E-ISSN : 2579-9258
P-ISSN: 2614-3038

Jurnal Cendekia: Jurnal Pendidikan Matematika
Volume 07, No. 1, December 2022 -March 2023, pp. 845-861

Improving Student's Critical Thinking Skills in Mathematics Education: *A Systematic Literature Review*

Riska Novia Sari[1]✉, Dadang Juandi[2]

[1, 2] Pendidikan Matematika, FMIPA, Universitas Pendidikan Indonesia,
Jl. Dr. Setiabudi No 229, Isola, Kota Bandung, Jawa Barat, Indonesia
riskanovia@upi.edu

Abstract

Improving students' critical thinking skills is the goal of 21st-century learning. Therefore, this Systematic Literature Review (SLR) aims to find the techniques for improving students' critical thinking skills, especially in mathematics education. Data collection was obtained from scopus database. 24 publications published between the years 2018 to 2022 were retrieved for further analysis. Various tools were employed, they are; Microsoft excel and VostViewer. The result of the analysis showed that the techniques used to improve critical thinking skills include teaching methods, teaching materials, robotic coding activities, teacher attitudes, and the Olympics. The teaching method mostly used to improve critical thinking in mathematics education which is popularly used is Problem Based Learning (PBL) and Science Technology Engineering Mathematics (STEM) approach. This literature review is intended to help educators better understand learning tools to enhance students' critical thinking skills. This can make the mathematics learning process more creative and meaningful.
Keywords: critical thinking skills, systematic literature review, teaching method

Abstrak

Meningkatkan kemampuan berpikir kritis siswa adalah tujuan dari pembelajaran abad ke-21. Oleh karena itu, Systematic Literature Review (SLR) ini bertujuan untuk menemukan teknik-teknik yang dapat meningkatkan kemampuan berpikir kritis siswa, khususnya dalam pendidikan matematika. Pengumpulan data diperoleh dari database scopus. Sebanyak 24 publikasi yang diterbitkan antara tahun 2018 hingga 2022 diambil untuk dianalisis lebih lanjut. Berbagai alat bantu digunakan, yaitu Microsoft excel dan VostViewer. Hasil analisis menunjukkan bahwa teknik yang digunakan untuk meningkatkan kemampuan berpikir kritis meliputi metode pengajaran, bahan ajar, kegiatan pengkodean robotik, sikap guru, dan Olimpiade. Metode pengajaran yang banyak digunakan untuk meningkatkan kemampuan berpikir kritis dalam pendidikan matematika yang populer digunakan adalah Problem Based Learning (PBL) dan pendekatan Science Technology Engineering Mathematics (STEM). Kajian literatur ini dimaksudkan untuk membantu para pendidik agar lebih memahami perangkat pembelajaran yang dapat meningkatkan kemampuan berpikir kritis siswa. Hal ini dapat membuat proses pembelajaran matematika menjadi lebih kreatif dan bermakna.
Kata kunci: kemampuan berpikir kritis, systematic literature review, metode pembelajaran

✉ Corresponding author: Riska Novia Sari
Email Address: riskanovia@upi.edu (Jl. Dr. Setiabudi No 229, Isola, Kota Bandung, Jawa Barat)
Received 03 January 2023, Accepted 28 March 2023, Published 29 March 2023
DoI: https://doi.org/10.31004/cendekia.v7i1.2091

INTRODUCTION

Critical Thinking skill is one of the important abilities of the 21st-century generation (Scott, 2015;Partnership for 21st Century Skills, 2008;Redecker & Punie, 2014;Davies & Barnett, 2015;Dwi Susandi et al., 2019;Smith et al., 2018). In Indonesia, critical thinking or critical reasoning has become one of Pancasila Youth Profiles *(Profil Pelajar Pancasila*) as stipulated in Ministry of Education and Culture Decree No. 22 of 2020 on the Strategic Plan of the Ministry of Education and Culture for the period 2020 to 2024. Therefore, one of the demands of teachers for this Merdeka curriculum is to develop students' critical thinking skills. Critical thinking is a thinking skill that involves cognitive processes and encourages students to think reflectively about problems.

Critical thinking includes mental activities related to problem-solving, hypothesis analysis, rationalization, evaluation, conducting research, and decision-making (Saputra, 2020). Furthermore, Ennis (1996) states that critical thinking is not just about solving mathematical puzzles and illogical problems. Rather, it involves cognitive processes that produce definite conclusions about what to understand and what to do. Facione (2011) describes the importance of using critical thinking as a personal reference in evaluating what involves interpretation, analysis, evaluation, and reasoning. Halpern (2002) defines critical thinking as the application of strategies or cognitive skills to solve problems, understand root causes, increase the likelihood of desired outcomes, and draw conclusions. Therefore, it can be concluded that the ability to think critically is the ability of a person to solve problems by gathering all relevant data and analyze them, evaluate, and draw relevantly logical conclusions to solve problems.

People who have critical thinking skills are prepared to deal with a lot of information and problems for which it is not clear how to properly solve the problem (Angeli & Valanides, 2009). This ability is also necessary to be able to make the right decisions (Sutini et al., 2017;Aizikovitsh & Amit, 2009; Gurcay & Ferah, 2018) and provide the right reasons (Gurcay & Ferah, 2018). In addition, critical thinking skills can also reflect success in school and work (Starkey, 2004). Critical thinking skills can be taught and mathematics has a potential role in developing these abilities.

In mathematics, critical thinking can enhance creativity by encouraging someone to explore new strategies for solving mathematical problems (Su et al., 2016). Astuti et al. (2020) states that critical thinking ability is one of the higher-order thinking skills or higher-order thinking skills (HOTS). It involves mental activities to connect, manipulate, and transform existing knowledge and experience in order to make decisions and solve problems. in a new situation. Therefore, it is important for teachers to be able to develop critical thinking skills in their students (Kusaeri & Aditomo, 2019;Abramovich et al., 2019;Afriansyah et al., 2019).

In her study about critical thinking skills, Setyawati et al. (2022), focused on discussing the results of previous studies that used his STEM-PjBL model to improve mathematical critical thinking skills. In addition, Mohamed Nor & Sihes (2021) used bibliometrics on 754 publications published between 1944 and 2020 to quantify aspects of publication year, document type, subject area, and keywords. Through the examination of the data, critical thinking skill in the world of education is discussed. Previous research has not specifically discussed tools used to improve critical thinking skills in mathematics students. Therefore, this study specifically describes the tools the researchers have used over the past five years to improve students' critical thinking skills in mathematics education.

This systematic literature review aimed to determine solutions to the research questions outlined below.

1. How is the description of improving students' critical thinking skills in mathematics education based on the year of publication?

2. How is the description of improving students' critical thinking skills in mathematics education based on research methodologies?
3. How is the description of improving students' critical thinking skills in mathematics education based on study level?
4. What are the most popular tools used in improving students' critical thinking skills in mathematics education?
5. Which country has the most research in the area of critical thinking skills in mathematics education?
6. What is the description of the trend of Improving critical thinking skills in mathematics education in the last 5 year-publication?

Thinking abilities are necessary for dealing with life's challenges. That includes critical thinking abilities, creative thinking skills, and skills for the problem-solving (Kalelioğlu & Gülbahar, 2014). Critical thinking is one of the skills required to deal with personal and social problems. Here are some examples of critical thinking definitions. According to Facione (2011), critical thinking is the ability to organize and generate evaluations, interpretations, inferences, and analyses, as well as reveal concepts, criteria, evidence, methodologies, and or contextual considerations as the basis for making decisions.

According to Choy & Cheah (2009), critical thinking is required to process cognitive information at a high level and to define complex processes. Critical thinking, according to Ennis (2011), is one of the skills of reflective reasoning and thinking that is concentrated on what has been believed or completed. Critical thinking skills involve original clarification, basic decision-making process, inference, providing an extra explanation, estimation, and incorporation, in addition to other abilities. Critical thinkers could indeed evaluate and analyze the presented data. According to Duron et al. (2006), being critical thinkers means being able to evaluate the data and analyze them, inform crucial questions and problems, formulate hypotheses and problems until they are clear, and collect and evaluate relevant information. Moreover, a critical thinker can use abstract ideas to find relevant information, be open-minded, and effectively communicate with others.

The purpose of critical thinking is to learn how to think deeper, solve problems better, communicate, collaborate, and innovate more effectively (Murawski, 2014). (As'ari, 2014) states that students who have critical thinking skills can continue learning to a higher level. Critical thinking skills can be learned and taught (Ennis, 2011). Therefore, the teacher plays a very important role in improving students' critical thinking skills. There are many ways that teachers can do to improve students' critical thinking. Umam & Susandi (2022) research findings show that developing a teaching model for mathematics teaching to improve students' critical thinking skills is highly recommended. Facione (2011) proposed some indicators of critical thinking skills, they are; interpretation, analysis, evaluation, explanation and inference.

Ennis (1985) formulated indicators of critical thinking skills which are abbreviated as FRISCO (Focus, Reason, Inference, Situation, Clarity, Overview). Furthermore, Glaser & Watson (2012)

provides five indicators as a selection tool in the academic field, they are interpretation, deduction, evaluation, inference, and recognition of assumptions.

METHOD

Research Design

This study used the Systematic Literature Review (SLR). SLR is a rigorous review of research results (Iden & Eikebrokk, 2013). SLR is a literature review that identifies, evaluates, and interprets all findings on a research topic to answer previously determined research questions (Iskandar & Juandi, 2022). This study reviews the results of primary research on improving critical thinking skills in mathematics education. This review was carried out with the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA). As Sierra-Correa & Cantera Kintz (2015), PRISMA has three main benefits. First, it provides precise research questions that allow systematic study. Second, it develops exclusion and inclusion criteria, and thirdly, it strives to analyze a massive scientific database publication within a certain time constraint. Finally, the PRISMA statement enables a comprehensive search for terms relating to innovative teaching. PRISMA is based on four steps: identification, screening, eligibility, and included.

Identification

The article search process is done using the Scopus database. A search string is required for more specific searches and to avoid filtering too large numbers. Search strings for this study: ("Critical Thinking Skills" OR "Critical Thinking Ability") AND ("Mathematics Education" OR "Mathematics Learning" OR "Mathematics")).

Screening

The selection process, that is, the process of first examining the titles and abstracts of articles to determine whether the studies are relevant (Zawacki-Ritcher et al., 2020). Additionally, the selected articles were segregated based on inclusion-exclusion criteria. The inclusion-exclusion criteria for this study are shown in the following table.

Table 1. The Inclusion-Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
The selected articles come from international journals indexed by Scopus	Book, book series, systematic literature review articles and conference proceeding
The research subjects are students/university students	Subjects are not students/university students
Year of publication 2018-2022	Year of publication before 2018
Using English	Non-English
Research that focuses on improving critical thinking skills in mathematics education	Research does not focus on improving critical thinking skills in mathematics education

Eligibility

The eligibility procedure follows the screening method. The author personally examined the articles extracted to guarantee that all of the remaining articles met the requirements. This was achieved

by reading the titles, abstracts, and complete contents of the papers. This part of the procedure resulted in the exclusion of 21 articles because they did not focus on improving students' critical thinking skills in mathematics education and were published as a book chapter. Hence, the systematic literature review potentially comprised 24 papers.

Included

The techniques for improving students' critical thinking skills in mathematics education were the focus of the publications in this systematic review. The Scopus databases were used to select 24 articles for the table. These databases were selected for the quality and nature of their publications, particularly in the education field. Only articles that are both relevant and fulfil the inclusion criteria will be analyzed (Juandi, 2021). Articles that do not meet the inclusion requirements are not taken into account for the following stage. Articles and journals that meet the inclusion criteria are then coded and sorted for subsequent review based on their relevance to the theme. The final step is to present the research findings. In this step, the research results are summarized in a systematic and clear manner. The Process is as follows:

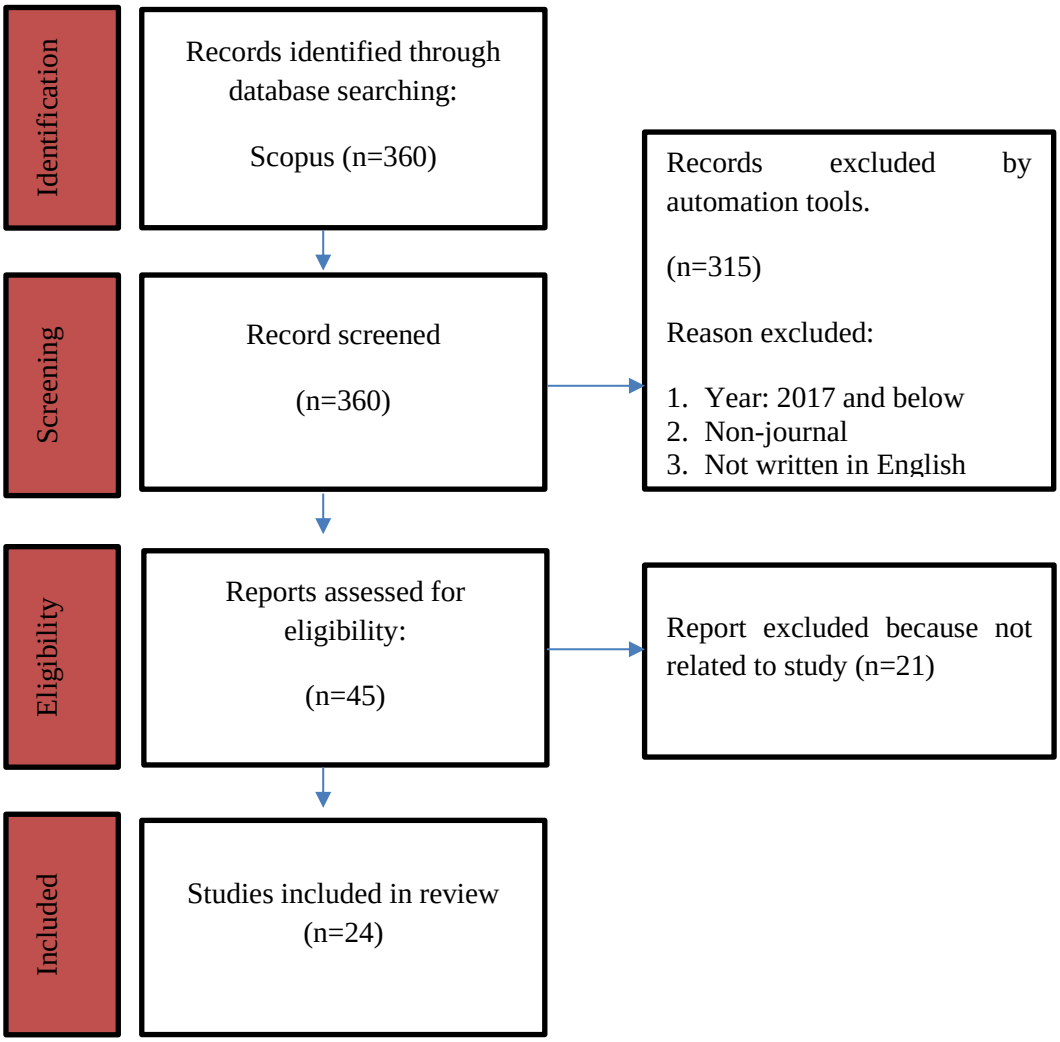

Figure 1. PRISMA Diagram Flow

RESULTS AND DISCUSSION

Year of Publication

From 2018 to 2022, a lot of articles were published on improving students' critical thinking skills in mathematics education. There were 24 articles selected based on inclusion-exclusion criteria. Figure 2 illustrates the distribution of the number of articles by year.

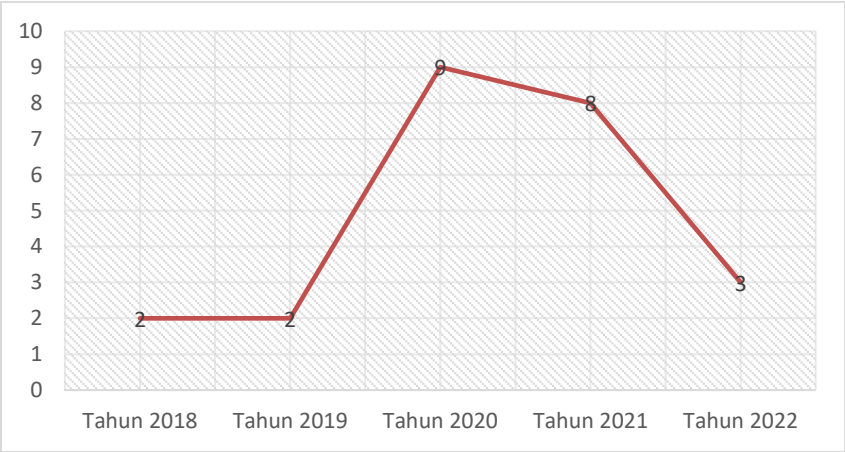

Figure 2. Database on Year of Publication

Figure 2 shows that the number of articles on improving students' critical thinking skills in mathematics education research increased slightly between 2019 and 2020. However, it has decreased from 2021 to 2022.

Research Methodologies

To improve students' mathematical critical thinking skills, researchers use different research methodologies. Figure 2 illustrates the research methodologies that are used by some research to increase students' critical thinking skills.

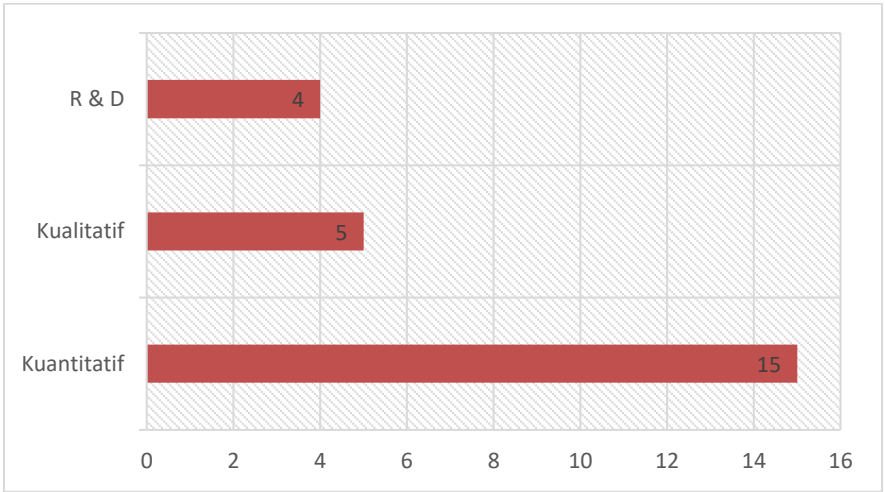

Figure 3. Database on Research Method

Based on Figure 3, quantitative research was the most dominant design the researchers employed to improve students' critical thinking skills. The most widely used type of quantitative research is quasi-experimental.

Study Level

One of the specified inclusion criteria is that the research subject is school students or university students. Figure 2 below depicts the research subjects of the 24 articles analyzed.

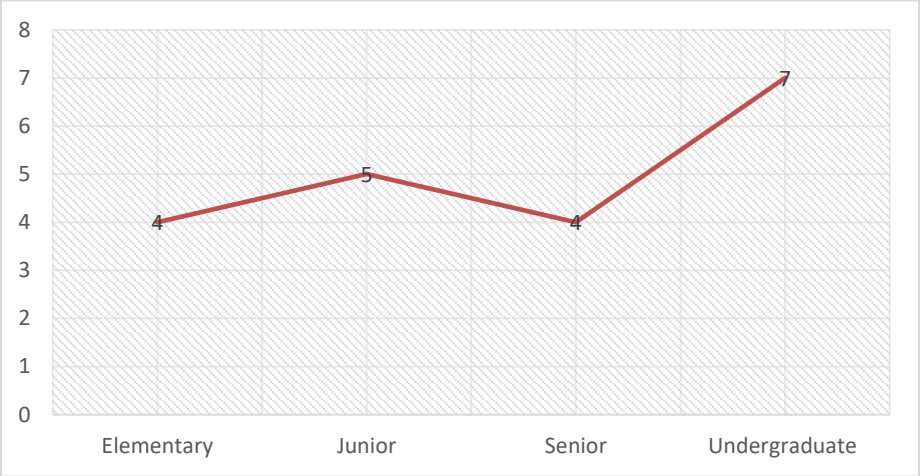

Figure 4. Database on The Study Level

Based on Figure 4, Selected research subjects were mostly students of undergraduate, consecutively followed by students of junior high school, senior high school, and those of elementary school.

The Most Popular Techniques

The percentage of the techniques used in improving students' critical thinking skills in mathematics education is illustrated in Figure 3. This result gives a comprehensive analysis with regard to the most popular tools that have been used in improving students' critical thinking skills in mathematics education.

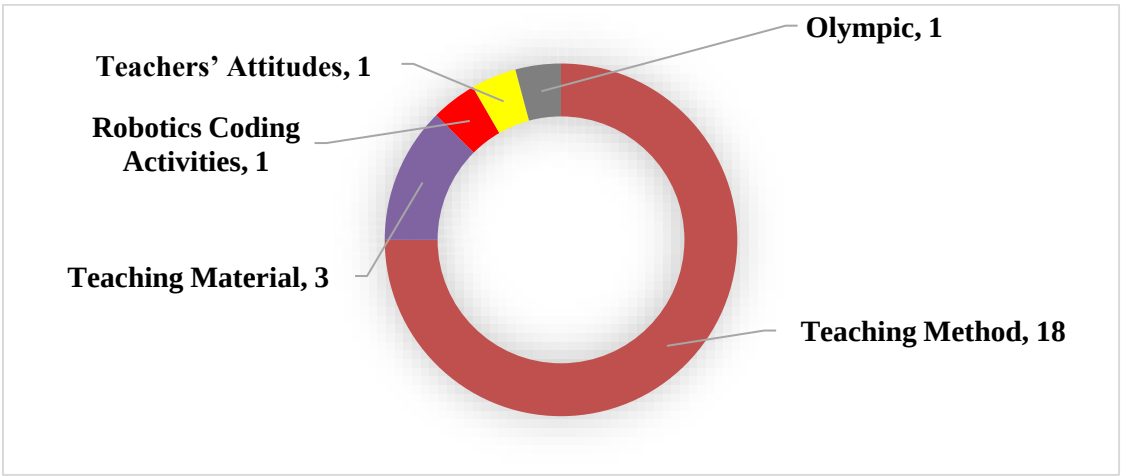

Figure 5. The Percentage of Techniques Used to Improve Students' Critical Thinking Skills

The figure showed that teaching method is the most popular technique to improve students' critical thinking skills. This is in line with Nurullaevna (2021) stating that the application of a variety of learning methods is expected to increase students' interest and abilities in mathematics. Less innovative teaching techniques as well as methods cause students' disinterest to the lessons and trigger students' boredom of the lesson. Teachers have then changed the paradigm by being not skepticism towards the change and later progress to become a professional and innovative teacher in conducting the class learning process (Sumantri, 2013). Further description can be seen in the following Table 2.

Table 2. The Finding of The Techniques Used to Improve Students' Critical Thinking Skills

No	Authors	Techniques				
		Teaching Method	Teaching Material	Robotic Coding Activitie	Teacher' Attitudes	Olympic
1	Evendi et al. (2022)	√				
2	Kim et al. (2021)			√		
3	Adhianto et al. (2020)	√				
4	Nelson, K (2018)	√				
5	Ilyas et al. (2022)	√				
6	Hikayat, C (2020)		√			
7	Tong et al. (2020)	√				
8	Hairun, MSY (2020)	√				
9	Arisoy & Aybek (2021)	√				
10	Sklymchuk & Sangwin (2021)				√	
11	Toheri et al (2020)	√				
12	Sutama et al. (2022)	√				
13	Mutakinati et al. (2018)	√				
14	Setambah et al (2019)	√				
15	Lestari et al (2021)		√			
16	Yasin et al. (2019)		√			
17	Pahrudin et al. (2021)	√				
18	Darhim et al. (2020)	√				
19	Arifin et al. (2020)	√				
20	Anggraini et al. (2021)	√				
21	Setiana et al. (2021)	√				
22	Priatna et al. (2020)	√				
23	Wahidin & Romli (2020)					√
24	Catarino & Vasco (2021)	√				

Based on Figure 5 and Table 2, it can be seen that the teaching method is the most widely used technique to improve students' critical thinking skills. The applied type of teaching method could be seen as follows:

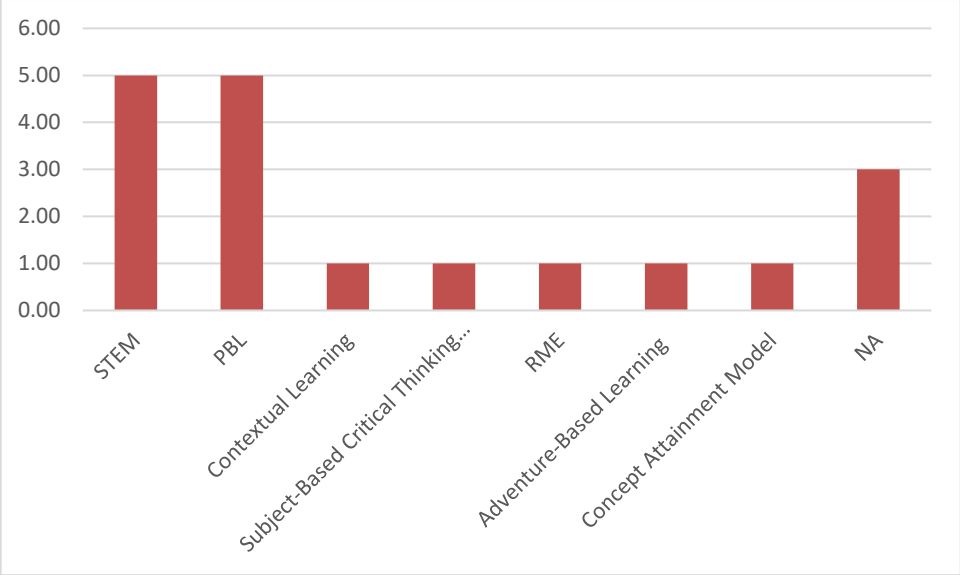

Figure 6. Various Types of Teaching Methods

The figure showed that STEM and PBL approach are the most widely used by the researchers to improve students' critical thinking skills. Furthermore, there are 3 studies on teaching materials with their types, they are; mathematics comics, worksheets, and e-modules.

The Country with The Most Research

In fact, there are 8 countries involved in this review. This study found that critical thinking skills research in mathematics are mostly conducted in Indonesia. In terms of quantity, sixteen studies have been conducted in Indonesia. Furthermore, two studies were conducted in the USA. Meanwhile, just one study improving students' critical thinking skills in mathematics education has been conducted in six countries: Malaysia, Japan, Turkey, New Zealand, Portugal, and Vietnam. Figure 6 shows findings on improving students' critical thinking skills in mathematics education research according to the list of countries.

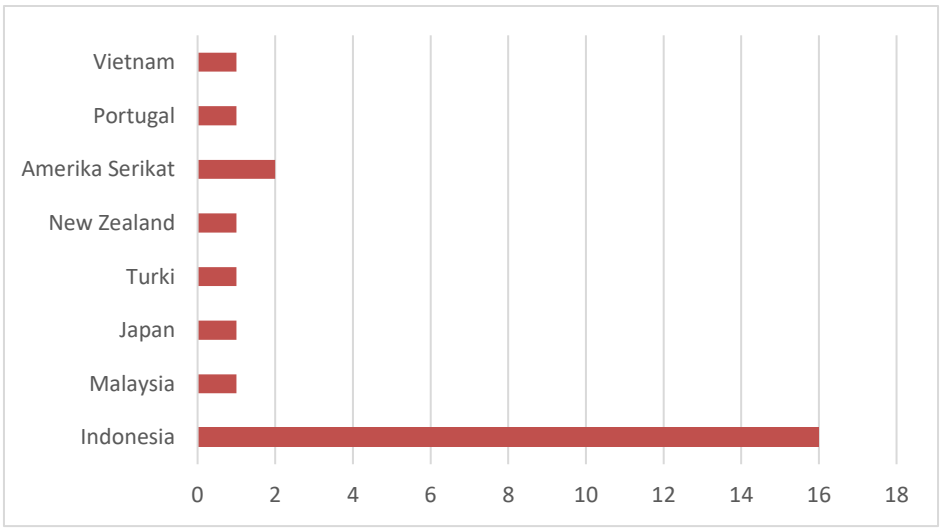

Figure 6. Findings on Improving Students' Critical Thinking Skills in Mathematics Education Research According to The List of Countries

The Trend of Improving Critical Thinking Skills in Mathematics Education in Last 5 Year-Publication

Figure 7 shows the trends over the last five years based on VOSviewer-processed bibliographic data. Colors that are the same color represent the same group, and the size of the circle represents keyword popularity. The larger the circle, the more frequently the topic is covered in the 24 articles. The VOSviewer simulated that 73 important keywords meet the threshold in form 11 clusters. In each group; critical thinking, critical thinking skills, problem-based learning, and STEM have the highest frequency; which means that those 4 keywords are primarily focused on and highly related to one another.

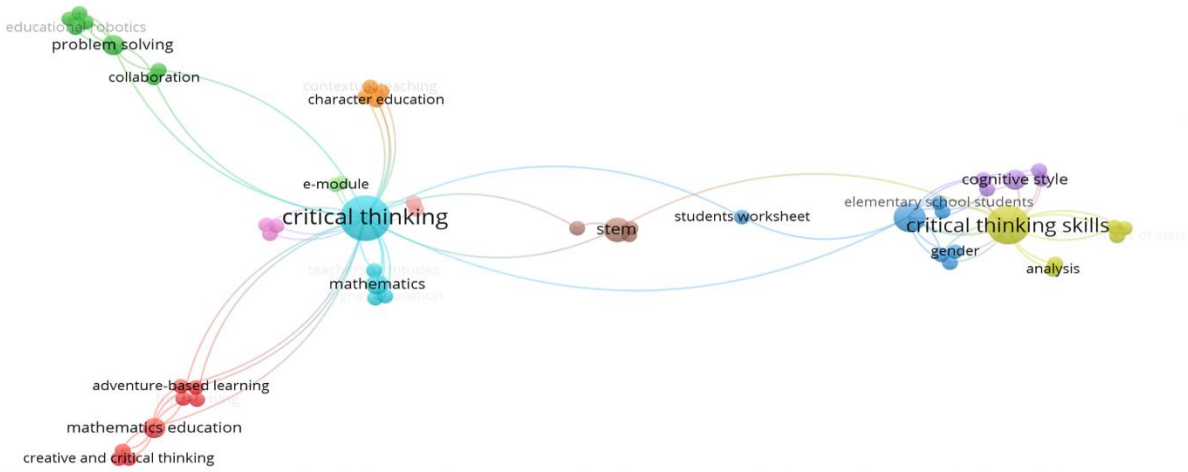

Figure 7. The Keyword Network Visualization

In figure 8, colors represent the trends of research theme. The lighter the colors, the more recent posts they belong to. Those highlighted in yellow shows the most recent publications which cover some keywords in educational robotic, collaboration, problem-solving, mathematics, and character education are trending. For the researchers, the information about the topic's novelty is critical in representing the current state of studies carried out throughout several periods.

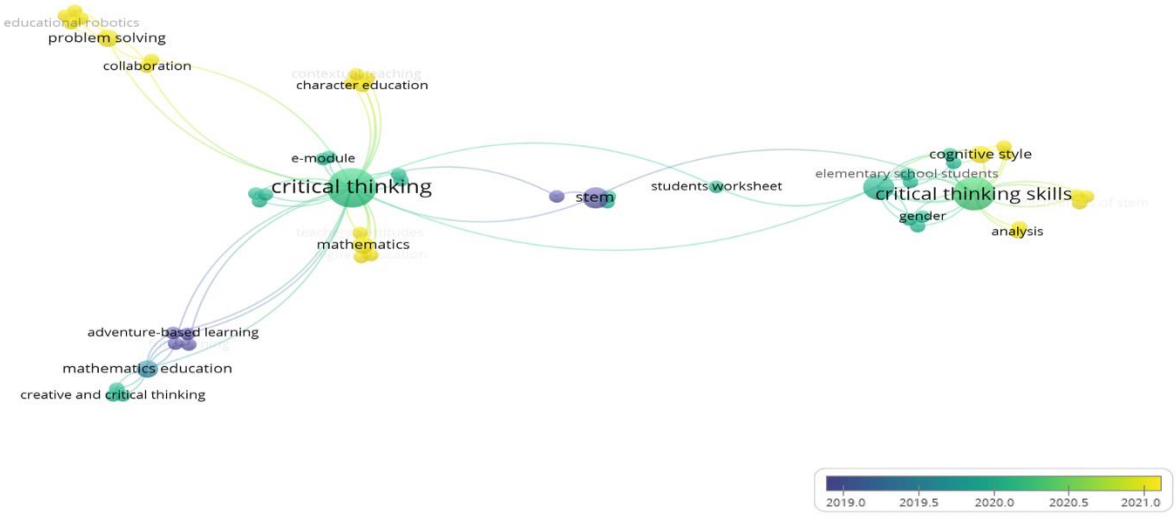

Figure 8. The Keyword Network Visualization

Discussion

Based on the research finding, research publications on improving students' critical thinking skills have increased from 2019 to 2020 and most of the authors are from Indonesia. This is due to the conditions of the covid-19 pandemic so teachers or lecturers try to carry out various techniques to improve students' critical thinking skills. Furthermore, based on Figure 3, quantitative research constituted the most dominant design the researchers employed to investigate critical thinking skills. The higher number of quantitative research than other types of research is in line with some previous studies reporting that the researchers preferred quantitative research design to conduct research in education, instead of qualitative one (Goktas et al., 2012; Uzunboylu & Aşıksoy, 2014). Furthermore, the results of the study show that research subjects are mostly those of undergraduate students. This is in line with (Fahim & Masouleh, 2012) preparing students' ability to think critically is the goal of many professionals in higher education and also the quality sought after by employers of university graduates. In addition, critical thinking is the core learning objective for the campus's general education program (Statssen et al., 2011).

There are a total of 18 out of 24 studies which primarily concerns on the teaching method in improving students' critical thinking skills. The teaching method is one of the largest percentages in developing CT in mathematics education, i.e., 75%. This systematic literature review explains various types of teaching methods used in the improvement of students' critical thinking skills in Mathematics education, such as PBL, STEM, Contextual Learning, Subject-Based Critical Thinking Education, Realistic Mathematics Education (RME), Adventure-Based Learning, Concept Attainment Model, and NA. for the NA model. However, the model is not specifically stated, it only mentions the mathematics learning model to improve critical thinking skills. The PBL and STEM approaches` are the most widely applied. This is in line with research results (Aswan et al., 2018); (Amin et al., 2020) the implementation of Problem-Based Learning also encourages students to think critically in the form of questioning, discussing problems, and making solutions (Narmaditya et al., 2018). On one hand, Morrison (Hafni et al., 2020) stated that STEM educates students to be a critical thinkers. Thus, STEM can shape students' ability such as critical thinking and industrial mindset to face the rapid-growing industry 4.0. STEM education approach improved better critical thinking of students (Ardianti et al., 2020; Hacioglu & Gulhan, 2021; Prasadi et al., 2020; Yulianti et al., 2020).

Teaching material is one of the obligatory components for its significant role as students' learning tools. The teacher has an important role to be selective of appropriate teaching materials that will be mastered by students and at the same time can provide guidelines for learning it. For this reason, teaching materials must be studied and furtherly examined by the teacher in order that the students can easily learn the material. The success of learning activities can be obtained if the components developed by the teacher existed, such as objectives, materials, strategies, and learning evaluation. One of the teacher's efforts to achieve learning success is to develop teaching materials that can arouse students' enthusiasm for learning (Nurafni et al., 2020). Teaching materials are significant components in

directing the students in teaching and learning activities. The teaching materials used by researchers to improve students' critical thinking skills in this study are mathematics comics, student PBL worksheets, and e-modules. The teaching material has the greatest role as the medium to attain Mathematics learning objectives. The implementation of the mathematics learning process requires effective teaching material. Hamdani says that the teaching material can assist the students in learning something (Mutmainah et al., 2019). Effective teaching material will help the students' experience in learning activities in order that mathematics learning is more meaningful and results in improved student cognitive ability.

During recent decades, the use of robotics in school mathematics as an instructional means of engaging and motivating students at the elementary grade levels has found to be favorably applied by classroom teachers (Alimisis, 2013; Bers et al., 2002; C. Kim et al., 2015). The study result conducted by Kim et al. (2021) shows that through their robotics coding activities, students discovered the concepts of special angle pairs in geometry— such as complementary and supplementary angles—as they learned to navigate the immediate feedback from the robot Sphero SPRK+ into a trial-and-error mathematics problem-solving process. Besides being able to improve critical thinking skills, robotic coding activities can also improve student computational thinking skills (Subramaniam, 2022).

The teacher's attitudes referred to in this research used provocative mathematics questions in teaching and assessment. Developing a skeptical habit of mind to analyze a mathematics question in a classroom should enhance an ability to critically analyze other situations outside of the mathematics (SKlymchuk & Sangwin, 2021). Efforts to improve the quality of critical thinking skills are developed through learning mathematics and science in various ways, such as olympics. Wahidin & Romli (2020) research results showed that the National Mathematics and Sciences Olympiad or ONMIPA have great potential to develop students' critical thinking skills reflected in several ways like competition factor, raising concept attainment, form, and question on ONMIPA test. It showed that MIPA's material requires higher-level thinking skills to understand. It is also because the questions tested are in addition to having medium and challenging levels of difficulty in the Bloom Cognitive domain.

CONCLUSION

Based on the results and discussion above, research on the critical thinking skills of students and college students has increased from 2019 to 2020. Furthermore, the most widely used research method is quantitative method and the most research subjects are students. Based on a systematic literature review, it was found that the most popular technique used to improve students' critical thinking skills, according to the findings of this study, is the teaching method. In addition, PBL and STEM are the most popular and widely used approaches by researchers. Future researchers can use PBL and STEM in collaboration with ICT to improve students' critical thinking skills. Furthermore, based on research trends using vostviewer, the use of robotic coding activities in learning mathematics is new and there are still few studies on it.

REFERENCES

Abramovich, S., Grinshpan, A. Z., & Milligan, D. L. (2019). Teaching Mathematics through Concept Motivation and Action Learning. *Hindawi: Education Research International*, *2019*, 1–13. https://doi.org/10.1155/2019/3745406

Afriansyah, E. A., Puspitasari, N., Luritawaty, I. P., Mardiani, D., & Sundayana, R. (2019). The analysis of mathematics with ATLAS.ti. *Journal of Physics: Conference Series*, *1402*(7). https://doi.org/10.1088/1742-6596/1402/7/077097

Aizikovitsh, E., & Amit, M. (2009). An Innovative Model for Developing Critical Thinking Skills Through Mathematical Education. *International Conference of the Mathematics Education into the 21st Century Project: Models in Developing Mathematics Education*.

Alimisis, D. (2013). Themes in science and technology education. *Themes in Science and Technology Education*, *6*(1), 63–71. http://earthlab.uoi.gr/theste/index.php/theste/article/view/119

Amin, S., Utaya, S., Bachri, S., Sumarmi, S., & Susilo, S. (2020). Effect of problem-based learning on critical thinking skills and environmental attitude. *Journal for the Education of Gifted Young Scientists*, *8*(2), 743–755. https://doi.org/10.1088/1742-6596/1810/1/012060

Angeli, C., & Valanides, N. (2009). Instructional effects on critical thinking: Performance on ill-defined issues. *Learning and Instruction*, *19*(4), 322–334. https://doi.org/10.1016/j.learninstruc.2008.06.010

Ardianti, S., Sulisworo, D., Pramudya, Y., & Raharjo, W. (2020). The impact of the use of STEM education approach on the blended learning to improve student's critical thinking skills. *Universal Journal of Educational Research*, *8*(3 B), 24–32. https://doi.org/10.13189/ujer.2020.081503

As'ari, A. R. (2014). Ideas for Developing Critical Thinking at Primary School Level. *International Seminar on Addressing Higher Order Thinking: Critical Thinking Issues in Primary Education*. https://doi.org/10.17809/14(2015)-12

Astuti, F. O., Juhanda, A., & Suhendar, S. (2020). Jurnal Pelita Pendidikan. *Jurnal Pelita Pendidikan*, *9*(2), 71–77. https://jurnal.unimed.ac.id/2012/index.php/pelita/article/view/17301/13178

Aswan, D. M., Lufri, L., & Sumarmin, R. (2018). Influence of Problem Based Learning on Critical Thinking Skills and Competence Class VIII SMPN 1 Gunuang Omeh, 2016/2017. *IOP Conference Series: Materials Science and Engineering*, *335*(1). https://doi.org/10.1088/1757-899X/335/1/012128

Bers, M., Ponte, I., Juelich, K., Viera, A., & Schenker, J. (2002). Teachers as Designers: Integrating Robotics i. *Information Technology in Childhood Education Annual*, 123–145.

Choy, S. C., & Cheah, P. K. (2009). Teacher Perceptions of Critical Thinking among Students and Its Influence on Higher Education. *International Journal of Teaching and Learning in Higher Education*, *20*(2), 198–206. https://doi.org/10.37648/ijrst.v10i04.002

Davies, M., & Barnett, R. (2015). *The Palgrave Handbook of Critical Thinking in Higher Education*. The Palgrave Handbook of Critical Thinking in Higher Education.

https://doi.org//https://doi.org/10.1057/978113737 8057

Duron, R., Limbach, B., & Waugh, W. (2006). Critical Thinking Framework For Any Discipline. *International Journal of Teaching and Learning in Higher Education*, *17*(2), 160–166.

Dwi Susandi, A., Sa'Dijah, C., Rahman As'Ari, A., & Susiswo. (2019). Students' critical ability of mathematics based on cognitive styles. *Journal of Physics: Conference Series*, *1315*(1). https://doi.org/10.1088/1742-6596/1315/1/012018

Ennis, R. H. (1985). A Logical Basis for Measuring Critical Thinking Skills. *Educational Leadership*, *40*(10), 44–48. https://pdfs.semanticscholar.org/80a7/c7d4a98987590751df4b1bd9adf747fd7aaa.pdf

Ennis, R. H. (1996). Critical Thinking Dispositions: Their Nature and Assessability. *Informal Logic*, *18*(2), 165–182. https://doi.org/10.22329/il.v18i2.2378

Ennis, R. H. (2011). The Nature of Critical Thinking: An Outline of Critical Thinking Dispositions and Abilities. *Sixth International Conference on Thinking*. https://doi.org/10.22329/il.v6i2.2729

Facione, P. a. (2011). Critical Thinking : What It Is and Why It Counts. *Insight Assessment*, *ISBN 13: 978-1-891557-07-1.*, 1–28. https://www.insightassessment.com/CT-Resources/Teaching-For-and-About-Critical-Thinking/Critical-Thinking-What-It-Is-and-Why-It-Counts/Critical-Thinking-What-It-Is-and-Why-It-Counts-PDF

Fahim, M., & Masouleh, N. S. (2012). Critical thinking in higher education: A pedagogical look. *Theory and Practice in Language Studies*, *2*(7), 1370–1375. https://doi.org/10.4304/tpls.2.7.1370-1375

Glaser, & Watson. (2012). *Critical Thinking Appraisal User-Guide and Technical Manual: UK Supervised and Unsupervised Versions 2012*. Pearson Education Ltd.

Goktas, Y., Akcay, A., Hasancebi, F., Bayrak, N., Varisoglu, B., Baran, M., & Sozbilir, M. (2012). Trends in Educational Research in Turkey : A Content. *Educational Sciences: Theory & Practice*, *12*(1), 455–459.

Gurcay, D., & Ferah, H. O. (2018). High School Students' Critical Thinking Related to Their Metacognitive Self-Regulation and Physics Self-Efficacy Beliefs. *Journal of Education and Training Studies*, *6*(4), 125–130. https://doi.org/10.11114/jets.v6i4.2980

Hacioglu, Y., & Gulhan, F. (2021). The Effects of STEM Education on the 7th Grade Students' Critical Thinking Skills and STEM Perceptions. *Journal of Education in Science, Environment and Health (JESEH)*, *7*(2), 139–155. https://doi.org/10.21891/jeseh.771331

Hafni, R. N., Herman, T., Nurlaelah, E., & Mustikasari, L. (2020). The importance of science, technology, engineering, and mathematics (STEM) education to enhance students' critical thinking skill in facing the industry 4.0. *Journal of Physics: Conference Series*, *1521*(4), 0–7. https://doi.org/10.1088/1742-6596/1521/4/042040

Halpern, D. F. (2002). *Thought & Knowledge: An Introduction to Critical Thinking*. Lawrence Erlbaum Associates, Inc.

Iden, J., & Eikebrokk, T. R. (2013). Implementing IT Service Management: A systematic literature

review. *International Journal of Information Management*, *33*(3), 512–523. https://doi.org/10.1016/j.ijinfomgt.2013.01.004

Iskandar, R. S. F., & Juandi, D. (2022). Study Literature Review: Realistic Mathematics Education Learning on Students' Mathematical Creative Thinking Ability. *SJME (Supremum Journal of Mathematics Education)*, *6*(1), 35–42. https://doi.org/10.35706/sjme.v6i1.5739

Juandi, D. (2021). Heterogeneity of problem-based learning outcomes for improving mathematical competence: A systematic literature review. *Journal of Physics: Conference Series*, *1722*(1). https://doi.org/10.1088/1742-6596/1722/1/012108

Kalelioğlu, F., & Gülbahar, Y. (2014). The Effect of Instructional Techniques on Critical Thinking and Critical Thinking Dispositions in Online Discussion. *Educational Technology & Society*, *17*(1), 248–258.

Kim, C., Kim, D., Yuan, J., Hill, R. B., Doshi, P., & Thai, C. N. (2015). Robotics to promote elementary education pre-service teachers' STEM engagement, learning, and teaching. *Computers and Education*, *91*, 14–31. https://doi.org/10.1016/j.compedu.2015.08.005

Kim, Y. R., Park, M. S., & Tjoe, H. (2021). Discovering concepts of geometry through robotics coding activities. *International Journal of Education in Mathematics, Science and Technology*, *9*(3), 406–425. https://doi.org/10.46328/IJEMST.1205

Kusaeri, kusaeri, & Aditomo, A. (2019). Pedagogical beliefs about Critical Thinking among Indonesian mathematics pre-service teachers. *International Journal of Instruction*, *12*(1), 573–590. https://doi.org/10.29333/iji.2019.12137a

Mohamed Nor, H., & Sihes, A. J. (2021). Critical Thinking Skills in Education: A Systematic Literature Review. *International Journal of Academic Research in Business and Social Sciences*, *11*(11). https://doi.org/10.6007/ijarbss/v11-i11/11529

Murawski, L. M. (2014). Critical thinking in the classroom... and beyond. *Journal of Learning in Higher Education*, *10*(1), 25–30. https://files.eric.ed.gov/fulltext/EJ1143316.pdf

Mutmainah, M., Rukayah, R., & Indriayu, M. (2019). Effectiveness of Experiential Learning-Based Teaching Material in Mathematics. *International Journal of Evaluation and Research in Education (IJERE)*, *8*(1), 57–63. https://doi.org/10.11591/ijere.v8.i1.pp57-63

Narmaditya, B. S., Wulandari, D., & Sakarji, S. R. (2018). Does Problem-Based Learning Improve Critical Thinking Skills? *Cakrawala Pendidikan*, *3*, 378–388.

Nurafni, A., Pujiastuti, H., & Mutaqin, A. (2020). Pengembangan Bahan Ajar Trigonometri Berbasis Kearifan Lokal. *Journal of Medives : Journal of Mathematics Education IKIP Veteran Semarang*, *4*(1), 71–80. https://doi.org/10.35334/borneo_saintek.v2i1.633

Partnership for 21st Century Skills. (2008). 21st Century Skills, Education & Competitiveness. *A Resource and Policy Guide*, 20.

Prasadi, A. H., Wiyanto, W., & Suharini, E. (2020). The Implementation of Student Worksheet Based on STEM (Science, Technology, Engineering, Mathematics) and Local Wisdom to Improve of

Critical Thinking Ability of Fourth Grade Students. *Journal of Primary Education*, *9*(3), 227–237. https://doi.org/10.15294/jpe.v9i3.37712

Redecker, C., & Punie, Y. (2014). The Future of Learning 2025: Developing a vision for change. *Future Learning*, *2*(1), 3–17. https://doi.org/10.7564/13-fule12

Saputra, H. (2020). Kemampuan Berfikir Kritis Matematis. *Perpustakaan IAI Agus Salim Metro Lampung*, *2*(April), 1–7.

Scott, C. L. (2015). Education Research and Foresight What Kind of Learning. *Education Research and Foresight*, 1–14.

Setyawati, R. D., Pramasdyahsari, A. S., Astutik, I. D., & Nusuki, U. (2022). *Improving Mathematical Critical Thinking Skill through STEM-PjBL : A Systematic Literature Review*. *4*(2), 1–17.

Sierra-Correa, P. C., & Cantera Kintz, J. R. (2015). Ecosystem-based adaptation for improving coastal planning for sea-level rise: A systematic review for mangrove coasts. *Marine Policy*, *51*, 385–393. https://doi.org/10.1016/j.marpol.2014.09.013

SKlymchuk, S., & Sangwin, C. (2021). Provocations in Mathematics : Teachers ' Attitudes Sergiy Klymchuk Auckland University of Technology. *Journal of Higher Education Theory and Practice*, *21*(10), 254–263.

Smith, T. E., Rama, P. S., & Helms, J. R. (2018). Teaching critical thinking in a GE class: A flipped model. *Thinking Skills and Creativity*, *28*, 73–83. https://doi.org/10.1016/j.tsc.2018.02.010

Starkey, L. (2004). Critical Thinking Skills Success in 20 Minutes a Day. In *Nurse Educator* (Vol. 19, Issue 6). LearningExpress. https://doi.org/10.1097/00006223-199411000-00008

Statssen, M. L. A., Herrington, A., & Henderson, L. (2011). Defining Critical Thinking in Higher Education. *To Improve The Academy*, *30*, 126–141. https://doi.org/10.1016/S0260-6917(95)80102-2

Su, H. F. H., Ricci, F. A., & Mnatsakanian, M. (2016). Mathematical teaching strategies: Pathways to critical thinking and metacognition. *International Journal of Research in Education and Science*, *2*(1), 190–200. https://doi.org/10.21890/ijres.57796

Subramaniam, S. (2022). *Cypriot Journal of Educational Computational thinking in mathematics education : A systematic*. *17*(6), 2029–2044.

Sutini, S., Susanto, H., Parta, N., & Miskun, S. (2017). Identification of Critical Thinking Process in Solving Mathematic Problems. *IOSR Journal of Research & Method in Education (IOSRJRME)*, *7*(4), 5–10. https://doi.org/10.9790/7388-0704010510

Umam, K., & Susandi, A. D. (2022). Critical thinking skills: Error identifications on students' with APOS theory. *International Journal of Evaluation and Research in Education (IJERE)*, *11*(1), 182–192. https://doi.org/10.11591/ijere.v11i1.21171

Uzunboylu, H., & Aşıksoy, G. (2014). Research in Physics Education: A Study of Content Analysis. *Procedia - Social and Behavioral Sciences*, *136*, 425–437. https://doi.org/10.1016/j.sbspro.2014.05.353

Wahidin, D., & Romli, L. A. M. (2020). Students critical thinking development in the national sciences and mathematics competition in Indonesia: A descriptive study. *Jurnal Pendidikan IPA Indonesia*, *9*(1), 106–115. https://doi.org/10.15294/jpii.v9i1.22240

Yulianti, D., Wiyanto, Rusilowati, A., & Nugroho, S. E. (2020). Student worksheets based on Science, Technology, Engineering and Mathematics (STEM) to facilitate the development of critical and creative thinking skills. *Journal of Physics: Conference Series*, *1567*(2). https://doi.org/10.1088/1742-6596/1567/2/022068

Zawacki-Ritcher, O., Kerres, M., Bedenlier, S., Bond, M., & Buntins, K. (2020). *Systematic Reviews in Educational Research*. Springer Nature.