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Systematic Literature Review: Technology-Based Media that Support Critical Thinking Skills in Mathematics Learning

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Abstract: *This study extensively reviews research on technology-based media used to support critical thinking skills in mathematics learning over the past ten years using accurate Scopus data. This study used a systematic literature review that includes six different steps, which analyzes 8 English language scientific articles published between 2016 and 2025. From the results of the selection of 8 articles that were analyzed descriptively qualitatively based on critical thinking skills, mathematics learning technology media in supporting critical thinking. Based on the research criteria, it is seen that research began in 2020-2025, with a dominance in 2022 and 2024 with 2 articles each. Most of the research was conducted at the junior high and senior high school levels, with the most prominent focus on algebra. This research is dominated by Jawa Island with 6 articles and experimental research methods and research & development dominate. In addition, technology based media referred to in learning include Interactive Digital Worksheets, Android-based Carom Game Comics, YouTube, the MathCityMap application, Assisted Video Animation, Augmented Reality, Smart Math learning media based on Articulate Storyline, and GeoGebra. This media explains the relationship between critical skills and mathematics learning, particularly in improving critical thinking skills. This research provides an opportunity to further explore technology-based media that have not yet been utilized.*

Keywords*: critical thinking, technology-based media, mathematics learning, sistematic literature review*

INTRODUCTION

Currently, critical thinking skills must be taken into account in the learning process in order to produce learners who are more adaptive, rational, and qualified in various aspects. As stated in Hidayat & Noer (2021) that the 21st century is a 4C mastery skill, one of which is critical thinking, which is closely related to everyday life and mastery of technology and information is something that students must have in order to be able to think critically. In Indonesia, critical thinking is part of the pancasila student profile as stipulated in the Decree of the Minister of Education and Culture number 22 of 2020 concerning the strategic plan of the ministry of education and culture for the period 2020-2024. Armianti et al., (2024) conveyed that critical reasoning from the pancasila student profile is relevant to the benefits of digital technology in learning. Technology provides students with the opportunity to independently access information from various sources, which can serve as a bridge to achieving critical thinking skills. In addition, research by Liu et al., (2022) suggests that student-centered teaching and successful technology integration in mathematics education in general are necessary to improve students critical mathematical thinking. One of the demands placed on teachers in the current curriculum is to develop students critical thinking skills. Someone with critical thinking skills will always be ready to face various unclear information and problems and be able to solve them appropriately. This ability is necessary to make the right decisions and provide

original reasoning. Critical thinking can be trained, and mathematics has the ability to develop this skill. In mathematics, critical thinking can enhance creativity through the exploration of new strategies for solving mathematical problems (Su et al., 2015).

The current digital era has brought rapid progress in education, renewal of traditional teaching methods, and improvement of learning experiences (Gunayasa et al., 2023; Mufida & Arfinanti, 2025; Wahyudi & Haryati, 2023). The availability of digital devices and resources, students have easy access to a wide range of information. In addition, digital technology provides opportunities for teachers to create engaging and customized learning situations by combining multimedia elements such as videos, simulations, and virtual reality. According to Sari & Juanda (2023), learning media simplify communication and collaboration between students-teachers, presenting a more interactive and open learning atmosphere. Learning media is one of the most important supporting elements in the achievement of the learning process. Its existence enables interaction between teachers and students, and to help convey lesson material in a clearer and more interesting way. Through the learning media, students tend to understand the information conveyed more easily, both directly from the teacher and from the use of the media itself (Huda & Mulyani, 2024). As a result, teachers are required to take advantage of technological developments as a means to build students interest in learning in order to develop critical thinking skills. This is relevant at the secondary school level, where the use of technology in learning is a must.

Expanding research efforts and literature exploration on technology-based media that supports critical thinking in education is necessary. This enables a systematic literature review to provide an overview of technology-based media that is suitable for critical thinking skills in mathematics learning. The systematic literature review currently being conducted focuses on trends and the types of technology-based media used to support critical thinking skills. Previous research on critical thinking skills focused on the use of android-based science learning media in improving the critical thinking of elementary school students by using a systematic literature review of 306 publications published between 2018 and 2022 to measure aspects based on year of publication, field of study, type of document, and keywords. Through in-depth data analysis, critical thinking skills in education, mainly in science learning, were discussed. However, previous studies have not provided information related to learning media used in mathematics learning to support critical thinking. This study specifically provides an overview of the technology-based media that have been used or studied by researchers over the past ten years in supporting critical thinking skills in mathematics learning. On the other hand, related to the current rapid technology advances in learning, schools now have smart tv that support learning. This makes it possible to explore in greater depth the technologies that support students critical thinking skills. Therefore, the researchers conducted a comprehensive and up to date systematic literature review to inform the latest research findings on the use of technology-based media that sanction students critical thinking skills, focusing on mathematics learning.

METHOD

This study used the systematic literature review (SLR) method to specify, consider, and synthesize findings from previous studies relevant to the topic of learning media technology that supports critical thinking. The systematic literature review was conducted systematically through several stages to ensure that the resulting literature review was comprehensive, reliable, and replicable. According to Halimah & Dewi (2023), the systematic literature review method includes steps such as planning, implementation, and reporting of literature reviews with the

aim of answering the main questions in this study. However, according to Zawacki-Richter et al., (2020) the stages of research using the systematic literature review method can be illustrated in the following chart.

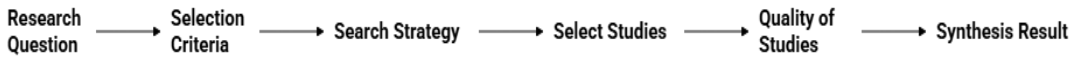

Figure 1. Procedure of SLR

This method was chosen to facilitate understanding of the scope of the review and to systematically answer questions according to a structured protocol to avoid subjectivity in the conclusion making process. Through this method, researchers can provide more comprehensive knowledge regarding mathematics learning technology media to support critical thinking skills in greater detail. The systematic literature review procedure described above consists of six main stages that are interrelated. Each stage is designed to ensure that the literature review process is conducted in an orderly and accurate manner. The stages are as follows:

1. Research Question

The first stage begins with formulating clear and specific research questions so that the focus of the study can be determined from the outset. As explained by Zawacki-Richter et al., (2020) well questions will be very helpful in the literature search process and in selecting variables for analysis. This stage is intended to identify specific literary characteristics that can provide meaningful knowledge about the research subject (Kania & Kusumah, 2025). As presented in the following table 1.

Table 1. Research Questions

Measure	Research Questions
Technology media supports critical thinking	How does technology-based media research in mathematics learning support the development of critical thinking skills based on the year of publication? What is the level of education? What mathematical material was used in the research? What research methods are most commonly used? Which regions in Indonesia are conducting research? What technology-based media was used to support students critical thinking skills in mathematics learning?

2. Selection Criteria

After the question was established, the next step was to determine the inclusion and exclusion criteria. This included the publication time frame, which was between 2016 and 2025, and the type of scopus indexed journals. The aim was to ensure that only articles that were truly relevant were included in the study. This systematic literature review deliberately focuses on searching scopus data because it covers a wide international scope and the most reputable at the global level so that the quality of the articles is guaranteed. Scopus and similar databases can provide many benefits in terms of broad search coverage, higher accuracy of results, and better search capabilities (Gusenbauer & Haddaway, 2021).

3. Search Strategy

In this stage, the researcher searched the literature using predetermined keywords directly related to critical thinking and technology in mathematics education. Logical operators such as AND and OR were used to ensure a comprehensive search,

encompassing all relevant studies exploring the intersection of technology, critical thinking, and mathematics learning. This step is important so that relevant studies can be collected completely (Zawacki-Richter et al., 2020). As presented in the following table 2.

Table 2. Keywords String

Keywords String	Scopus
critical thinking OR technology media	180
critical thinking OR technology media OR mathematics learning	121
"critical thinking" OR "higher order thinking" OR "critical skill" OR "analytical thinking" OR "reasoning skill" AND "media" OR "technology" OR "digital tool" OR "educational media" OR "learning media" OR "instructional media" OR "multimedia" OR "game-based learning".	36
TOTAL	**337**

4. Select Studies

At this stage, methodology techniques are efficiently developed to select and to evaluate relevant studies in order to build a comprehensive framework that includes search criteria and procedures. The aim is to ensure that the articles meet the established selection criteria. This process is carried out systematically so that only articles of good quality are included in the analysis stage (Handayani & Rahayu, 2020). The checking process is carried out in two stages about the title and abstract, which are first examined to determine whether the study is relevant to the research. Furthermore, software such as covidence is used to assist authors in checking relevant studies based on the Criteria & Exclusion Reasons. These requirements include the components shown in the following table 3.

Table 3. The Criteria of Search Items

Criteria	Included	Excluded
Publication time	$2016 - 2025$	before 2016
Document type	Article	Book, chapter books, procedings, etc
Source type	Journal	Non-journal
Languange	English	Non-english
The topic of the research	Focus on mathematics education, technology, critical thinking	Not focus on matheatics education, technology, critical thinking

5. The Quality of Studies

The fifth step is to evaluate the quality of each study. The aspects assessed include the clarity of the research methods, the media used, and the extent to which the research results can be trusted. This evaluation is important so that the synthesis is based only on truly credible sources (Fernanda et all., 2024).

6. Synthesis Result

The final stage is to compile and categorize the selected research results. This categorization is based on themes, emerging trends, or approaches used by each study. This synthesis will later become the basis for drawing conclusions and recommendations for the direction of future research (Nareswari & Arfinanti, 2023). The article selection process is presented in a prism diagram as shown below.

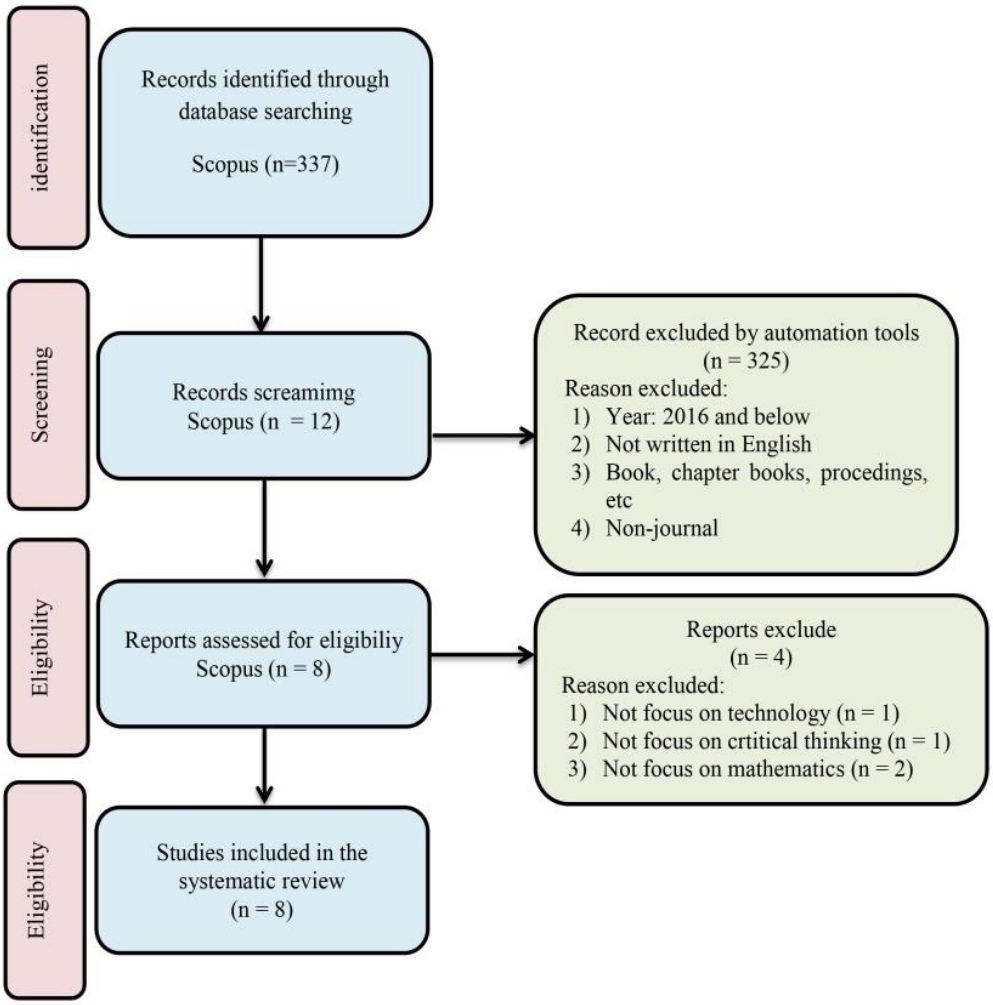

Figure 2. Diagram of technology-based media prism that support critical thinking skills

This systematic literature review has incorporated three important sections, namely identification, screening, and eligibility, into the systematic literature review search model, using thinking as a theoretical structure. The next step is to extract high quality data from previously evaluated publications, with a particular emphasis on the important elements found in each work, namely the abstract, findings, and discussion. Furthermore, the screening process was adapted to support technological media, focusing on critical thinking and mathematics learning. After the data has been extracted, a comprehensive analysis is carried out. Next, codes are developed to analyze the content of 8 articles.

RESULT AND DISCUSSION

The search of articles in the scopus database for the period 2016-2025 using the predetermined keywords yielded 337 articles. The articles found were then selected according to inclusion and exclusion criteria, resulting in a total of 8 articles. The results of the article review were then processed based on the publication year, level of education, type of research, location of research, teaching materials used, and media that support critical thinking skills in mathematics learning.

Based on Publication Year

Based on the results of a review of 8 articles focusing on how articles published between 2016 and 2025 that focus on research related to technology based media in mathematics learning that supports critical thinking skills can be seen in the following figure.

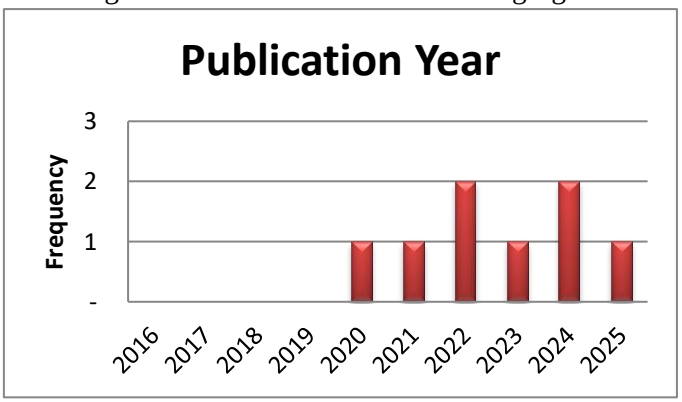

Figure 3. Number of Articles by Publication Year

Based on the presentation in figure 3 above, it shows that the research trend each year is quite low based on the data obtained, where for 2022 and 2024 there are 2 articles each, for 2020, 2021, 2023 and 2025 there is 1 article each, and from 2016 to 2019 there are no related article. The dominant trends in 2022 and 2024 indicated an academic response to post pandemic digital disruption and the integration of technology in education. However, the stagnation in the number of articles indicates that the development of specific digital media to stimulate critical thinking is slower and quite worrying. This certainly requires further study, given the high demand for critical thinking skills in the 21st century. Digital learning media is very relevant in supporting the demands of the current era because it has characteristics that suit the learning styles and to need of modern students (Irawan et al., 2025). According to Ochildinovna (2024) critical thinking skills applied in the classroom can benefit students in improving their future quality of life. These skills enable them to deal with problems systematically, make the right decisions, communicate effectively, and adapt to changing situations.

Based on Education Level

A review of articles related to the use of technology-based media that supports critical thinking skills based on education level is presented in the following figure 4.

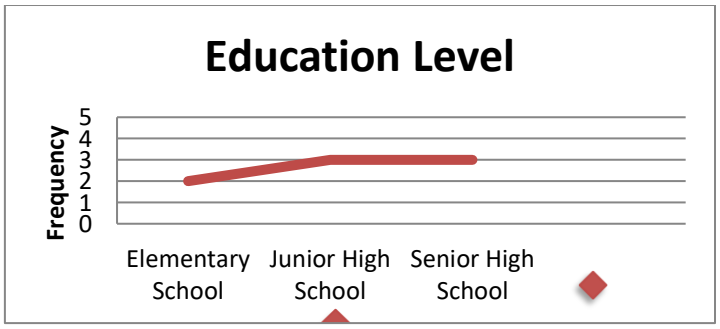

Figure 4. Based on Education Level

Based on figure 4, studies on technology-based media that support critical thinking skills in mathematics learning have been conducted at various levels of school education, namely elementary school, junior high school, and senior high school. However, based on the

image, it can be seen that there is a dominant similarity, namely that studies have been conducted at the junior high and senior high school levels, but the number of articles studied at the elementary school level is not significantly different. This is likely because at the high school levels, students critical thinking skills are already emphasized, and there is a need for supporting media to help students critical reasoning skills. This is consistent with findings by Noor et al., (2025) states that the results of the analysis of 21 articles producing 23 data points in accordance with the inclusion and exclusion criteria concluded that the use of digital based learning media has a positive and significant effect on students mathematical critical thinking skills. In addition, the formation of critical thinking begins gradually from elementary school to higher levels Aizikovitsh-udi & Cheng (2015), this illustrates that adjustments to technology-based media also need to be made starting at that level so that the differences in the use of technology-based media from the image above are not significantly different. This illustrates that adjustments to technology-based media also need to be made starting at that level so that the differences in the use of the technology media from the image above are not significantly different.

Based on Learning Material

Details of learning studies based on education levels from elementary school to senior high school are presented in the following table.

Table 4. Based on Learning Material

Learning Material	Frequency
Algebra	4
Geometry & Trigonometrt	1
Others (GeoGebra Implementation, no specific material)	3

According to table 4, the results show that the branch of mathematics most widely used in research related to media technology that supports critical thinking skills is algebra, with 4 articles. There are 3 other articles, which do not specifically describe the material used, and the teaching materials that are still rarely used in research are geometry and trigonometry. This can be a consideration for future researchers to expand their research on other materials in mathematics learning.

Based on Research Method

Details of research method related to technology-based media in mathematics learning that supports critical thinking skills are presented in the following figure.

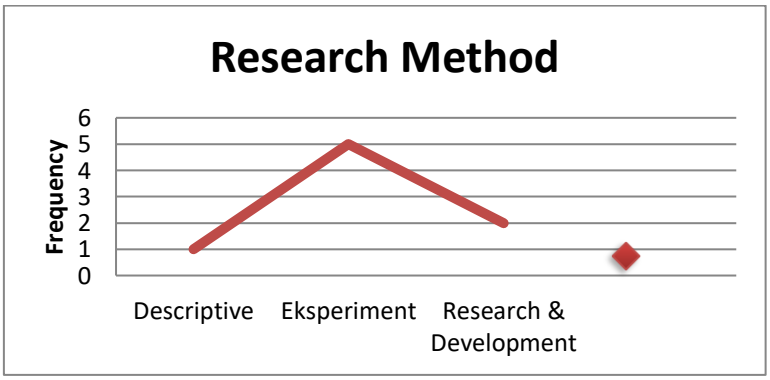

Figure 5. Based on Research Method

As a result in figure 5, research on technology-based media in supporting critical thinking skills mostly used the experimental method in 5 articles, which tested whether the media used supported critical thinking skills and whether there were differences before as well as after the use of technology-based media that affected critical thinking skills in mathematics learning. Furthermore, there are 2 articles on research and development, where of 1 article adopts the ADDIE model and 1 article used the Borg and Gall model. In addition, there is 1 article on descriptive research, which examines how students critical thinking skills are formed through the use of technology-based media in the learning process.

Based on Research Location

The distribution of studies based on coverage of various regions in Indonesia is presented in the following table.

Table 5. Based on Research Location

Research Location	Frequency
Jawa	6
Sulawesi	1
Sumatera	1

The data in table 5 above shows that 6 articles out of the total are concentrated on the island of Jawa, followed by Sumatra and Sulawesi, which have the same number of articles, namely 1 article each. The concentration of research on Jawa indicates an imbalance in digital infrastructure and access to technological literacy in Indonesia. As can be seen, digital infrastructure in Jawa is better than in areas outside Jawa. One of these disparities is that Jawa receives more technological training opportunities than areas outside Jawa. Based on this, further research is recommended in other regions of Indonesia to generate more representative information. This is to make it easier to adapt the technology needed in each region to support critical thinking skills.

Studies discussing technology-based media that support students critical thinking skills in mathematics learning.

Research related to technology-based media that support students critical thinking skills in mathematics learning over the past ten years (2016-2025) shows that MathCityMap application based mathematics learning media with a contextual approach is feasible for to use in improving the critical thinking skills of high school students. This media has been proven to be practical with a suitability rate of 85.78% based on student questionnaires. In addition, this media is considered effective because it produces an n-gain score of 1.17 and has succeeded in improving the critical thinking skills of more than 80% of students. The MathCityMap application helps students formulate, believe in and transmit the right decisions critically from the work on the assignments given in the trigonometry material, where the assignment consists of four parts, namely calculating the height of the flagpole, measuring the length of the ladder to repair the basketball hoop net, calculating the length of the ladder, and measuring the height of the gate of the UPGRIS campus (Buchori & Puspitasari, 2023). In addition, research by Rahayu & Kuswanto (2021) it is suggested that Android-based Carom Games Comic integrated with discovery learning demonstrates critical thinking and mathematical representation abilities in the experiment class with significant improvement.

Critical thinking and mathematical representation skills improved significantly in the experimental class using an Android-based carrom game comic integrated with discovery

learning compared to the control class using PowerPoint. The media with discovery learning was effective in improving students critical thinking and mathematical representation skills, with scores of 0.287 (large effect size) and 0.179 (medium effect size). The media can be used as an alternative learning medium to improve critical thinking and mathematical representation skills. Other media, namely Interactive Digital Worksheets can develop problem solving and critical thinking skills and increase the overall effectiveness of the learning process. This is evidenced by the average post test results of 74.41 for the control group and 81.26 for the experimental group, indicating improvement. Furthermore, collaborative learning on fractions with the aid of interactive digital worksheets effectively facilitated students understanding of the material, significantly supporting critical thinking (Utaminingsih et al., 2024). In line with the e-worksheets in research by Kusuma (2023) specifically designed by integrating critical thinking ability indicators in spatial building material, it obtained results with a very high category in increasing critical thinking ability as seen from the media practicality test.

Research by Setyawan et al., (2024) shows that learning using the GeoGebra integrated project based learning model significantly improves students mathematical critical thinking skills. The data shows that the PjBL model is far superior to expository techniques in terms of improving students average mathematical critical thinking skills. Learning becomes more active, dynamic, and participatory when GeoGebra is combined with the project based learning (PjBL) model, where students are directly involved in research, modeling and presenting their work. The interactive elements of GeoGebra and the PjBL method have been shown to strengthen conceptual understanding and sharpen students critical thinking skills. Research shows by Supratman & Iswatiningsih (2025) that using GeoGebra through in deep learning of geometry can improve students critical thinking skills. GeoGebra's advanced visualization helps students engage actively, motivate, and think effectively, encouraging the development of critical, independent, and creative thinking in a deeper understanding of mathematical concepts. Next media,

The Articulate Storyline-based Smart Math learning, significantly improves critical thinking skills and independence among fifth grade elementary school students. The main findings include of 32.5% increase in critical thinking skills in the experiment group, significantly outperforming the 12.8% increase in the control group. Students showed improvements in analysis, evaluation, inference, and reasoning, enabling them to solve mathematical problems more systematically and effectively (Setyawan et al., 2024). Research by Latipah et al., (2020) use of Augmented Reality (AR) based media can create an interactive learning atmosphere, engage students in the learning process, make it easier for students to understand integers, and provide opportunities to solve problems related to everyday life.

The use of AR learning media for integer material is very effective in improving students critical thinking skills. Other media is YouTube, where the use of online learning media influences students interest in learning mathematics, and its use also affects students critical thinking skills. Using YouTube can construct a better understanding than without YouTube. It increases student interest because they directly see instructions on the material that aligns with the needs of the current digital era. However, this study indicates that the influence of YouTube online learning media is low, both in terms of interest and students critical thinking skills (Jamil et al., 2022). This is based on the results showing that the media significantly affects students critical thinking skills, but its impact and effectiveness are not significant or the low category. This effect is generally seen in the YouTube system, which provides insufficient feedback on learning, focusing solely on viewing activities without direct interaction.

The last research by Pratiwi et al., (2022) it was found that Assisted Video Animation showed quite good results through the application of the Indonesian Realistic Mathematics Education Approach (PMRI) and Lesson study for learning community (LSLC) namely Plan or planning stage, Do or implementation, See or observation and reflection, and Redesign by animated videos. Although this ability has emerged, not all students achieved maximum scores, with the analysis indicator being the most frequently appearing, while the interpretation indicator was the least frequently appearing. The presence of animated videos through the PMRI and LSLC approaches helps teachers develop students critical thinking skills during the pandemic when students focus on online learning.

Based on the above research results, several the technology media were found to be used, each tailored to specific needs, so that no single medium appeared dominant in terms of usage, as in Salsabila et al., (2024) states that media is also designed to support differentiated learning that adapts to the needs of each student.

This finding shows that media should be designed to support the skills needed today, not only through the material presented but also how the media supports students abilities, especially their critical thinking skills. The media allows for dynamic visualization that helps students identify problems, conduct investigations, and to draw the logical conclusions. In addition, video based media and interactive simulations provide an engaging learning environment, which indirectly motivates students to think critically in solving problems. On the other hand, integration with learning models helps students to better understand and practice their critical thinking skills.

CONCLUSION AND SUGGESTIONS

Studies related to technology media that support critical thinking skills in mathematics learning have received relatively little attention. In previous years, from 2016 to 2019 no related studies were found and 2022 and 2024 at most two articles were published. Most of this research was conducted in Jawa, with fewer studies conducted outside Jawa, particularly in Sumatra and Sulawesi. Most of the research was conducted at the junior high and senior high school levels, where critical thinking skills are already focused on due to the more complex material and the widespread use of mathematics topics in algebra. This was followed by trigonometry and geometry, with three articles. These findings provide some information regarding technology-based media used in mathematics learning, such as interactive Interactive Digital Worksheets, Android-based Carom Game Comics, YouTube, the MathCityMap application, Assisted Video Animation, Augmented Reality, Smart Math learning media based on Articulate Storyline, and GeoGebra.

These findings certainly warrant further attention to increase research and development related to technology media that support critical thinking skills, particularly in mathematics, amidst the pressing need for educators to utilize technology. Furthermore, educators must innovate by developing learning media based on mathematics learning needs, both in terms of individual critical thinking indicators and rarely used materials.

LIMITATIONS

While this study provides valuable insights into the role of technology in supporting critical thinking skills in mathematics learning, several limitations warrant consideration. The use of only eight articles and the restriction to English-language literature may introduce linguistic and cultural biases, making the findings less representative of the global context. The research database is limited, and the researchers referenced a few articles with similar themes as initial generalizations. Future research should expand the scope of data sources to address the inherent limitations identified in this SLR.

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