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Mathematical Creative Thinking Ability in Online Learning during the Covid-19 Pandemic: A Systematic Review

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Abstract

As a result of the increased focus on creative mathematical thinking in mathematics education during the covid-19 pandemic, there has been an increase in the need to investigate how to assess mathematical creative thinking skills in online learning environments. As a result, a systematic review was carried out to determine how mathematical creative thinking has been evaluated in the literature. We examined 124 journal articles from SCOPUS, ELSEVIER, WoS, ERIC, and SAGE to analyze specific MCT assessments from four perspectives: assessment of the familiar mathematics context, an indicator of measurement test, assessment of the unfamiliar mathematics context, and measurement test. We discovered that (a) the most familiar mathematics context for assessing mathematical creative thinking is based on students' curriculum according to their class level, and (b) indicators for assessing mathematical creative thinking frequently used open-ended questions to gather information. During this systematic review, we identified research gaps and potential future research topics to conceptualize and assess mathematical creative thinking skills while participating in online learning activities. Researchers and teachers are expected to benefit from the findings, which will aid them in determining the most effective method of teaching and assessing mathematical creative thinking.

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INTRODUCTION

Mathematical Creative Thinking (MCT) is necessary for solving mathematical problems and coming up with new ideas. This procedure entails determining objects' most recent regular properties and their transformation (Perry & Karpova, 2017). MCT is a necessary skill for students, and it is typically based on either an underlying process or a manifested product. Based on the 21st-century framework, creativity can aid students' rapidly changing global competencies. As a result, MCT ability should be integrated into educational studies. This means that the MCT is essential for students. 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). In regard to Programme for International Student Assessment (PISA), MCT is the ability to engage in productive learning, evaluation, and improvement of ideas that can result in novel, practical solutions (OECD, 2019).

During an online learning lesson, there are a variety of educational approaches that can be used to encourage creative thinking. Many people have been forced to switch from offline to online

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learning as a result of the COVID-19 pandemic, which has had a significant impact on learning. Today, there are numerous platforms for studying mathematics independently, including conferences, videos, webinars, and online learning materials, all of which help to promote MCT (Suherman et al., 2020). On the other hand, online learning necessitates a high level of self-organization, concentration, stress tolerance, and planning abilities (King et al., 2019; Schiavio et al., 2021).

Ritchie & Sharpe (2021) presents an online learning method for students at the University of Chichester Conservatoire, which he developed. Their research demonstrates that distance learning promotes greater independence while also producing better learning outcomes in a shorter period. The learning approach is based on the blended learning model, which combines in-class activities with independent work and positively impacts the students. It is believed that, due to the pandemic situation, it is not yet possible to make the transition to full-time learning in today's world, and that fully online learning is not as effective as it could be. As a result, Ritchie & Sharpe (2021) propose the blended learning model, which allows students to combine the above-mentioned learning models while also developing theoretical and practical skills.

Mathematics research has encouraged MCT's research towards a profound knowledge of the mathematical concept (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 which uses MCT is difficult and demands students to explore their abilities. In other words, the mind mapping and the indicator of MCT should be clear so that can support teachers in the learning process and increase student engagement in learning (Ketelhut et al., 2020).

Some studies have analyzed the work related to MCT element. The MCT has 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 et al., 2020; Torrance, 1966). The TTCT have identified three creative aspects: flexibility, fluency, and originality. Furthermore, some researchers also have applied the concepts of fluency, flexibility, elaboration, and originality to MCT (Nufus et al., 2018; Sahliawati & Nurlaelah, 2020) and the concepts of fluency, flexibility, and elaboration as element of MCT (Gilat & Amit, 2013; Huljannah et al., 2018).

Since its emergence, MCT abilities has contributed to various fields of research. However, systematic reviews of the MCT abilities current practice have been limited, particularly in mathematics education in pandemic-19 era. Research has demonstrated that the indicators used in measuring the MCT test have not been oriented to creative thinking (CT) skills. In addition, the review of the research revealed a limited of indicators on the MCT in mathematics, making further research on assessing MCT unclear. This study aimed to review studies on the MCT systematically.

Two research questions (RQs) formed the basis of this review:
RQ1: What are the mathematics contexts for assessing MCT?
RQ2: What is the indicator needed to support assessing MCT?

METHOD

The research was conducted through a systematic review. We used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Liberati et al., 2009). The steps used were as follows: (1) identified the topics 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. Figure 1 illustrates PRISMA steps. Regarding the reference type, the original search of several databases was conducted to investigate articles published in scientific journals. Potentially relevant research was identified by SCOPUS, ELSEVIER, WoS, ERIC, and SAGE.

To select articles, we applied 6 for inclusion criteria. (1) searched the keywords "mathematical creative thinking" OR "creative thinking in covid-19 pandemic" with category (1) title, abstract and keywords, or main text; stages 2 is written in English; (3) published during covid-19 pandemic; (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 124 articles.

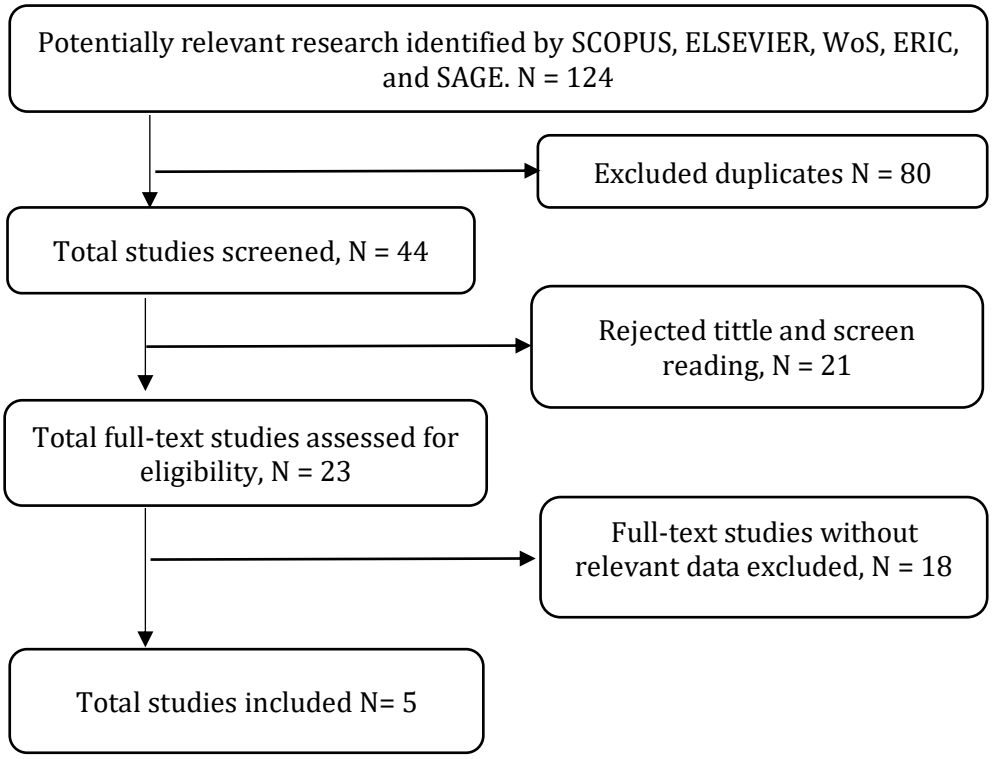

Figure 1. Stages of the systematic review

To collect the articles, the author used articles on the search platform by using the EndNote XML format, the PubMed format, or the RIS text format. Five research studies on MCT are present concerning the final investigation based on the extraction stages from the 124 original articles. During the review, the selected articles were analyzed by using recorded keywords: (1) authors and publication year, (2) indicators of MCT, (3) the title, and (4) findings.

RESULTS AND DISCUSSION

A few studies have been conducted to implement MCT across secondary school levels. The information of the study were 15 studies is presented in Table 1. This table shows the authors and year, subject domain for measuring MCT, instruments used to measure MCT abilities, MCT indicators, respondents, and fundings. Then, Table 2 shows indicators of MCT skills and findings from studies.

Table 1. Subject domain in creative thinking learning

Authors	Subject Domain	Research Methods	MCT Instruments	Respondent	Codes
(Rubai'ah, 2021)	Economic problems	Qualitative	Open-ended	Two students of the 10th grade	A
(Sarnita et al., 2021)	Statistics	Quasi-experimental	Open-ended	100 students of the undergraduate	B
(Casing & Roble, 2021)	Statistics and Probability	Quasi-experimental	Open-ended	100 students of the 8th grade	C

Authors	Subject Domain	Research Methods	MCT Instruments	Respondent	Codes
(Mashitoh et al., 2021)	Sequence and series	Quasi-experimental	Open-ended	62 students of the 8h grade	D
(Susanti & Erviana, 2020)	Statistics	Quasi-experimental	Open-ended	22 students of the undergraduate	E

Table 2. Indicators of MCT and finding studies

Codes	MCT Indicators	Fundings
A	Fluency, Flexibility, and Novelty	Students with open-ended problems have improved their MCT abilities and the level of students with high abilities in level 3 of creative thinking (creative).
B	Fluency, Flexibility, and Originality	Students in the learning model using the application of STEM-based online learning can improve their creative thinking during the COVID-19 pandemic.
C	Fluency, Flexibility, Originality, and Elaboration.	Students exposed to PEDE Productive Failure Model performed significantly better in terms of creative thinking ability posttest score.
D	Fluency, Flexibility, Novelty, and Originality	Students can provide answers for sequence and series problems based on MCT indicators.
E	Fluency, Flexibility, Novelty, and Elaboration	Students can improve their creativity and more independent in knowledge both in discussions and learning.

The topic covered on the MCT test differed depending on the grade level being tested. Gradually increasing levels of sub-topic and subject competency are required as students' progress from junior high school to higher education. The Ministry of Education and Culture, which oversees early childhood education, elementary education, secondary education, community education affairs, and culture management within the Indonesian government, was able to accommodate every subject competency. There are no restrictions on what can be taught at the undergraduate level because every higher educational institution has the ability to modify and create its own curriculum. However, every institution or university in Indonesia has the authority to design and implement its own educational system, which is governed by the national education department as a whole. Table 1 contains a detailed list of the topics covered by the mathematical items.

Researchers have investigated creative thinking (CT), and it has proven to be the most useful capability in the twenty-first century. This is especially true during a pandemic situation. This systematic review sought to evaluate CT in mathematics during the pandemic era by identifying what researchers have discussed and where there are research gaps. Although we only included a small number of studies in our review, this paper contributes to understanding CT in mathematical practice. As a result of the findings, MCT tests are now available from junior high school through undergraduate levels.

Firstly and foremost, most research has concentrated on the final outcome of CT in terms of learning at the junior, high, and college levels. Researchers have attempted to explore CT skills and apply cognitive development to them in the early stages of the classroom, even though researchers find assessing CT difficult in regard to developmental students due to their limited understanding of mathematical concepts (Colmar et al., 2019). It should be noted that there is no reason to believe that secondary schools are the only important stages in which students can cultivate ideas in CT, and that additional research is required to enrich and deepen the literature on MCT measurement for secondary schools (Jablonka, 2020) and universities. As a result, researchers and practitioners will be able to identify resources that are appropriate for the CT skills training trajectory.

According to the first point, to understand the process of CT applied in educational contexts, more CT assessments should be developed. Every test was tailored to a specific domain. The

majority of them used the CT indicators framework and CT indicators like fluency, flexibility, originality, and elaboration to do so. A slightly different set of three indicators (fluency, flexibility, and novelty) was used in some of the other studies we discovered (Rubai'ah, 2021). We found more detailed that the four of MCT were taken by some author (Casing & Roble, 2021; Mashitoh et al., 2021; Sarnita et al., 2021; Susanti & Erviana, 2020). In mathematics, fluency is defined as the ability to generate multiple solutions or ideas in a short period of time (Kozlowski et al., 2019). Individuals' ability to change thinking paths when they encounter an impasse or a thinking obstruction and their ability to generate different types of solutions/ideas is referred to as flexibility in the context of mathematics. Individuals who are unwilling to be flexible will typically pursue a solution path until it is unsuccessful; however, this is uncommon (Imai, 2000; Kozlowski et al., 2019).

In regard to MCT, researchers have discovered that open-ended questions on a test are frequently used as an assessment tool. That open-ended questions are also used as the primary instrument. That is important that the familiar test was an open-ended questions.

CONCLUSION

As a result, the Indonesian Government established a mathematics curriculum taught in every school throughout the country. On the other hand, teachers are given the authority to create local curriculum-based assessment tools in online learning. Finally, some articles have been reviewed that have presented the indicator of MCT as a learning assessment.

There are some limitations to this review. Primarily, the literature reviewed emphasized the use of assessment indicators to measure MCT. Still, most research focuses on the outcome of MCT, such as the effect of learning models on MCT skills, rather than the assessment indicators. Furthermore, we ignored the students' intervention in our review. Thus, while many studies report MCT interventions, no research has specifically addressed MCT, particularly in developing assessment learning strategies.

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