many as pattern. The highest possible score is 2. There is no right or wrong here.

6. At the bottom of this page is a piece of colored paper in a curved shape.
Add lines to the incomplete figures below to make pictures out of them. Try to tell complete stories with your pictures. Try to think of a picture that no one else will think of. When you have completed your picture, give your pictures titles. Make your title as clever and unusual as possible.

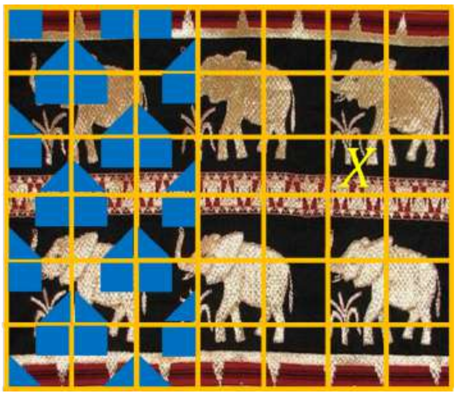
Students can provide as many as pattern. The highest possible score is 3. There is no right or wrong here.

7. Here are some squares with little figures drawn inside of them. Try to make each little figure into something else. You can do whatever you want with these. You can make them funny or beautiful. You can add words. You can use more than one at a time–whatever you want. There is no right or wrong here.



Students can provide as many as pattern. The highest possible score is 3.

8. Above is Tapis Lampung with Elephant Motif. If the pattern in the following figure is continued, determine the image formed on the square marked X.



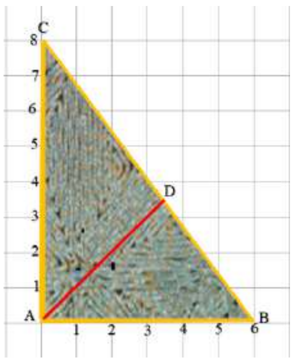
Students can provide the pattern. The highest possible score is 5.

9. The pictures is part of Tapis Lampung with Slops Motifs and Mountain Motifs. Add the other figure using the shapes are given, then given the name!

Motifs	Shapes	Complete Drawing
Mountain Motif		
Slops Motif		

Students can provide the pattern. The highest possible score is 2. There is no right or wrong here.

10. The triangle is designed by Tapis Lampung ornamnt with *Jung Sarat* motif. The triangle is a right triangle with legs 8 and 6. The vertices are at the points $A(0,0)$, $B(0,6)$, and $C(0,8)$. The red line segment is perpendicular to hypotenuse. Find the length of the red line segment.



Students can solved the problem.

$L.ABC = \frac{1}{2} x\ a\ x\ t$

$L = \frac{1}{2} x\ 6\ x\ 8 = 24$ unit area

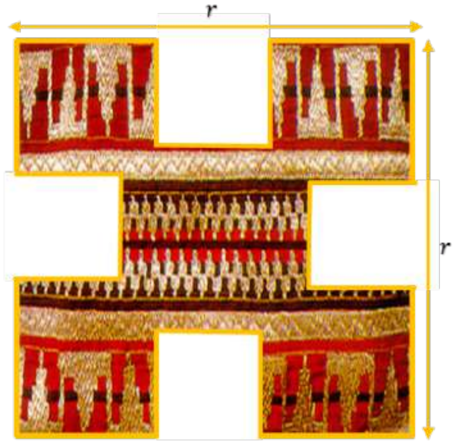
Hence,

$L.ABC = \frac{1}{2} x\ BC\ x\ AD$

$24 = \frac{1}{2} x\ 10\ x\ AD$

$AD = \frac{24}{5}$

11. The picture below is Tapis Lampung pattern with Lereng-Lereng Motifs. Express the perimeter and area of the following shapes in algebraic form!

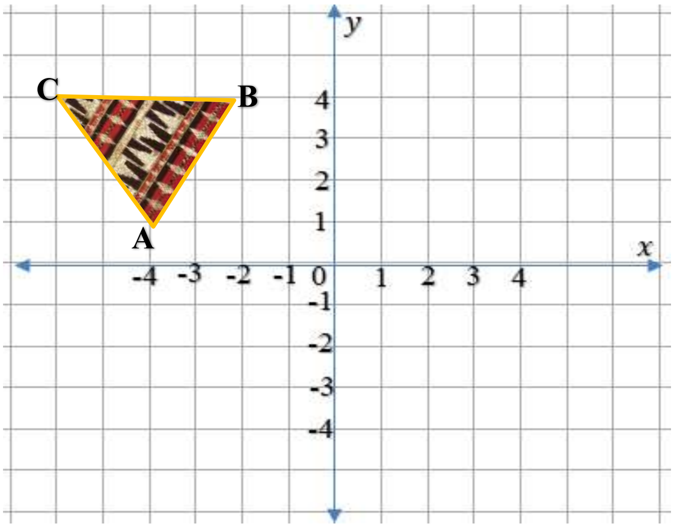


Students can solved the problem.

$K = 4r + 4q$

$L = r^2 - 4q^2$

12. The ABC triangle is Tapis Lampung with Mountain Motif in the figure below.



a. Rotate the ABC triangle with a rotation angle of 90^0 clockwise with the center of the rotation $(0, 0)$. What are the coordinates of the vertices of the triangle $A'B'C'$, which are the shadows of the ABC triangle?

b. Rotate the ABC triangle with a rotation angle of 180^0 clockwise with the center of the rotation $(0, 0)$. What are the coordinates of the vertices of the triangle $A'B'C'$, which are the shadows of the ABC triangle?

Students can solved the problem.

a. Using the 90° clockwise rotation rule: (x,y)→(y,−x)
   Applying this to each point:
   A(−3,−1)→(−1,3)
   B(−2,3)→(3,2)
   C(−4,3)→(3,4)
   New coordinates:
   A′(−1,3), B′(3,2), C′(3,4)

b. Using the 180° clockwise rotation rule: (x,y)→(−x,−y)
   Applying this to each point:
   A(−3,−1)→(3,1)
   B(−2,3)→(2,−3)
   C(−4,3)→(4,−3)
   New coordinates:
   A′(3,1), B′(2,−3), C′(4,−3)

13. The three figures below are divided into small congruent triangles.

a. Complete the table below. First, fill in how many small triangles make in Figure 3. Then, find the number of small triangles that would be needed for the 4^{th} figure if the sequence of figures is extended.

Figure	Number of Small Triangles
1	2
2	8
3	
4	

b. The sequence of figures is extended to the 7^{th} figure. How many small triangle would be needed for Figure 7?

c. The sequence of figures is extended to the 50^{th} figure. Explain a way to find the number of small triangles in the 50^{th} figure that does not involve drawing it and counting the number of triangles.

Students can solved the problem.

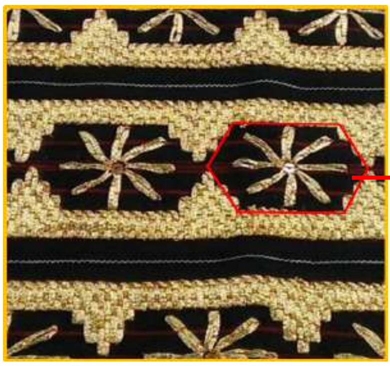
a.

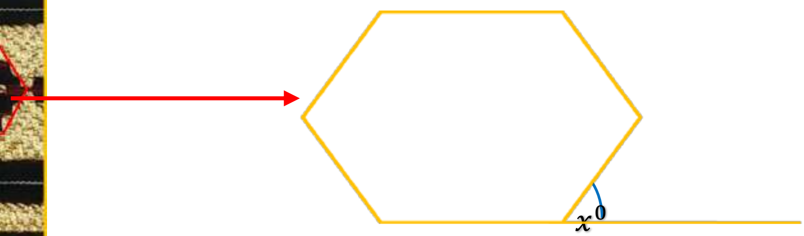
Figure	Number of Small Triangles
1	2
2	8
3	18
4	32

b. 98

c. 5000

14. The figure above is a regular hexagon in Tapis Lampung pattern. The representation of this pattern is hexagonal. What is the value of x?

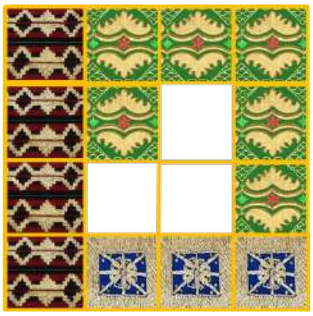




Students can solved the problem.

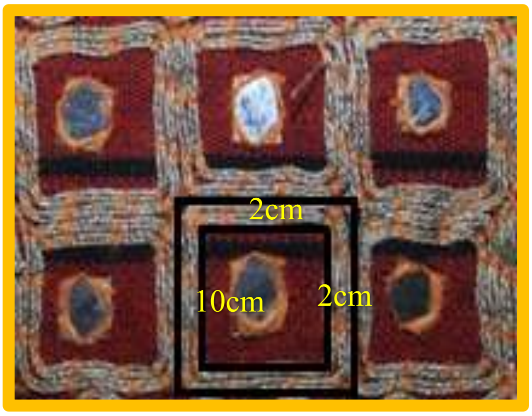
$$x^0 = 180^0 - 120^0 = 60^0$$

15. Create an illustrated multiplication problem by the following image.



4a+3b+3c+6d=16

16. A square-shaped *Tapis Kaca* with dimensions 10 cm x 10 cm has a 2 cm wide cemented path along its length and a 2 cm wide path along its width (as shown in the figure below).
   a. Write down the problem into a question!
   b. Write down the data you need!
   c. Find the area of the shaded gold portion!
   d. Show other ways to determine the area of the shaded gold area!



a. Writing the problem as a question:
   What is the area of the shaded gold portion of the square-shaped Tapis Kaca after accounting for the 2 cm wide cemented path along its length and width?
b. Writing down the necessary data:
   1. The total dimensions of the square Tapis Kaca: 10 cm × 10 cm
   2. The width of the cemented path along the length: 2 cm on each side
   3. The width of the cemented path along the width: 2 cm on each side
c. Finding the area of the shaded gold portion
   1. Calculate the remaining length of the inner square:
      Since the cemented path is 2 cm wide on each side, the total reduction is:
      $2\times2=4\ cm^2$,
      Therefore, the side length of the remaining gold area is: $s' = 10-4=6$
   2. Calculate the area of the gold portion:
      Area= $s' \ x \ s'$ = 6x6 36 cm^2
      The area of the shaded gold portion:

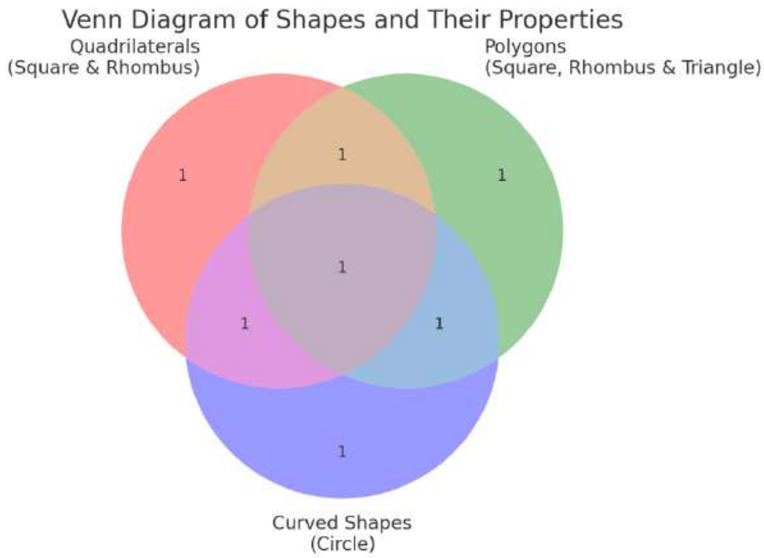
      $A_{total}=10\times10=100\ cm^2$

   3. Area of the removed portion (cemented path):

      $A_{removed} = At_{otal} - A_{gold} = 100\text{-}36 = 64\ cm^2$

17. Looking at the following design pictures!
   a. Mention the name of the flat shape on each of the Tapis Lampung designs!
   b. Mention the properties of the shape in your answer to a problem in number a!
   c. Make a Venn diagram of the relationship between the shapes and the properties of the shapes you mentioned in problem b!.

   a. Square, circle, rhombus, triangle
   b. Properties of the Shapes:
      Square: Four equal sides, four right angles (90°), opposite sides are parallel, and diagonals bisect each other at right angles.
      Circle: No sides or vertices, all points on the boundary are equidistant from the center, and the diameter is twice the radius.
      Rhombus: Four equal sides, opposite angles are equal, diagonals bisect each other at right angles, and opposite sides are parallel.
      Triangle: Three sides, three angles, the sum of the interior angles is always 180°, and can have different classifications (e.g., equilateral, isosceles, scalene).
   c. Diagram ven

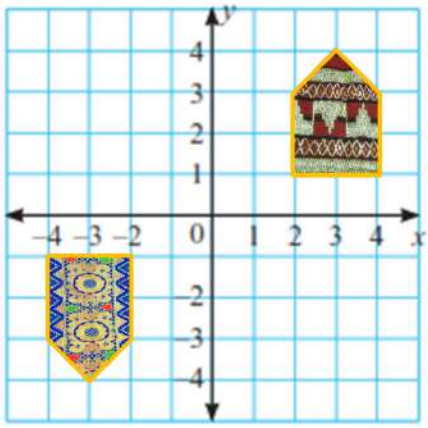


Note:
Quadrilaterals (Square & Rhombus): Shapes with four sides.
Polygons (Square, Rhombus & Triangle): Closed shapes with straight edges.
Curved Shapes (Circle): A shape with no straight edges.

18. Looking at the Tapis Lampung pattern! Determine the number of folding symmetries contained in the image below!

Students can solved the problem: 2

19. The pentagon is known as Tapis Lampung pattern in the cartesius diagram!
    a. Asking questions. Explain whether the blue pattern results from the red pattern's rotation.
    b. Guessing Causes: List as possible out what the angle of rotation is and the direction of the rotation.



Students can solved the problem

a. *Is the blue pattern identical in shape to the red pattern?, Can you identify any specific features in the blue pattern that align with the red pattern after rotating it?, If you rotate the red pattern by 90°, 180°, or 270°, does it transform into the blue pattern?, Are there any other transformations (scaling, reflection, etc.) involved besides rotation to form the blue pattern from the red one?, How can you confirm that the blue pattern is indeed the result of a rotation of the red pattern?*
b. 90° (a quarter turn), 180° (a half turn), 270° (three-quarters turn), 360° (a full turn, resulting in the same pattern)

20. On Sundays the traditional tapis crafter group makes Tapis Lampung. Each person is able to make one line of *Pucuk Rebung Motifs* in 60 minutes. She started making the traditional tapis from 8 am. If she wants to make 3 different motif lines in this day:
    a. Asking Questions: Write all the questions you can think about what is happening in the picture.
    b. Asking answers: Write the possible answer based on the cases
    c. Guessing Consequences: List as many possibilities as you can of what might happen right afterwards or things that might happen as a result long afterwards in the future.

Students can solved the problem

a. Asking Questions:
   1. What is the significance of the Pucuk Rebung motif in the traditional tapis craft?
   2. How long does it take to complete each line of the Pucuk Rebung motif?
   3. How many hours does she have to complete the 3 different motif lines in total?
   4. What tools or materials are needed to create the Pucuk Rebung motif?
   5. Is she working alone or with other people in the tapis crafter group?
   6. What time does she plan to finish making the 3 motif lines?
   7. Is she making the motifs in a specific order or pattern?
   8. Does she take breaks while crafting the tapis, and if so, how long are they?
   9. How many people are in the traditional tapis crafter group, and do they work on the same motifs or different ones?
   10. What is the importance of making these tapis designs on Sundays?
   11. Is the tapis crafted for personal use, sale, or some cultural event?
   12. How does the quality of the work change based on the amount of time spent on each motif?
   13. Does the crafter have any specific techniques or styles for creating the Pucuk Rebung motif?

b. Asking Answers: Write the possible answer based on the cases.
   1. The Pucuk Rebung motif is a traditional design used in Tapis Lampung, often symbolizing growth or new beginnings.
   2. Each line of the Pucuk Rebung motif takes 60 minutes to make.
   3. She has 12 hours to work, starting at 8 am, which means she will be done by 8 pm if she works straight through.
   4. The tools likely include thread, needles, and fabric, along with any decorative elements like beads or embroidery floss.
   5. She could be working alone or in a group of tapis crafters who might each be responsible for different parts of the design.
   6. She aims to complete all three motifs by the end of the day, probably by working at a steady pace without long breaks.
   7. She may follow a specific design pattern, or each motif may be distinct, requiring her to switch techniques between each one.
   8. She may take short breaks to rest her hands, but since each line takes 60 minutes, the breaks would be minimal.
   9. The group might be working on different motifs in parallel or collaborating to create a larger design.
   10. Sunday could be a day set aside for crafting and cultural preservation, perhaps tied to a community event or personal tradition.
   11. The tapis could be created for a cultural event, sold to tourists, or made as part of a personal or family collection.
   12. The crafter may prioritize quality over speed, meaning she might slow down if she is not satisfied with a motif.
   13. Her technique might involve specific stitching methods or color choices that reflect her personal or regional style.

c. Guessing Consequences:
   1. Right afterward:
      a. She might take a break after completing each motif to rest before starting the next one.

   b. If she completes all three motifs on time, she could present them to the group or a customer.
   c. If she encounters any difficulty or mistake, she may need extra time to correct it.
2. Later in the day:
   a. She might start another set of motifs or create additional pieces if she finishes early.
   b. If the tapis is part of a larger project, the motifs she completes could be assembled with others to create a full tapis design.
   c. She might face challenges with fatigue after working all day, which could affect the quality of her work in the later stages.
3. In the future:
   a. The motifs she creates might be passed down to future generations, preserving the tradition of Tapis Lampung.
   b. Her tapis work might become highly sought after, leading to recognition in local or international markets.
   c. If she continues crafting at this pace, she might develop faster and more efficient techniques for creating motifs in the future.
   d. If she teaches others her technique, the tradition of making Tapis Lampung could grow and spread to more people.
   e. The practice might influence her community's involvement in traditional crafts, leading to a resurgence in interest and pride in cultural heritage.
   f. She may decide to teach her children or other artisans how to make the Pucuk Rebung motif, passing on valuable knowledge.

APPENDIX H

MATHEMATICAL CREATIVE THINKING-ETHNOMATHEMATICS BASED TEST (INDONESIAN VERSION)

Mengukur Kemampuan Berpikir Kreatif Matematis dengan Konteks Etnomatematika pada Siswa SMP/MTs

Assalamualaikum. Wr. Wb.

Saya (Suherman) merupakan seorang mahasiswa Doktoral di University of Szeged, Hungary. Saat ini sedang ujicoba soal berpikir kreatif dengan konten etnomatematika, di bawah bimbingan Prof. Tibor Vidákovich.
Saya mengundang semua siswa/i di sekolah menengah (SMP/MTs) untuk berpartisipasi dalam ujicoba instrumen soal ini. Item ini berisi 20 soal terdiri dari soal menggambar, menentukan pola gambar, memprediksi suatu kasus dalam gambar yang diberikan, dan menghitung. Jawaban dapat sekreatif mungkin. Data dan informasi yang dikumpulkan akan dimasukkan ke dalam laporan tertulis dan akan dilaporkan sedemikian rupa sehingga identitas peserta tidak akan diketahui pihak lain. Semua dokumen yang dikumpulkan akan dirahasiakan. Tidak ada pihak lain selain peneliti yang akan melihat jawaban/respon Anda. Partisipasi Anda dapat berkontribusi pada hasil ujicoba instrumen ini di Indonesia. Terima kasih.

Jawaban dapat di kirim melalui link disetiap akhir pertanyaan, namun jika mengalami kesulitan dapat dikirim melalu email suherman@edu.u-szeged.hu atau bisa dikirim melalui WA +6285669722714.

Wassalamualaikum. Wr. Wb.

* Indicates required question

1. Usia *

____

2. Nama Sekolah *

____

3. Tipe Sekolah * — Dropdown

Mark only one oval.

( ) Negeri
( ) Swasta

4. Lokasi Sekolah * Dropdown

Mark only one oval.

- Desa
- Kota
- Kota Kecil
- Kota Besar

5. Jenis Kelamin * Dropdown

Mark only one oval.

- Laki-Laki
- Perempuan

6. Kelas * Dropdown

Mark only one oval.

- 7
- 8
- 9

7. No. HP (WA) *

8. Pendidikan Ayah * Dropdown

Mark only one oval.

- Tidak tamat SD
- SD
- SMP
- SMA
- Diploma
- S
- S2
- S3

9. Pendidikan Ibu * Dropdown

Mark only one oval.

- Tidak tamat SD
- SD
- SMP
- SMA
- Diploma
- S
- S2
- S3

10. Pekerjaan orang tua * Dropdown

Mark only one oval.

- Bekerja
- Tidak Bekerja

11. Hobi *

____

12. Mata pelajaran yang disukai *

13. Mata pelajaran yang tidak disukai *

14. **Petunjuk Pengerjaan** *

1. Bacalah dengan hati-hati.
2. Isilah Identitas Anda dengan benar.
3. Anda diminta menjawab pertanyaan berikut yang terdiri dari 20 soal terbuka.
4. Soal ini untuk mengukur kemampuan berpikir kreatif matematis siswa dengan konteks etnomatematika. Hasil jawaban Anda tidak ada hubungannya dengan nilai matematika Anda di sekolah. Oleh karena itu, jawablah pertanyaan dengan jujur dan sekreatif mungkin.
5. Hasil jawaban Anda akan kami jaga kerasahasiaannya. Hanya peneliti yang bisa membukanya.

15. 1. Di bawah adalah motif Tapis Lampung. Anda bisa melihat banyak pola segitiga pada motif tersebut. Buatlah 5 gambar apapun dari bentuk segitiga yang kalian temukan, dan berikan judul untuk setiap gambarnya. *

Files submitted:

16. 2. Di bawah adalah Tapis Lampung dengan Motif Kapal. *
a. Temukan bangun belah ketupat pada pola Tapis Lampung tersebut!
b. Berdasarkan temuan Anda. Buatlah gambar apapun sebanyak 5 gambar. Anda bisa menggambar apasaja dari bentuk belah ketupat tersebut. Jadikan gambar yang menarik dari gambar yang Anda buat. Cobalah untuk memikirkan gambar yang tidak akan dipikirkan oleh orang lain. Kemudian berikan judul pada masing-masing gambar Anda.

Files submitted:

17. 3. Di bawah ini adalah Tapis Lampung dengan lingkaran bermotif. Gambar di bawah memiliki 16 titik (sebagai lingkaran kecil) yang disusun dengan jarak 1 satuan luas di antara titik-titik tersebut. Hubungkan garis di antara titik-titik untuk membuat gambar sebanyak mungkin dengan luas 2 satuan luas. Jika dua atau lebih angka digabungkan saat diputar atau dibalik, gambar dianggap identik. Tidak ada gambar yang harus dibagi menjadi dua atau memiliki satu titik yang sama dengan yang lain. *

Files submitted:

18. 4. Di bawah ini adalah Tapis Lampung dengan Motif Flaura (Mato Kibaw). *
Seperti yang ditunjukkan pada contoh di bawah ini, 3 lembar kertas berbentuk heksagonal beraturan dapat disatukan di sepanjang sisinya dengan 3 cara. Kemudian, buatlah semua gambar bagaimana cara menyambung 6 lembar kertas berbentuk segi enam beraturan di sepanjang sisinya, seperti pada contoh di atas. Jika dua atau lebih angka yang tumpang tindih saat diputar atau dibalik, hal tersebut dianggap identik.

Perhatikan contoh bahwa:

dan

adalah sama

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19. 5. Gambar-gambar tersebut merupakan bagian dari Tapis Lampung dengan Motif Miring dan Motif Gunung. Tambahkan gambar lain dengan menggunakan bentuk yang diberikan, lalu beri nama! *

Motifs	Bangun Datar	Gambar Lengkap
Mountain Motif		
Slops Motif		

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20. 6. Di bawah ini terdapat gambar yang berbentuk lengkung. Pikirkan gambar atau objek di mana bentuk ini akan menjadi bagian yang penting. Kemudian tambahkan garis dengan pensil atau krayon untuk membuat gambar. Coba pikirkan gambar yang tidak akan dipikirkan oleh orang lain. Kemudian tambahkan ide-ide baru ke ide pertama Anda untuk membuatnya menjadi cerita semenarik mungkin. Ketika Anda telah menyelesaikan gambar Anda, pikirkan nama atau judul dan tulis di bagian bawah gambar tersebut. Buat judul Anda secerdas mungkin dan mungkin tidak biasa. *

 

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21. 7. Berikut adalah beberapa kotak dengan gambar kecil di dalamnya. Disamping adalah 4 gambar yang berbeda. Cobalah untuk membuat setiap sosok kecil menjadi sesuatu yang lain. Anda dapat melakukan apapun yang Anda inginkan dengan ini. Anda bisa membuatnya lucu atau cantik. Anda dapat menambahkan kata-kata. Anda dapat menggunakan lebih dari satu sekaligus atau apa pun yang Anda inginkan. Tidak ada benar atau salah di sini. *

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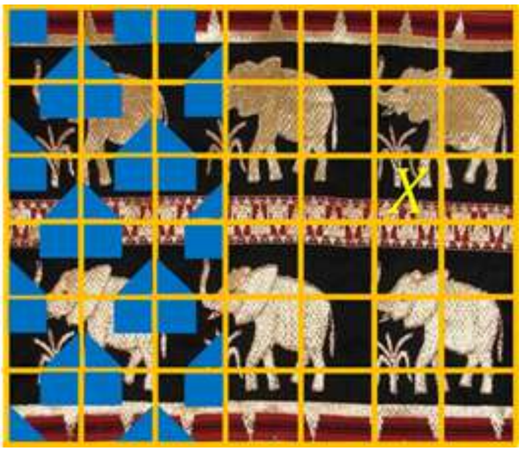
22. 8. Di bawah ini adalah pola gambar dari Tapis Lampung dengan motif Gajah. Jika pola pada gambar berikut dilanjutkan terus menerus, tentukan gambar yang terbentuk pada persegi bertanda X. *



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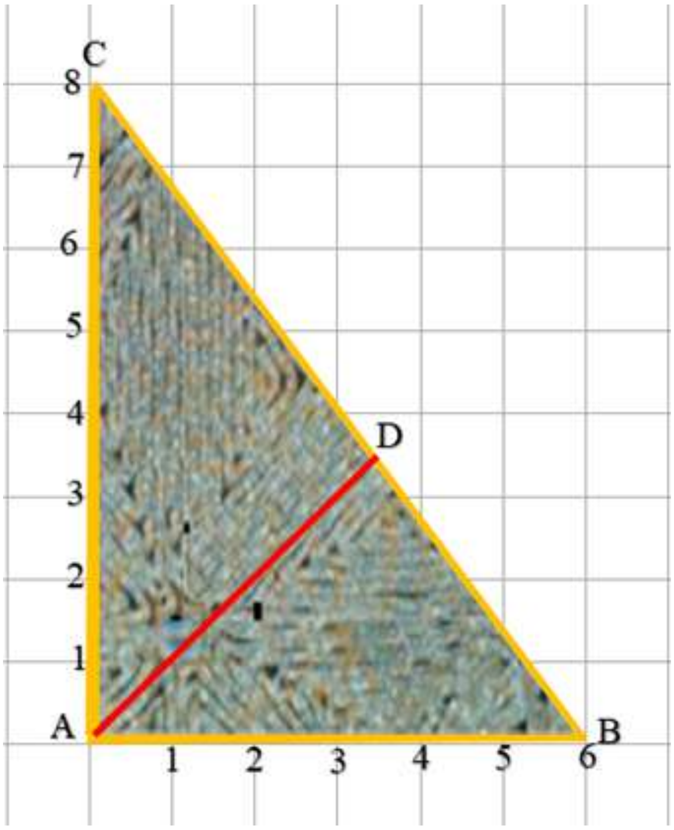
23. 9. Gambar-gambar tersebut merupakan bagian dari Tapis Lampung dengan Motif Miring dan Motif Gunung. Tambahkan gambar lain dengan menggunakan bentuk yang diberikan, lalu beri nama! *

Motifs	Gambar	Lengkapi gambar
Motif gunung		
Motif Slops		

24. 10. Segitiga ini didesain oleh hiasan Tapis Lampung dengan motif Jung Sarat. Segitiga tersebut merupakan segitiga siku-siku dengan kaki 8 dan 6. Titik-titik sudutnya berada di titik A(0,0), B(0,6), dan C(0,8). Segmen garis merah tegak lurus dengan sisi miring. Tentukan panjang ruas garis merah! *



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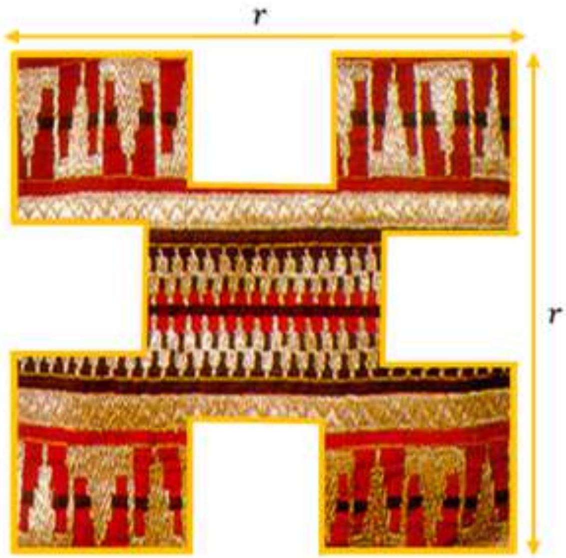
25. 11. Gambar di bawah adalah Tapis Lampung dengan motif Lereng-Lereng. Nyatakan keliling dan luas bangun-bangun berikut dalam bentuk aljabar! *



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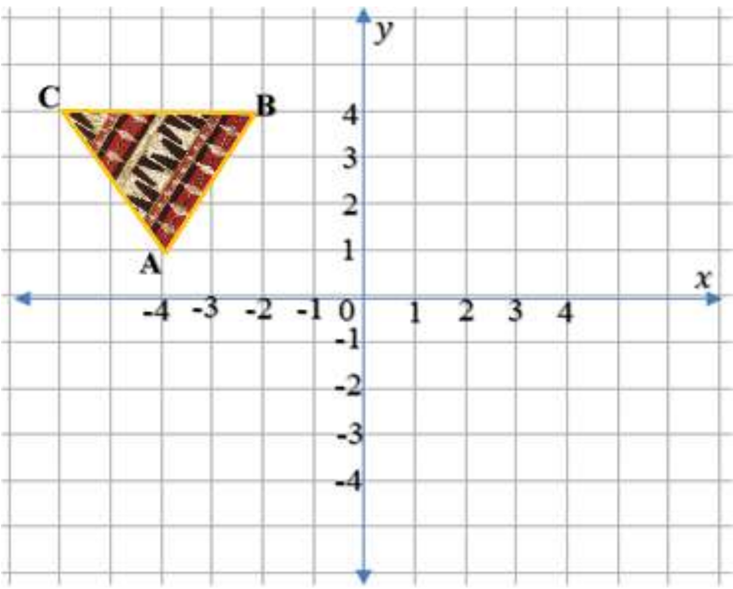
26. 12. Diketahui segitiga ABC terbentuk dari Tapis Lampung dengan Motif Gunung seperti pada gambar di bawah ini. Rotasikan segitiga ABC dengan sudut rotasi 90o searah jarum jam dengan pusat rotasi titik asal (0,0). Berapakah koordinat titik sudut dari segitiga A'B'C' yang merupakan bayangan dari segitiga ABC? *

Rotasikan segitiga ABC dengan sudut rotasi 180o searah jarum jam dengan pusat rotasi titik asal (0,0). Berapakah koordinat titik sudut dari segitiga A'B'C' yang merupakan bayangan dari segitiga ABC?



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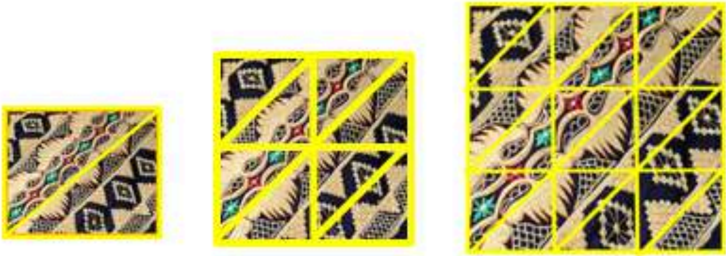
27. 13. Ketiga gambar di bawah ini dibagi menjadi segitiga-segitiga kecil yang berukuran sama. *



a. Gambar tersebut dilanjutkan hingga gambar 4 dengan pola yang sama. Lengkapi tabel di bawah ini.

Figure	Number of Small Triangles
1	2
2	8
3	
4	

b. Jika gambar tersebut dilanjutkan hingga gambar 7, tentukan banyak segitiga yang terbentuk.

c. Jika gambar tersebut dilanjutkan hingga gambar 50. Jelaskan cara kalian untuk menentukan banyak segitiga kecil yang terbentuk, tanpa menggambar dan mencacah satu per satu gambar.

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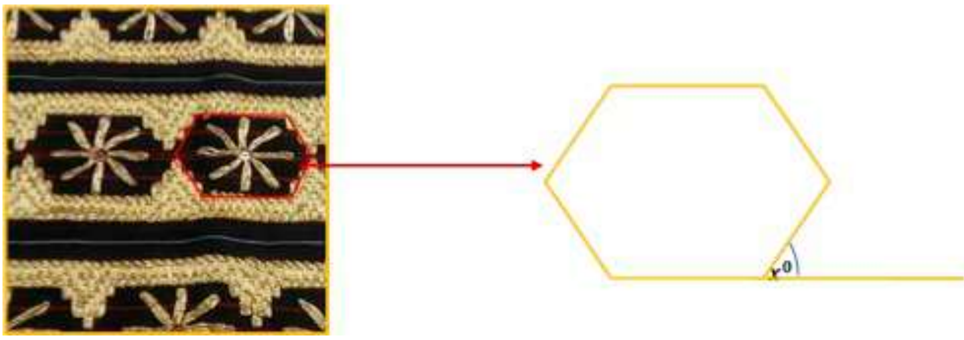
28. 14. Gambar di bawah adalah segi enam beraturan dengan Tapis Lampung sebagai ornamennya. Berapakah nilai x? *



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29. 15. Buatlah masalah soal perkalian berdasarkan gambar di bawah! *

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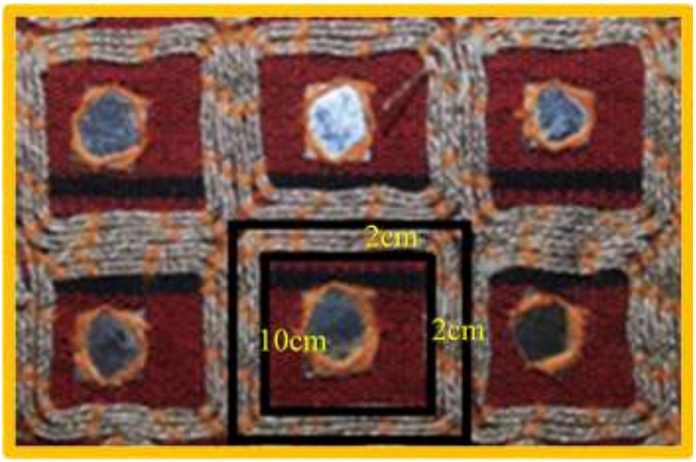
30. 16. Sebuah Tapis Kaca berbentuk bujur sangkar dibingkai dengan ukuran 10 cm x 10 cm. Di luar ukuran tersebut dibuat kembali bingkai dengan lebar 2 cm (seperti terlihat pada gambar).a. Tuliskan masalah kedalam sebuah pertanyaan!b. Tuliskan data yang Anda butuhkan!c. Temukan luas bagian yang diarsir (berwarna emas)! d. Tunjukkan cara lain untuk menentukan luas daerah yang diarsir emas! *



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31. 17. Perhatikan gambar desain berikut! *

a. Sebutkan nama bangun datar pada setiap desain Tapis Lampung!
b. Sebutkan sifat-sifat bangun ruang dalam jawabanmu untuk soal nomor a!
c. Buatlah diagram Venn dari hubungan antara bentuk dan sifat-sifat bentuk yang Anda sebutkan dalam masalah b!

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32. 18. Perhatikan gambar Tapis Lampung! Berapakah simetri lipat yang dapat dibuat dari gambar tersebut? *

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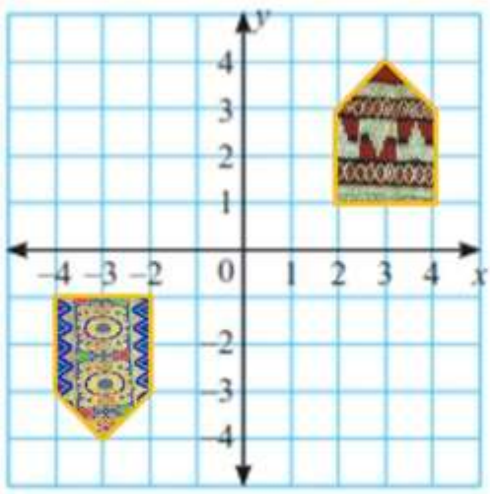
33. 19. Tapis Lampung berbentuk segilima dalam diagram kartesius. *

a. Jelaskan apakah motif Tapis Lampung segilima berwarna biru merupakan hasil rotasi dari segilima berwarna merah!

b. Sebutkan sebanyak mungkin berapa sudut putaran dan arah putarannya.



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34. 20 Pada hari Minggu kelompok perajin tapis tradisional membuat Tapis Lampung. Setiap orang mampu membuat satu baris Motif Pucuk Rebung dalam waktu 60 menit. Dia mulai membuat tapis tradisional dari jam 8 pagi. Jika dia ingin membuat 3 garis motif yang berbeda pada hari ini. Terdapat 3 pertanyaan yang harus dijawab, yaitu: (a) Mengajukan Pertanyaan: Tulis semua pertanyaan yang dapat Anda pikirkan tentang apa yang terjadi dalam gambar. (b) Mengajukan jawaban: Tulis kemungkinan jawaban berdasarkan gambar. (c) Menebak Konsekuensi: Buat daftar sebanyak mungkin kemungkinan tentang apa yang mungkin terjadi setelah itu atau hal-hal yang mungkin terjadi sebagai akibatnya di masa depan. *

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APPENDIX I

THE ETHICAL APPROVAL

University of Szeged

Institutional Review Board
Doctoral School of Education

6722 Szeged, 30-34 Petőfi S. Av., Hungary
Phone/fax: +36 62 544-032

Suherman Suherman
PhD Student: Doctoral School of Education
Reference number: 6/2023
Subject: Ethical evaluation of a research project

Date: 8 May, 2023

ETHICAL APPROVAL

The Insitutional Review Board (IRB) of the Doctoral School of Education, University of Szeged has recently reviewed your application for an ethical approval (Title of the Research Project: "*Assessing of Students' Mathematical Creative Thinking Skill-Ethnomathematics based test*"), supervisor: Prof. Dr. Tibor Vidákovich). This proposal is deemed to meet the requirements of the ethical conducts on social research with human subjects of the Doctoral School of Education, University of Szeged.

IRB decision: approved

Justification:

The research project meets the requirements of the professional-ethical criteria of the social research including human subjects within the field of education science. The study aims to improve the mathematical concepts and students' skills, especially in creative thinking based on local culture which will contribute to improving the assessment of mathematics skills policies. Participants of this study will be students (N = 500-900, aged between 12-15 years) who are randomly administrated come from different secondary schools in Indonesia and they were also asked to fill out a survey online based on an ethnomathematical test (figural and verbal). Participation is voluntary. The data collection does not involve participant identification. Informed consent of both the students and the parents are obtained.

Procedure of the data collection does not harm their privacy law, it does not have an impact on the participants' mental or physical health. Data cannot be handled by persons to whom they are not concerned.

In a summary, full ethical approval has been granted.

We wish you all the best for the conduct of the project.

Prof. Dr. Bettina Pikó
IRB coordinator