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Designing Closed-Ended Questions into Open-Ended Questions to Support Student's Creative Thinking Skills and Mathematical Communication Skills

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ABSTRACT

The ability of creative thinking and mathematical communication is important in learning mathematics. However, in fact mathematics learning in schools today has not shown an optimal effort to help students develop creative thinking skills and mathematical communication skills. The purpose of this study is to examine the use of open-ended questions in mathematics learning and in the evaluation of mathematics learning to support the ability of creative thinking and mathematical communication skills of students, this will be implemented in the perspective of literature review. The type of research used is a systematic and structured literature review, where researchers synthesize relevant study results from international and national literature through Google Scholar, Eric, DOAJ, Scopus and ScienceDirect. Based on the analysis results obtained that mathematical learning using open-ended questions is effectively used to support the ability of creative thinking and mathematical communication skills of students; the provision of open-ended questions can be familiarized with providing learning methods leading to an open-ended approach; the test in the form of open-ended questions can be used as a tool to measure the ability of creative thinking and mathematical communication skills of students; the use of open-ended question can be applied to all levels of education; and the need for high creativity from teachers to prepare learning by applying open-ended questions.

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A. INTRODUCTION

The development of the 21st century requires humans to continue to improve various skills in various aspects, including the aspects of education. Skills developed today to prepare people for technology that has not been invented today, work that does not exist today, and solve various forms of problems (Trilling & Fadel, 2009). Binkley (as cited in Griffin, McGaw, & Care, 2012, p. 18) states that there are four groups of skills that must be mastered by humans in facing various challenges of the 21st century, namely: how to think (creative thinking and innovation, critical thinking, metacognition thinking); how to work (ability to communicate and collaborate); ability to use technology and information; and the ability to live in the world (socializing, career, personal responsibility social, and cultural).

Mathematics learning is a leading subject that can prepare students to survive in the era of 21st century knowledge (Soeyono, 2014). Therefore, mathematics learning not only teaches

knowledge about mathematics, but mathematics is used as a mindset and media in carrying out daily life activities. Learning mathematics should make students to learn meaningful, so that learning mathematics can facilitate students achieve various abilities, including the ability to think creatively and communication skills (Damayanti & Sumardi, 2018; Pourdavood & Wachira, 2015). Based on this explanation, it can be said that meaningful learning of mathematics means not excluding the value of the abstractness of the meaning of mathematics. Students who have good creative abilities, allow students to explain abstract concepts in mathematics, so students can construct their mathematical knowledge and generate responses to problems encountered in learning mathematics as well as in everyday life.

Creative thinking in mathematics has strong implications for progress in society because every topic in mathematics has a wide range and close to everyday life (Kozlowski, Chamberlin, & Mann., 2019). Creative thinking is a manifestation of high-level thinking ability, and the combination of logical thinking with divergent thinking to produce something new (Ali et al., 2021). Students ' creative thinking ability can be measured based on several aspects of problem solving such as flexibility, fluency, originality, and elaboration (Suryandari et al., 2021; Greenstein, 2012). Another component that students need to achieve success in mathematics is accuracy in communicating (Pourdavood & Wachira, 2015). Communication is an important part of the learning process. In mathematics learning language and communication is an important aspect used as a means of exchanging ideas and as a means of clarifying understanding (Pourdavood & Wachira, 2015). Communication skills in mathematics are defined as the ability of students to express mathematical ideas using mathematical language precisely, clearly, and coherently to friends and teachers to evaluate mathematical thoughts, as well as to elaborate mathematical problems into mathematical models (Naili Luma'ati Noor, 2020; NCTM, 2000).

Assessment of students' creative thinking and mathematical communication skills is an important thing to do. The use of routine problems or closed-ended problems is not effective enough to measure creative thinking skills and mathematical communication skills (Rahayuningsih et al., 2021). In fact, mathematics learning in schools today has not shown optimal efforts to help students develop and conduct an assessment of creative thinking skills and mathematical communication skills. As is the case with the learning of mathematics in the classroom takes place in one direction, teachers dominate the learning process with lecture methods that impact little opportunity for students to construct their ideas and results of thinking (Viseu & Oliveira, 2012). Assessment of mathematics learning is commonly used in the form of everyday problems that are designed with only exactly one solution or closed-ended questions (Romli et al., 2018). Then, Damayanti and Sumardi (2018) in their research stated that the achievement of Indonesian students in the field of mathematics is still lower than in other countries. This is in line with the Program International for Student Assessment (PISA) result in 2018, in the mathematics category Indonesia ranked 73 out of 79 countries (Organisation for Economic Cooperation and Development, [OECD] 2019). Among the underlying causes is the lack of students' ability to solve high-level or non-routine problems as a result of students getting used to learning evaluation by applying low-level questions so that students use formal knowledge to solve problems (Damayanti & Sumardi, 2018).

The problems that occur become a challenge for educators to develop measuring and evaluation tools that can develop students' knowledge, broaden students' understanding horizons, and improve students' thinking including students' creative thinking and mathematical communication skills (Erhan & Bingölbali, 2021). Handayani (2018) and Briggs (2007) stated that creative thinking skills and mathematical communication capabilities can be improved by applying open-ended questions. Open-ended questions are questions that have several different answers and the solutions offered are acceptable (Cakir & Cengiz, 2016; Munroe, 2015). In line with that, familiarizing students to solve open-ended questions can be done by applying learning that leads to an open learning process, such as by applying an open-ended learning approach. By using open-ended questions students are given the opportunity to open up and cultivate a spirit of creativity within them that is useful for future implementation (Kozlowski et al., 2019). Another advantage of applying open problems compared to closed problems is that students become more active in learning, students have the opportunity to use their knowledge and abilities, and students can solve problems in various ways (Karadag et al., 2021). Students' creative thinking ability can be seen by measuring several aspects of problem-solving such as *fluency, flexibility, originality,* and *elaboration* (Greenstein, 2012; Isaksen et al., 2011; Silver, 1997), while students' mathematical communication skills can be measured by several indicators, namely: (1) stating mathematical ideas using writing, oral, and being able to describe virtually; (2) using symbols, notation, and mathematical structures in making mathematical modelling according to problems; (3) communicating mathematical thinking clearly and logically; (4) draw conclusions based on the solution obtained from solving the problem (Ahdhianto et al., 2020; Maulyda, 2020; NCTM, 2000). Therefore, the purpose of the study is to examine the use of open questions on mathematics learning and in the evaluation of mathematics learning to support students' creative thinking and mathematical communication skills, this will be implemented in the perspective of a literature review. The advantages of this study are expected to be an innovation in implementing the evaluation of mathematics learning.

B. METHODS

The method used in this study is a systematic and structured literature review. This method was chosen to find and synthesize relevant study results from international and national literature through Google Scholar, Eric, DOAJ, Scopus, and ScienceDirect with a range of publishing years 2012 to 2022. The steps taken are as follows: (1) identify topics and search for relevant studies; (2) data extraction; (3) examine feasibility studies; (4) include analysis documents. Related to investigating articles published in scientific journals, conducted an original search of several databases. The data collection technique is done by reviewing some literature in the form of articles from national and international journals by the purpose of the research. The selection of articles was carried out by various criteria: (1) applying the keywords "open-ended question", "open-ended assessment in mathematics learning", "mathematical creative thinking" and "mathematical communication"; (2) published between 2012 and 2022; (3) written in English; (4) available in full text; (5) assessment results in empirical studies related to creative thinking and mathematical communication of students. Then the researchers downloaded the selected articles for further analysis of each information related

to the use of open-ended questions that can support students' creative thinking and mathematical communication skills. After that, the author conducts filtering of titles and abstracts, to select articles that correspond to the purpose of the study. The next stage is a full-text review until the selected article is analyzed according to the criteria: (1) title; (2) author and year of publication; and (3) research findings.

The main focus of the analysis is to see the effect of the use of open-ended questions in the assessment of mathematical learning on the ability of creative thinking and mathematical communication skills of students. In a systematic review, the authors identified the school levels covered in the study starting from primary to secondary school. Several things need to be considered in literature review research, namely: (1) the author is dealing with previous research data; (2) the data obtained is ready to use; (3) the library material obtained is not limited to space and time. Selected and analyzed articles can be seen in Table 1.

Table 1. Detail of Manuscript to be Analyzed

Author (year)	Title	Manuscript Identity
Damayanti and Sumardi (2018)	Mathematical Creative Thinking Ability of Junior High School Students in Solving Open-Ended Problem	https://doi.org/10.23917/jramathedu.v3i1.5869
Bennevall (2016)	Cultivating Creativity in the Mathematics Classroom using Open-ended Tasks	diva2:909145
Rahayuningsih et al. (2021)	Using Open-ended Problem-solving Tests to Identify Students' Mathematical Creative Thinking Ability	http://dx.doi.org/10.17275/per.21.66.8.3
Kozlowski et al. (2019)	Factors that Influence Mathematical Creativity	https://doi.org/10.54870/1551-3440.1471
Romli et al. (2018)	Designing students' worksheet based on open-ended approach to foster students' creative thinking skills	https://doi.org/10.1088/1742-6596/948/1/012050
Suherman and Vidákovich (2022)	Assessment of mathematical creative thinking: A systematic review	https://doi.org/10.1016/j.tsc.2022.101019
Yuniarti et al. (2021)	The Effectiveness of Open-Ended Problems Based Analytic-Synthetic Learning on the Mathematical Creative Thinking Ability of Pre-Service Elementary School Teachers	https://doi.org/10.29333/iejme/640
Erhan and Bingölbali (2021)	An Examination of Open-Ended Mathematics Questions' Affordances	https://doi.org/10.29329/ijpe.2021.366.1
Bahar and June Maker (2015)	Cognitive Backgrounds of Problem Solving: A Comparison of Open-ended vs. Closed Mathematics Problems	https://doi.org/10.12973/eurasia.2015.1410a
Rodriguez and Bonner (2018)	The Impact of Teacher Questioning and Open-Ended Problems on Mathematical Communication	practicalteacherresearch.com
Viseu and Oliveira (2012)	Open-ended tasks in the promotion of classroom communication in Mathematics	Iejee.com
Wijaya (2018)	How Do Open-Ended Problems Promote Mathematical Creativity? A Reflection of Bare Mathematics Problem and Contextual Problem	https://doi.org/10.1088/1742-6596/983/1/012114

Author (year)	Title	Manuscript Identity
Munahefi et al. (2021)	Analysis of Mathematical Reative Thinking Test Instruments on Open-Ended Problems with Ethnomatematic Nuances	https://doi.org/10.1088/1742-6596/1918/4/042060
Islam et al. (2021)	The Analysis of Students' Creative Thinking Skills in Solving Open Ended Questions in Terms of Gender	https://doi.org/10.24127/ajpm.v10i2.3660

C. RESULT AND DISCUSSION

Based on the various literature obtained, the research design used related to the use of open-ended questions that support the ability of creative thinking and mathematical communication is the qualitative descriptive, systematic literature review, and quasi-experiment. The percentage of use of qualitative descriptive design, systematic literature review, and quasi-experiment found can be seen in Table 2.

Table 2. Percentage of Research Design

Research Design	Amount	Percentage (%)	Researchers
Qualitative Descriptive	10	71,5	Damayanti and Sumardi (2018), Rahayuningsih et al. (2021), Bahar and June Maker (2015), Erhan and Bingölbali (2021), Islam et al.(2021), Munahefi et al. (2021); Rodriguez and Bonner (2018), Romli et al. (2018), Viseu and Oliveira (2012), Wijaya (2018)
Systematic literature Review	3	21,4	Bennevall (2016), Kozlowski et al. (2019); Suherman and Vidákovich (2022)
Quasi Experiment	1	7,1	Yuniarti et al. (2021)

Based on Table 2. shows that the research that adopts the most open questions is descriptive qualitative research with a percentage of 71,5%, in the second-ranking is systematic literature review research with a percentage of 21,4%, and quasi-experiment research is only one manuscript with a percentage of 7,1%. The use of descriptive qualitative design is a research method that requires a focus on deep observation, containing detailed methods, reporting, creation of key concepts, theory generation and testing (Cohen et al., 2018, p. 287)

Based on the results of the review, the use of open-ended questions to support creative thinking skills and mathematical communication skills is applied to elementary, junior high, upper secondary, and higher education levels. The percentage of application of open questions at each level of education can be seen in Table 3.

Table 3. Educational Levels of the Reviewed Open-Ended Question

Education Level	Number of Manuscripts	Percentage (%)	Researchers
Primary Education	4	28,6	Bahar and June Maker (2015), Erhan and Bingölbali (2021), Rodriguez and Bonner (2018), Yuniarti et al. (2021).
Junior Secondary Education	3	21,4	Damayanti and Sumardi (2018), Islam et al. (2021), Viseu and Oliveira (2012).
Senior Secondary Education	1	7,1	Romli et al. (2018)
College	3	21,4	Munahefi et al. (2021), Rahayuningsih et al. (2021), Wijaya (2018).
Primary Education - College	3	21,4	Bennevall (2016), Kozlowski et al. (2019), Suherman and Vidákovich (2022).

Based on Table 3. it can be seen that research related to the use of open-ended questions for creative thinking skills and mathematical communication skills of students was studied in primary school, namely as many as four manuscripts with a percentage of 28,6%. The research related to the use of open questions at every level of Education shows the importance of the use of open questions to support and assess the ability of creative thinking and mathematical communication skills of students.

Literature research shows how the role of open-ended problems plays a role in improving students ' creative thinking and mathematical communication skills. Based on the results of the review, open-ended problems have an influence and can support the ability of creative thinking and mathematical communication skills of students. A summary of the results of the review can be seen in Table 4.

Table 4. Summary of Literature Review Results

Author (year)	Result
Damayanti & Sumardi (2018)	Student creativity is measured based on aspects of creative thinking ability achieved by students. Aspects measured are fluency, flexibility, and originality. This aspect was tested on students with different levels of ability, namely high ability, medium ability, and low ability. The measurement results showed that high and medium ability students can achieve these three aspects well, while students with low ability have not achieved the aspect of creativity well.
Bennevall (2016)	The application of open-ended tasks shows good results on students ' creative thinking ability. The types of open-ended tasks used to promote creativity are divided into six groups: insight, posing problems, problem-solving, open classical analogy, redefinition, and generative.
Rahayuningsih et al. (2021)	Open-ended problem-solving tasks are effective for measuring students ' creative thinking skills on processes and products. Student's creative thinking process is demonstrated when the students are capable in aspects of cognitive flexibility and cognitive fluency.
Kozlowski et al. (2019)	With the use of open problems, students' creativity is not closed and constrained but can be open and fostered. Students can internalize a good creative method used as a problem-solving strategy
Romli et al. (2018)	The application of open-ended based worksheets can improve students ' creative thinking skills based on aspects of material summary, open problem, presentation, and exploration.

Author (year)	Result
Suherman and Vidákovich (2022)	The Open-ended test is the most widely used tool to measure students ' creative thinking skills from primary school to college. The open-ended test provides students with arguing and writing down problem-solving ideas. In solving open-ended problems students are encouraged to produce an unlimited variety of answers.
Yuniarti et al. (2021)	The results showed that the experimental class by applying learning with open problems measured by the ability to think creatively showed better results than the control group that applied conventional learning. This significant difference can be seen in the average obtained by experimental class students is 33.19 and control class students is 26.51. And the average value of achieving the level of creative thinking ability is mathematically obtained sig. value < .05, so that the achievement of mathematical creative thinking ability in the experimental group is better than the control group.
Erhan and Bingölbali (2021)	Open-ended questions provide an opportunity for students to give different answers but can generate general rules so that they affect the creativity of students in finding ideas. The use of open-ended questions also increases educators ' interest in measurement and evaluation.
Bahar and June Maker (2015)	In closed problems that contribute significantly to the work of problem-solving there are mathematical and general knowledge. While the variables that contribute significantly to the performance of open problem solving are creativity and verbal ability.
Rodriguez and Bonner (2018)	The use of open-ended problem-based questions has a positive impact on communication skills. Teachers improve students' questioning skills and engage students during discussions, mathematical modelling, and written explanations. With open-ended questions, students are allowed to engage with teachers and friends in dialogical interactions that lead to problem-solving strategies.
Viseu & Oliveira (2012)	The use of open problems brings changes to students' mathematical communication skills. Teachers pay attention to what each student says and does. Teachers encourage students to ask questions and communicate with each other related to math problems.
Wijaya (2018)	Combining various forms of open-ended problems in math assignments can improve students' creative abilities. The presentation of contextual problems and the use of GeoGebra lead students to explore more at a higher level.
Munahefi et al. (2021)	Open questions designed with valid and reliable ethnomathematic nuances are used as a test instrument for creative thinking ability to measure several aspects, namely fluency, flexibility, originality, and elaboration
Islam et al. (2021)	Open-ended questions are used in the students' creative thinking ability test to measure the achievement of indicators of creative thinking ability, namely fluency, flexibility, and novelty based on male and female gender. The results showed that each person has a different level of creative potential and excels in certain aspects.

Based on several research results that have been presented related to the influence of open problems on the ability of creative thinking and mathematical communication skills, show that the application of open-ended problems can encourage the development of creative thinking skills and mathematical communication skills of students. The use of questions based on open-ended problems can be applied by teachers as a solution to support students' creative thinking skills and mathematical communication skills and is also used as a teacher as an assessment of mathematics learning in measuring students' creative thinking skills and mathematical

communication skills, because open-ended questions give students flexibility. In answering questions and broadly students can communicate mathematical problem-solving ideas.

1. Open-Ended Question

Open-ended question is one type of test in the form of essay questions that can be used as an alternative solution for math learning evaluation to measure students ' creative thinking and mathematical communication skills. Open-ended questions related to daily life can train students to solve problems creatively, foster originality of ideas, create high cognitive, critical, communication interaction, and socialization (Rahayuningsih et al., 2021; Sarwanto et al., 2020; Kozlowski et al., 2019; Rodriguez & Bonner, 2018;). Open-ended question focuses on the process of finding answers, this is different from closed-ended problem which focuses on the final result of the answer so that it can make students easily bored and easily discouraged. By solving open problems, it is expected to provide an intellectual experience for students in discovering something new. Furthermore, open-ended questions are more advantageous than closed-ended questions because open-ended questions are suitable for partial assessments and are easy for teachers to prepare for (Karadag et al., 2021). Open-ended questions can also be used as a test instrument development that can potentially reduce students to cheating during exams (Munahefi et al., 2021).

The Open-ended question can also provide an opportunity for students to present more than one method and solution in their solution (Cakir & Cengiz, 2016; Erhan & Bingölbali, 2021; Munroe, 2015). Furthermore, the open-ended questions also makes students think freely, makes students dare to express opinions or ideas, and dare to ask questions so as to support students' communication skills. Open-ended questions can expand students' mathematical language when solving each problem, and relate students' ideas, as well as further investigate students' answers (Viseu & Oliveira, 2012). Students who work on open problems tend to actively participate in learning, more often to express ideas, and actively discuss with other students.

In line with the research that has been done by some previous researchers regarding the use of open-ended questions (Suherman & Vidákovich, 2022, Erhan & Bingölbali, 2021; Rahayuningsih et al., 2021; Romli et al., 2018; Bennevall 2016; Munroe, 2015), teachers can be facilitators for students in solving open questions. The teacher must be able to plan the activities carried out carefully, the teacher must think and be selective about the questions asked. The use of open-ended problems allows teachers to ask diverse and specific types of questions to support students ' creative and communication skills. Teachers who produce quality open-ended questions will create a learning atmosphere that actively engages students and engages students in various forms of mathematical communication. Furthermore, by providing open problems, teachers can evaluate the diversity of student knowledge and the level of student ability.

2. Creative Thinking Skills

Creativity is a manifestation of the ability to think at a high level that produces a novelty and different from usual. A person who has the ability to think creatively is a person who can think in a flexible, smooth, original, and also detailed (Suryandari et al., 2021). The ability to

think creatively can be said that as a unit of thinking logically, differently, and producing something new at the same time which is an indication of creative thinking in mathematics. The ability to think creatively is very necessary to be developed especially in the face of the Industrial Revolution 4.0 and society 5.0 in order to create something new in the future. Students ' understanding in finding many possible answers that also emphasize the quality and accuracy shows the high ability of creative thinking of a person.

Students who have a high level of creative thinking skills will show a broad interest and prefer to be creative. They dare to take risks compared to students who have a low level of creative thinking ability, and they will dare to try new things and make them challenged to find a solution to a mathematical problem. Therefore, the development of creative thinking skills can be the main focus of mathematics learning activities. Mathematics learning is very complex learning that teachers really need to design the learning process in such a way that the development of students' creative thinking skills can also run optimally. Teachers become facilitators for students in developing their ideas in solving mathematical problems (Bahar & June Maker, 2015).

The ability to think creatively can be measured by several indicators including flexibility, fluency, originality, and elaboration. Flexibility is the ability to change the direction of one's thoughts and point of view. Freedom, flexibility, and an open environment are needed to increase creativity. Fluency, namely the ability of individuals to generate ideas, put forward suggestions, and solve problems with various alternatives smoothly in a certain time. Originality is the ability to discover new and different ideas from others. Originality emphasizes spontaneity, new possibilities, and self-expression. Elaboration is the ability to add a description to the idea so that the resulting idea becomes complete and clear (Yuniarti et al., 2021; Kozlowski et al., 2019; Greenstein, 2012; Treffinger et al., 2002).

In line with research conducted by several previous researchers (Suherman & Vidákovich, 2022; Islam et al., 2021; Munahefi et al., 2021; Rahayuningsih et al., 2021; Yuniarti et al., 2021; Kholil, 2020; Kozlowski et al., 2019; Damayanti & Sumardi, 2018; Romli et al., 2018; Bennevall, 2016), it is seen that the importance of developing creative thinking skills in students so that teachers can be facilitators in preparing appropriate learning strategies, and preparing appropriate assessments to measure students' creative thinking skills such as by using open-ended questions.

3. Mathematical Communication Skills

Communication is a medium for interacting with others. Someone who can communicate well means already have the capital to cooperate with others so as to produce something innovative (Rustam & Ramlan, 2018). Communication is also one of the important abilities that students need to have in learning mathematics because good mathematical communication can regulate students ' mathematical thinking well as well. Mathematical communication is one of the standard processes that need to be achieved in learning mathematics as a way to share ideas and used to clarify the mathematical understanding of students delivered through oral, written, and demonstrated virtually in the form of symbols or mathematical notations with the aim of making it easier for students to understand mathematical problems (Surya et al., 2018; Pourdavood & Wachira, 2015; NCTM, 2000).

Mathematical communication skills refer to the ability of students to: (1) relate each idea to the results of Mathematical Thinking; (2) convey mathematical thoughts in the form of oral or written; (3) communicate mathematical logic to friends and teachers; (4) analyze mathematical thoughts conveyed by others; (5) use appropriate mathematical language to convey mathematical ideas (NCTM, 2000). Mathematical language needs to be developed in students to help communicate their mathematical ideas. Communication skills in learning mathematics play a role in further analysis of information from teachers or everything they gain during the learning process (Rohid et al., 2019; Rodriguez & Bonner, 2018). In addition, the importance of mathematical communication skills for students aims that students have the strength in formulating mathematical concepts, as a capital for students to investigate further mathematics related to the process, discussion, and decisions made (Viseu & Oliveira, 2012). In line with previous research by several researchers (Rohid et al., 2019; Rodriguez & Bonner, 2018; Rustam & Ramlan, 2018; Viseu & Oliveira, 2012; Kosko & Wilkins, 2011). so important mathematical communication skills that the role of teachers as facilitators and an appropriate assessment to measure students ' communication skills such as the use of assessment in the form of open-ended question.

D. CONCLUSION AND SUGGESTIONS

Related to the results of the study of the use of open questions in mathematics learning and in the evaluation of mathematics learning to support the ability to think creatively and mathematical communication skills of students obtained several main things including: Learning mathematics using open-ended questions is effectively used to support the ability of creative thinking and mathematical communication skills of students; the provision of open-ended question can be familiarized with providing learning methods leading to an open-ended approach; the test in the form of open-ended question can be used as a tool to measure the ability of creative thinking; the use of open-ended questions can be applied to all levels of education; and the need for high creativity from teachers to prepare for learning by applying open-ended questions.

This literature review research contributes to expanding teacher's literature related to efforts in improving creative thinking skills and mathematical communication skills by applying open-ended questions in the learning process of mathematics and also as an alternative to the preparation of appropriate assessment in mathematics learning. This research has some weaknesses, such as primary research literature related to the use of open-ended questions to develop students ' creative thinking and mathematical communication skills indexed by Scopus is relatively small. Certain characteristics such as study areas are not observed as this has the potential to affect the heterogeneity of literature sources. Therefore, it is necessary to increase the publication of research results related to the effect of the application of open-ended questions on improving the ability of creative thinking and mathematical communication of students at every level of Education.

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