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Systematic Review on the Essentials of Creative Mathematical Thinking

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ABSTRACT

Creative thinking skills can prepare students to be tangent, creative, and competent problem solvers in an ever-evolving world, so educators are required to understand patterns and factors that positively influence the development of creative thinking skills. The aim of this research is to identify patterns and factors that influence creative thinking skills in learning. The method used in this research is the exploration and conceptualization of mathematical creative thinking skills. The research explored 15 articles through Scopus databases, Google Scholar, Publish or Perish, and Google. Data analysis is conducted through CAQDAS ATLAS.ti, with coding objectives, methodology, and research conclusion. This research found that most of the articles highlighted task orientation, epistemological approaches, problem submission tasks, Multidimensional Creativity Assessment (MCA), tutor beliefs, problem solving, SCAMPER methods, valid instruments, social skills, confidence, belief and anxiety, and Practical Mathematical Talent Models. Overall, the contributions from this research have shown the importance of building creative thinking skills in mathematics and science education, along with various approaches and factors that contribute to the development of such skills.

Keywords:
CAQDAS; Creative thinking; Essential of mathematic; Mathematical creativity

1. Introduction

Mathematical creativity necessitates a blend of logical and unconventional thinking. Gender, teaching strategy, mentality, aptitude, personality, and student knowledge are all factors that can influence this combination. There are various advantages to developing mathematical creative thinking skills. This is consistent with the belief that stimulating and developing students' creative abilities requires the development of creative thinking in mathematics learning [1]. In addition, other research has shown that the use of dynamic mathematics software in project-based learning enhances the communication, problem-solving, and creative thinking skills of mathematics teachers who have received training [2]. Moreover, other studies have found that problem-based learning and a combination of challenge-based learning, problem-solving processes, project-based learning, well-designed questions, and in-depth learning styles foster and stimulate the creative and perceptive thinking of gifted students in mathematics [3,4]. Overall, the results of the above study indicate that

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developing students' mathematical creative thinking skills can enhance their problem-solving, communication, and self-confidence.

The significance of mathematical creative thinking abilities necessitates a thorough understanding of how they differ from other types of creative thinking abilities. Many reports regarding creative thinking have been well-documented [5,6]. According to literature, students have a wide range of mathematics creative thinking abilities, and female students with epistemic curiosity outperform male students with perceptual curiosity [7]. In line with this study, another study discovered that male students could master an indicator of creative mathematical thinking (originality), whereas female students could master indicators of creative mathematical thinking such as subtlety, originality, and detail but were not flexible [8]. According to other studies, two of the three subjects with kinaesthetic learning styles were less creative in their ability to think creatively mathematically [9]. Finally, Schoevers contends that creativity is vital in mathematics, and that both general creativity and mathematical aptitude are required for creative thinking [10]. As a result, educators must understand the patterns and factors that can support or influence the development of students' mathematical creative thinking skills.

This research aims to determine the patterns and determinant factors that influence the development of creative thinking abilities in a learning context by conducting a comprehensive literature review with one type of CAQDAS, ATLAS.ti. These findings will be a valuable contribution to the academic community, inspire more research, and be a valuable resource for students and educators. The novelty of this research is ATLAS.ti, a type of CAQDAS that can be used to determine patterns and determinant factors that influence the development of creative thinking abilities.

2. Methodology

We conducted a standard systematic literature review using the Scopus, Google Scholar, publish or perish, and Google databases to identify 15 articles on creative thinking skills. Detailed information regarding how to search article is shown elsewhere [11,12].

SLR was a research technique employed to evaluate the outcomes of primary research in order to present facts that were more comprehensive and balanced in accordance with the research objectives [13]. One of the objectives of employing SLR was to reduce review bias, which might result in incomplete data or studies [14]. The SLR method consisted of three phases: planning a review, conducting a review, reporting, and dissemination. Using the Scopus Database, the researcher was involved in establishing research objectives and conceptual boundaries during the planning review. At the review stage, articles were limited based on inclusion criteria, such as determining search limits, search terms, and period. Articles that met the requirements were analysed using ATLAS.ti with description codes for the objectives, methodology, and conclusion sections during the reporting and outreach phases.

3. Results

The findings of this study are based on searches on Scopus, Google Schoolar, publish or perish, and the Google database for articles related to the essential skills of mathematical creative thinking for learning mathematics. Objectives, methodology, and conclusion of the research was coded using one type of CAQDASS, namely ATLAS.ti for data analysis. According to reports on the objectives of the articles, mathematical creativity plays an important role in enhancing problem-solving and other academic skills. Various methods and strategies, as depicted in Figure 1, can also be used to enhance creative reasoning. In the methodology report section of the studied articles, it was discovered that

specialists investigating mathematical creative thinking skills employed a variety of methods, including quantitative, qualitative, experimental, SLR, and development methods, as shown in Figure 2. Then, Figure 3 illustrates that there are a variety of ways to enhance students' mathematical creativity and its relationship to other skills. Here is the description for further information.

3.1 Report of Objectives

Statements quoted from several experts about mathematical creative thinking skills provide insight into specific research goals and objectives from various academic studies. One of the goals is to describe students' mathematical creative thinking abilities with kinaesthetic learning styles in transformation material. Barazza and his colleagues, in their research, proposed a theoretical model that explored the relationship between mathematical talent and mathematical creativity [11]. Cenberci conducted a study to determine the level of creative thinking tendencies of prospective mathematics teachers and examined this level in relation to different variables [12]. Furthermore, other researchers conducted research to examine the idea of mathematical creativity and its relationship with epistemological beliefs about the nature of mathematics and mathematics anxiety [13]. Then, Gunawan and colleagues described the characteristics of students' confidence-based mathematical creative thinking ability [14]. Hadi and colleagues aimed to obtain three research objectives, namely:

i. to find out the effect of applying learning strategies and social skills on students' ability to understand the concepts and procedures for computer creation courses
ii. to obtain background information about students' social skills
iii. to know the influence of social skills related to the process of creative performance [15].

Other researchers created instruments to assess creative thinking skills in mathematics at the junior high school level [16]. Besides, a valid mathematical creative thinking assessment can be used by teachers to obtain information about how creative thinking skills are possessed by each eighth-grade junior high school student.

Furthermore, there is study that investigates the effect of CPS on mathematical creativity in engineering students [17]. Lu conducted research to explore and present a comprehensive understanding of the role of creativity in the context of students' mathematical modelling competencies [18]. In accordance with this, Khalid undertook research with the goal of encouraging creativity through mathematics through creative problem solving [19]. Going deeper, Newton investigated some of the barriers to encouraging undergraduate mathematics students' creative thinking that arose from the tutor's notions about mathematical creativity [20]. Hamid examined students' insights into creativity through problem-posing tasks in his study to determine the impact of the mathematical creative approach (MCA) on mathematical creativity and mathematics achievement among students and to explore the relationship between mathematical creativity and achievement in mathematics [21]. While Pelczer examined students' insights into creativity through problem-posing tasks, Rilling proposed a creativity framework based on what it means to know or do and accept that creativity is something that can be cultivated in all students [22,23].

Finally, Nasir and friends conducted research to identify comprehensive teaching approaches and strategies that could enhance students' creative thinking skills in secondary science classes [24]. In summary, the aims and objectives of the several studies above reflect various focuses and areas of investigation related to mathematical creative thinking skills in academic research as illustrated clearly in Figure 1.

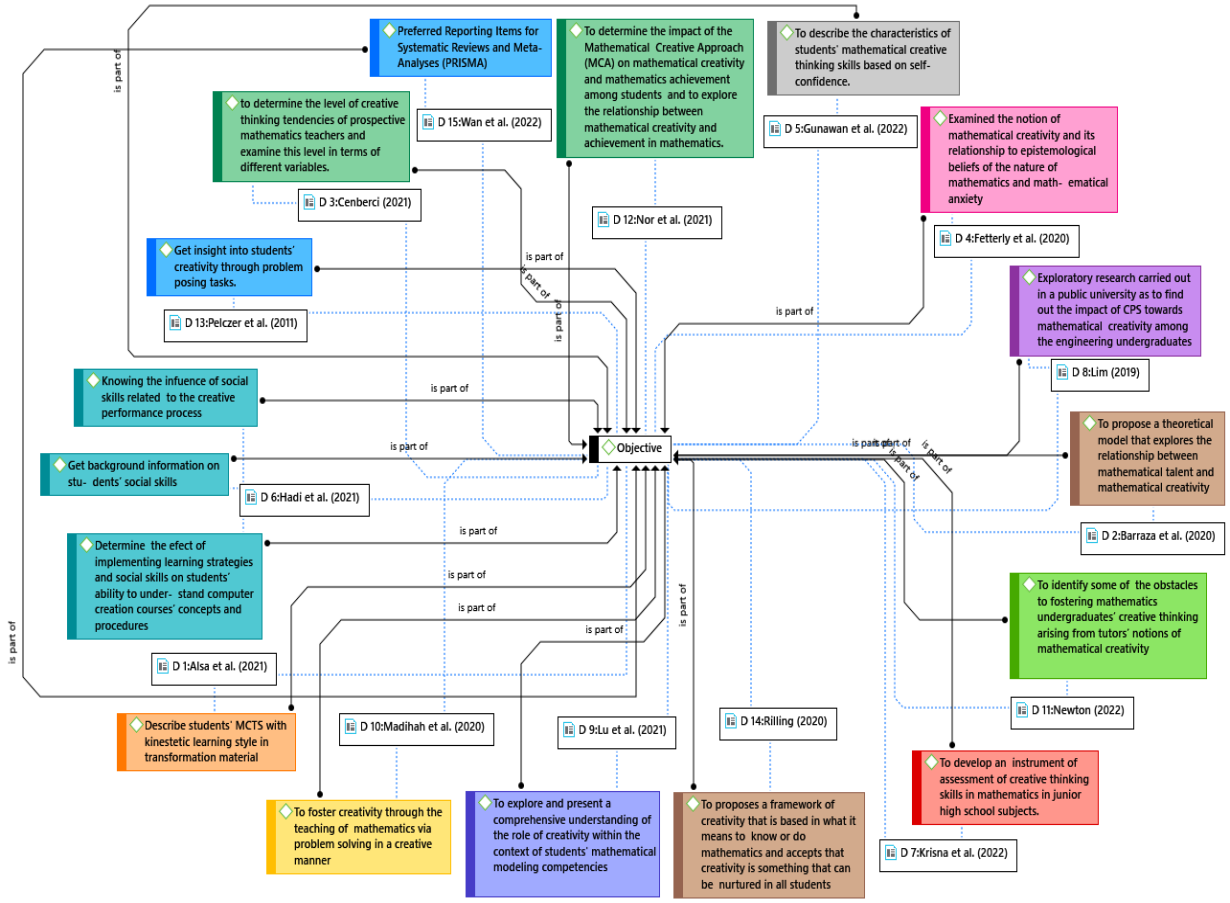

Fig. 1. Report of objectives

3.2 Report of Methodologies

Figure 2 explains the citations from multiple articles and provides a concise summary of the research methodologies employed in the various academic articles. Some researchers employ qualitative descriptive techniques [6,14,25-27], while several other researchers use a combination of qualitative and quantitative methodologies [13,18,19]. Furthermore, some researches use a quasi-experimental approach [15,21]. There are also those who utilize essentially identical methods, such as Wan, who use the systematic literature review method [28], and Barazza, who employs a systematic review and comprehensive approach [15]. Cenberci uses descriptive research [16]. Lim conducted his investigation using a case study [21]. Kartono conducted research and development (R&D) [20]. Finally, Newton is the most distinctive researcher; he used the phenomenographic approach to do research [20]. According to the search results of several articles, a researcher who wishes to investigate mathematical creative thinking skills in particular can employ a variety of methodologies, while also adapting them to their own research objectives. Figure 2 clearly depicts this concise description, which provides an overview of the many research methodologies and designs used by researchers across disciplines.

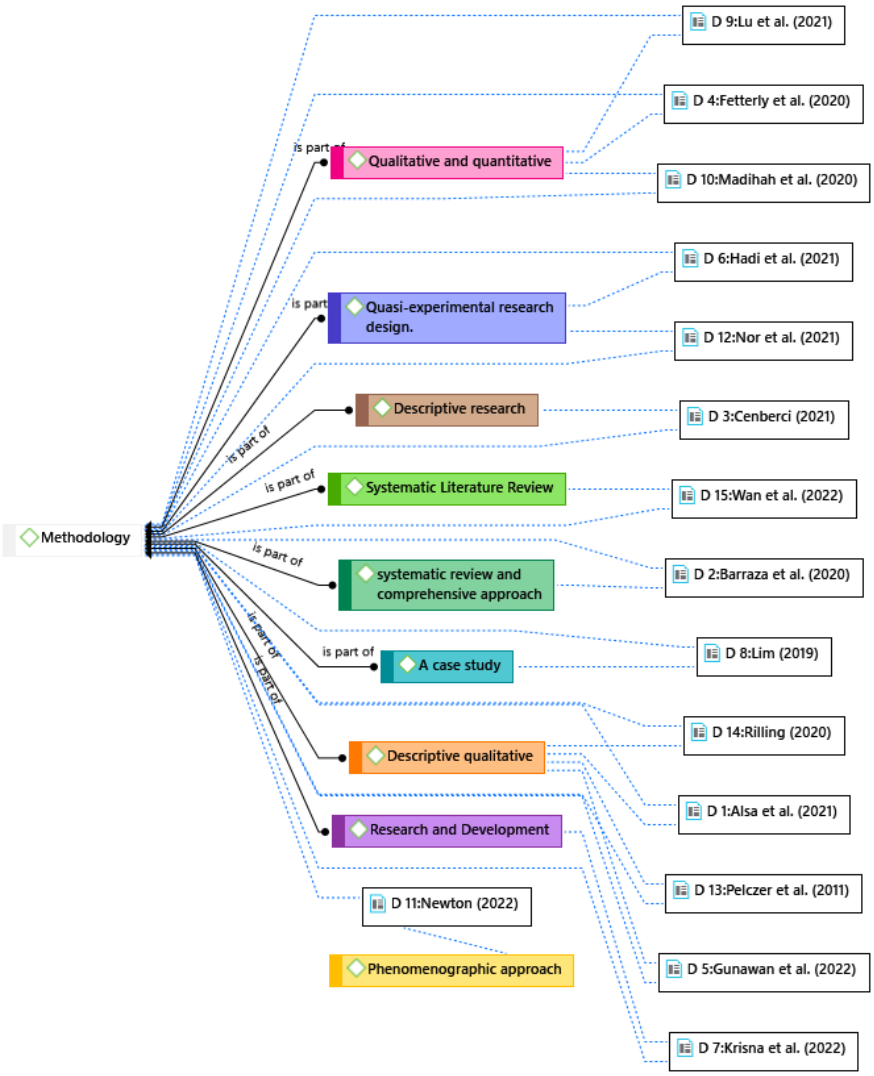

Fig. 2. Report of methodologies

3.3 Report of Conclusions

Figure 3 illustrates the conclusions presented by the articles. All articles report positive conclusions, while negative reports are due to a condition that is very unlikely to promote success in improving creative thinking skills. Likewise, Alsa concluded that children with kinaesthetic learning styles do not comprehend learning material correctly due to COVID conditions that require kids to study at home and are not conducive to using touch and taste in learning [6]. Barazza found that it is critical to cultivate creative thinking in order to preserve and increase mathematical talent [11]. According to Cenberci, determining the level of creative thinking tendencies of prospective mathematics teachers and taking appropriate precautions cannot be overlooked because the current understanding of education is student-centred and requires creative mathematics teachers who try to build knowledge by exploring [16].

The results of the study, which Fetterly concluded, support this:

i. Intentional encounters with mathematical creativity significantly influence mathematical beliefs and anxiety
ii. Mathematical creativity can be fostered and maintained under certain conditions [13].

Kharisudin examined the relationship between mathematical creative thinking skills and learning independence, and it can be concluded that:

i. self-confidence is an important aspect of developing creative thinking skills
ii. students with low, medium, and high self-confidence can each write different answers [14].

Hadi and colleagues draw the following conclusions from their research: creative problem solving is heavily influenced by social skills in understanding concepts and procedures, and these social skills are related to students' internal factors: learning readiness, the ability to understand one's own needs, and the ability to understand one's own learning style [15]. Krisna determined that the four questions in the mathematical creative thinking ability assessment instrument that describe the capacity to think creatively were legitimate based on the reviews of seven experts and the significant values in the Aiken table for each item [16]. Lim also concluded two research findings:

i. creative problem solving can be applied using open-ended questions
ii. engineering students interact and collaborate in the process of creative problem solving to produce different creative methods using brainstorming [17].

In addition to Kharisudin, Lu investigates the relationship between mathematical creativity and creative thinking skills, and it can be stated that the multiple relationship between creativity and mathematical modelling ability is highly thorough [18].

Madihah concluded from the results of her research that students' creative problem-solving and learning frameworks address the basic characteristics of important learning, and the methods used have achieved many of the documented requirements of meaningful learning [19]. Another study discovered considerable discrepancies between mathematical creativity and human mathematical creativity [20]. Nor and his colleagues, on the other hand, found from their research that using MCA can increase students' performance in solving arithmetic problems, leading to higher math accomplishment scores [25]. Pelczer's findings also revealed that the requirements for creative thinking skills can be discovered by conducting a qualitative analysis of a series of problem-posing experiments with middle school students, teachers, and Olympiad participants [26]. Accordingly, Rilling finds that a framework like this might help instructors notice creative activity in which their students are already involved, which is a tiny but crucial step toward cultivating students' mathematical creativity and widening what counts as mathematics [27].

Finally, the results of the study [24] concluded that brainstorming, small team work assignments, research-based work, use of technology, student-centred methods such as dialogue, arguments, or worksheets, and related problem-solving activities were among the activities suggested to promote creative thinking skills [57-59]. In summary, the purpose of this paragraph is to present a complete overview of many research findings in the field of mathematics education on the relevance of creative thinking skills, as illustrated in Figure 3. This study gives information for further development as reported elsewhere regarding several subjects in Mathematics [29-56].

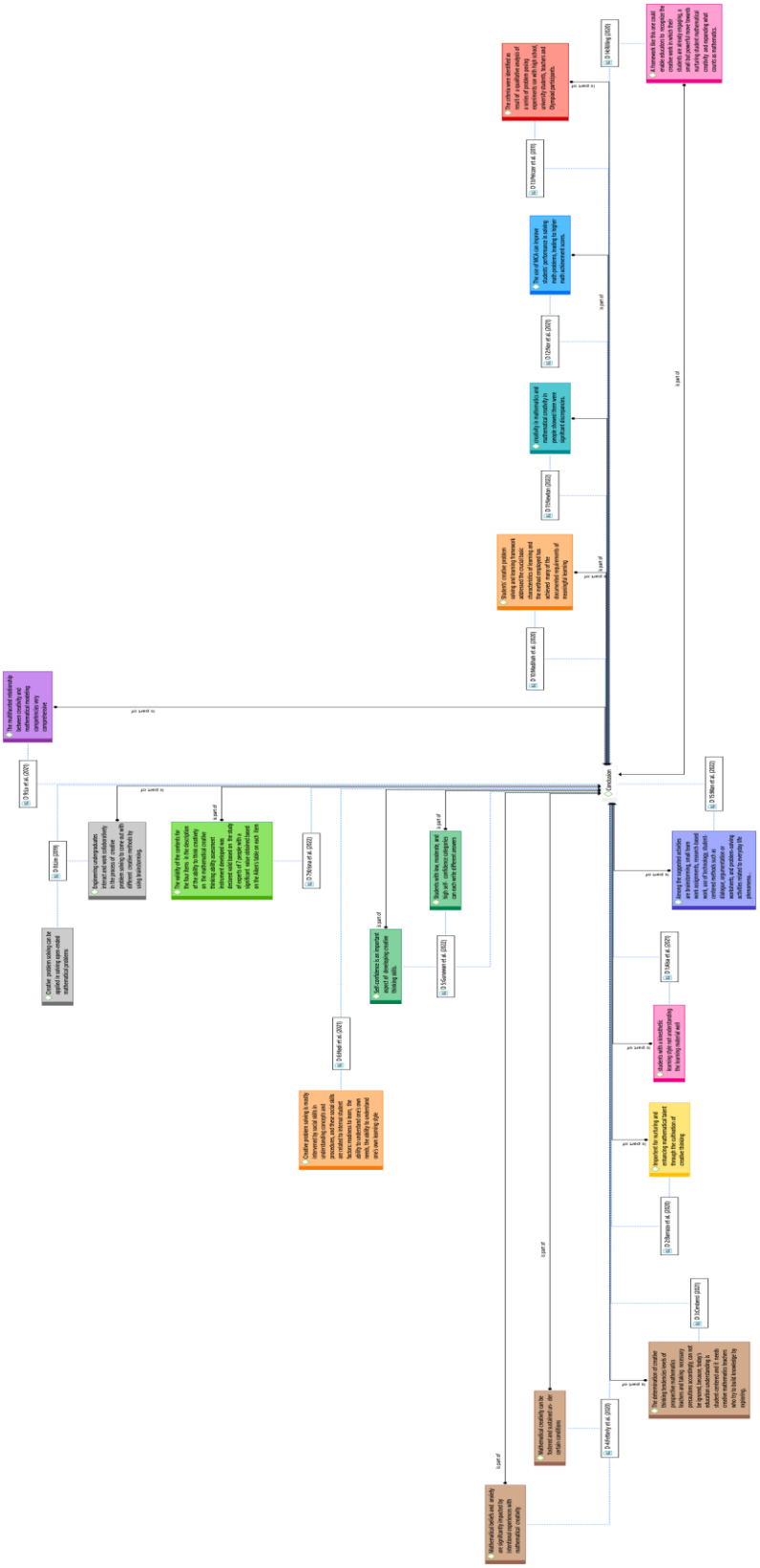

Fig. 3. Report of conclusions

4. Conclusions

In conclusion, a systematic literature review using ATLAS.ti highlights the importance of developing mathematical creative thinking skills in both mathematics and science education. The findings show that mathematical creative thinking skills play an important role in improving students' problem-solving abilities and overall math performance. Mathematical creative thinking skills are also closely related to other learning abilities and the factors that influence them. In addition, mathematical creative thinking skills can be improved through various methods. This study emphasizes the importance of incorporating creative thinking into mathematics curriculum and using effective teaching strategies to enhance students' creative thinking skills. Furthermore, the review highlights the need for further research in this area to gain a more comprehensive understanding of how to cultivate and maintain mathematical creative thinking skills in students.

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