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THE CRITICAL THINKING SKILL OF MATHEMATICS EDUCATION STUDENTS DURING PANDEMIC: A REVIEW

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Absract: Learning in higher education is expected to be able to optimize students' critical thinking skills. However, learning mathematics during the pandemic encountered many obstacles affecting students' critical thinking skills. Furthermore, even before the pandemic occurs, mathematics education students still face difficulties optimizing their critical thinking skills. This study aims to analyze the level of critical thinking skills of mathematics education students during the pandemic and the learning models that can be applied to improve these abilities through online learning. The method used is a systematic literature review (SLR) on Google Scholar, ERIC, Science Direct, and DOAJ databases restricted for publish year in 2019-2022. The findings are the level of critical thinking ability of mathematics education students varies depending on the course used in the research. Secondly, several models or learning media can be applied in online classes during the pandemic to improve the critical thinking skills of mathematics education students. Some of them are a combination of Google meet with scaffolding-based online Geogebra, E-Academic based on collaborative learning, PDEODE strategy. The use of Geogebra Javascript, Realistic Mathematics Education approach, Problem Based Learning, using e-books instead conventional books and articles in newspapers as learning media.

Keywords: *Online Learning, Critical Thinking, Preservice Mathematics Teacher, Covid-19 Pandemic*

INTRODUCTION

Pandemic has changed the face of higher education [1]. Initially, mathematics learning was mostly done face-to-face. However, after the pandemic occurred, mathematics learning was generally done online. There were several obstacles encountered during online learning. These obstacles include lack of interaction with other students, many distractions at home [2], lack of attention, and lack of understanding of the material given in the course [3]. Furthermore, students believe that mathematics lessons are better when they are taught face-to-face with direct interaction from the teacher and between students [4].

Learning in higher education is expected to improve student critical thinking skills [5]. This skill is one of the skills needed in the labor market [6]. This ability is useful to help someone make decisions and engage in social, political, business, and other relationships [7]. However, the obstacles in online learning also could affect the achievement of students' critical thinking skills [8]. Many scholars agree that critical thinking is difficult to accomplish [9].

Before the pandemic, mathematics education students still face some obstacles in developing their critical thinking skills when solving mathematical problems [10]. This study is in line with As'ari, Mahmudi, and Nuerlaelah found that most prospective mathematics teachers' critical thinking dispositions are at the non-critical thinker level [11]. Therefore, it is necessary to have alternative learning solutions that can be used to foster the critical thinking skill of mathematics education students.

It is a challenge to maintain the critical thinking skill of mathematics education students during the pandemic. Conducting a review of the critical thinking skills of mathematics education students during a pandemic and the learning model that can be carried out to optimize the critical thinking skills of mathematics education students will be important things to study. This study aims to investigate critical thinking skills to investigate the level of critical thinking skills of mathematics education students during the pandemic and the learning model that can be applied during the pandemic to stimulate the critical thinking abilities of mathematics education students. The results of this study are expected to be the basic consideration for choosing the model of effective learning to foster critical thinking skills during the pandemic.

RESEARCH METHODS

This research is a *systematic literature* review SLR. The systematic literature review contains explicit and detailed methods for identifying, selecting, and assessing the quality of individual studies and overall evidence but does not incorporate the overall study results [12]. This research uses published studies from Google Scholar, Educational Resource Information Center (ERIC), Science Direct, and Directory of Open Acces Journal (DOAJ) in English and Bahasa. Since the pandemic occurred in 2019, the systematic search was restricted to articles published in 2019-2022.

A systematic search in Google Scholar, ERIC, Science Direct, and DOAJ was carried out

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in March 2022. The systematic search is presented in Figure 1.

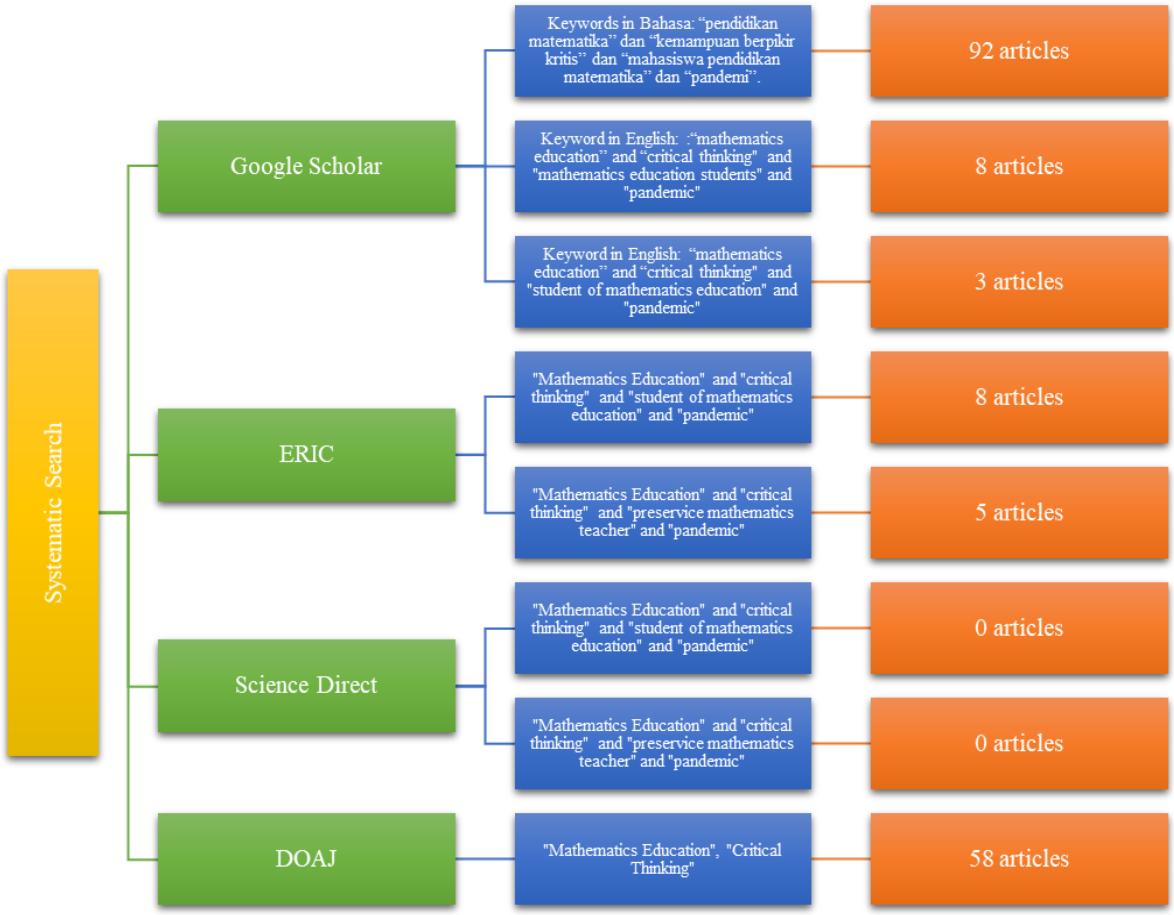

Figure 1. The Systematic Search in Google Scholar, ERIC, Science Direct, and DOAJ

Based on Figure 1, for the Google Scholar database, we used keywords both in Bahasa and English. In Bahasa, the keywords were "pendidikan matematika" dan "kemampuan berpikir kritis" dan "mahasiswa pendidikan matematika" dan "pandemi". There were 92 articles generated from this search. For English keywords, we used various keywords. First, we used "mathematics education" and "critical thinking" and "mathematics education students" and "pandemic" in Google Scholar. There were eight articles generated from those keywords. We also used "mathematics education" and "critical thinking" and "students of mathematics education" and "pandemic" in Google Scholar. From those keywords, three articles were obtained. For ERIC, we did twice systematic research. First, using keywords "Mathematics Education" and "critical thinking" and "student of mathematics education" and "pandemic", eight articles were returned. Second, using "Mathematics Education" and "critical thinking" and "preservice mathematics teacher" and "pandemic", five articles were obtained. We used the same keyword as in the ERIC database for the Science Direct database, but 0 articles were founded. Moreover, for DOAJ, keywords "mathematics education" and "critical thinking" were used. There were 58 articles obtained.

Total 175 articles were generated from systematic search in Google Scholar, ERIC, and Science Direct. After selecting the articles from three databases, the authors read the articles and determine the relevant articles to the aim of this study. There were 14 articles which relevant and 161 articles which not relevant. The article was considered irrelevant if the research subject is not students of mathematics education or preservice mathematics teachers. The main topic discussed in the research was not about critical thinking. The findings in the article do not discuss the level of critical thinking skills or learning models that can improve the critical thinking skills of mathematics education students. Furthermore, 14 relevant articles used research subjects from several countries. There were 13 articles whose mathematics education students in Indonesia as the

subject of research and 1 article with mathematics education students from Turkey as the research subject.

RESULT AND DISCUSSION

The level of critical thinking of mathematics education students during the pandemic

The study of Riayuliatun and Sutarni had analyzed students' critical thinking in solving problems in the Group Algebraic Structure course during the Covid-19 Pandemic. The research was conducted in one of the higher institutions in Surakarta. The type of research was qualitative research with 30 participants. This research used four indicators of critical thinking. Understanding what is known and asked in each problem, writing the concept used in solving each problem, formulating problems into mathematical models, solving problems by principles and mathematical models, and being able to draw conclusions from each problem and provide further explanation in solving each problem. The result of the study is presented in Figure 2.

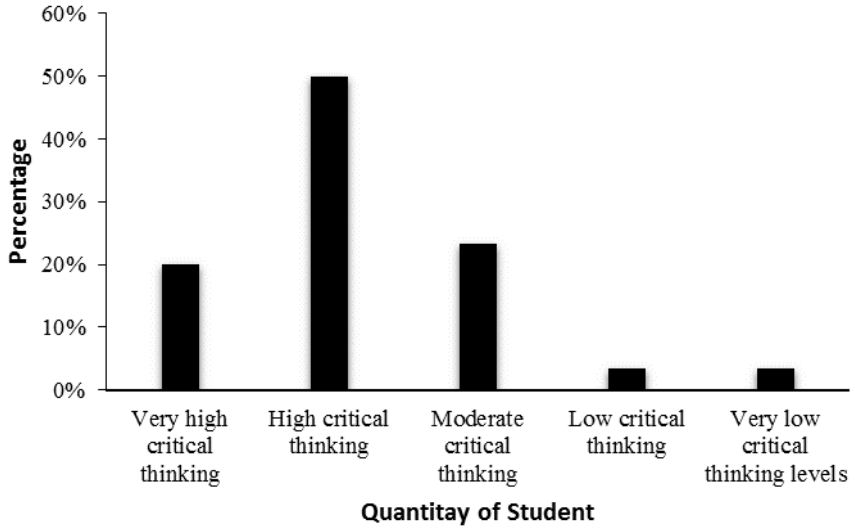

Figure 2. The Result of Study About Students Critical Thinking in Solving Problems in The Group Algebraic Structure Course

In figure 2, students with very high critical thinking levels were 20%, high critical thinking levels were 50%, moderate critical thinking levels were 23.33%, low critical thinking levels were 3.33%, and very low critical thinking levels were 3.33% [13]. It can be concluded that half of the participants had high critical thinking, and less than 10% of students had low critical thinking. Students' critical thinking skills are still relatively good even though the pandemic is ongoing.

The study from Rialiyatun and Sutarni is in line with Sulistyorini and Napfiah. Their study with three participants from mathematics education students in one of the universities in Malang found that all subjects showed high critical thinking skills [14]. Another study with three mathematics education students in one of the universities in Surabaya also resulted in the critical thinking of prospective mathematics teacher students in proving the geometry theorem is very good [15].

The study from Rialiyatun and Sutarni contrasts with the study from Chasanah. Chasanah held a study on the first-year students of the Mathematics Education Program in one of the higher education institutions in Magelang on Differential Calculus course. The researcher applied cognitive growth learning model to identify the students' mathematical critical thinking skills. This study used four indicators to measure students' critical thinking, namely analyzing arguments, evaluating information, synthesizing evidence, and drawing a conclusion. The result of students' critical thinking skills presented in Figure 2.

Figure 3 shows that 30 % of students were able to analyze arguments, and only 16,7% of them were able to conclude every problem correctly [16]. The result shows that less than 50% of students were able to achieve four indicators of critical thinking. It can be concluded that the critical thinking skill of the student is still weak.

Critical thinking skill is one of the high-order thinking skills [17]. Another study from Payadnya dan Suwija also found that mathematics education students have low high order thinking skills in the method of statistics course [18]. That phenomenon occurs due to the reduced time for students to interact during learning in the pandemic era, which also causes a lack of time to exchange understanding and knowledge [19]. Yet, interactions involving conflicting viewpoints

promoted more discussion among students, so that able to enhance critical thinking skills [20].

According to several studies from researchers [13-16][18], the levels of critical thinking of mathematics education students are different. It is probably due to the different courses used in research, the number of students used in research, and the indicator used to determine students' critical thinking.

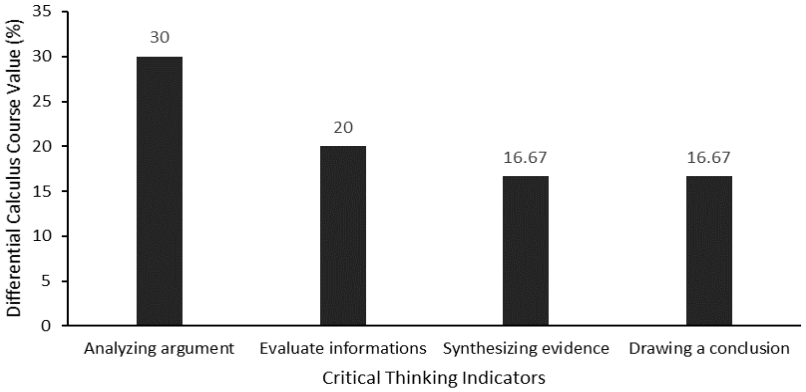

Figure 3. The result of critical thinking skills of students in Differential Calculus Course

The learning instructional which stimulates the critical thinking skill of mathematics education student

A quasi-experimental study was conducted on mathematics education students Faculty of Teacher Training and Education. The subjects were selected using random cluster sampling. Twenty-three students from the experiment class studied using Google meet and online Geogebra based on scaffolding, and 23 students from the control class did not study using Google meet and online Geogebra based on scaffolding. The study found that students' critical thinking ability was significantly higher than students who did not study using Google meet and online Geogebra based on scaffolding [20].

Another quasi-experimental study on mathematics education students used random cluster sampling on geometry courses. There were two classes: the experimental class consisted of 31 students, and the control class consisted of 30 students. The experimental class was given an E-Academic integrated online-based collaborative learning model, while the control class was given an online-based direct learning model. This research showed that the experimental class got better critical thinking ability than the control class [21].

For the calculus course, a study was conducted to develop Geogebra Javascript to enhance prospective teacher reasoning ability. The research conclusion was that learning using Geogebra Javascript could improve reasoning ability than learning without Geogebra script. Since right logical reasoning is the ability involved in critical thinking [22], this media can be an alternative tool to improving critical thinking skills [23]

In the Environmental Knowledge course for mathematics education students, the PDEODE (Predict-Discuss-Explain-Observe-Discuss-Explain) learning strategy was implemented for students with different cognitive styles. The cognitive style in that research referred to reflective and impulsive cognitive style. Reflective students implement an analytic process and are cognitively mature [24]. They tend to answer questions slowly but carefully, and their answers tend to be correct. At the same time, impulsive students are students who have characteristics in solving questions fast but are less accurate, and the answers tend to be wrong [25]. The study found that the PDEODE strategy can be applied in virtual learning to optimize critical thinking for students with reflective and impulsive cognitive styles [26].

A study investigated student critical thinking based on their learning style in terms of learning style. Data for the study were taken from 56 students of Mathematics Education in one of the universities in Semarang. There are three types of learning styles: visual (learning by sight), auditory (learning by listening), and kinesthetic (learning with motion and emotion) [27]. The result of the study was problem-based learning is considered adequate for developing mathematical critical thinking ability, especially for kinesthetic learning styles [28].

In the Program Linear course, a classroom-action-research aimed to improve students' critical thinking skills in the Mathematics Education Major through the Realistic Mathematics Education (RME) Approach. The research subject was 37 students of mathematics education from one of the universities in Malang. Based on the results of this study, it can be concluded that the RME

approach was able to optimize students' critical thinking skills [29]

In the Elementary Algebra course, a quasi-experimental study was held to investigate the use of e-books to enhance the critical thinking of mathematics education students. Sample for the study was students, an experimental group using e-books to study, and a control group with lectures using conventional textbooks. The study result was students who studied using e-books achieved higher critical thinking skills than students who studied using conventional books [30]. It is probably because the flexibility of e-books accommodates the mobile lifestyle of our learners [31].

Study of prospective mathematics teacher from Turkey provide newspaper article example as the strategy to empower critical thinking in statistics education course. The research was a case study for four fourth-year prospective mathematics teachers. This study suggested the tasks involving media articles to promote critical thinking in statistic education [32].

There are some learning models or strategies that can be applied to optimize student of mathematics education during this pandemic [20-33]. Google meets and online Geogebra based on scaffolding, given an E-Academic integrated online-based collaborative learning model, PDEODE learning strategy, RME approach, and problem-based learning. Media also contribute to fostering student critical thinking skills, namely, Geogebra Javascript, using e-books instead of conventional books, and using newspaper articles as learning media.

CONCLUSION

The levels of critical thinking of students of mathematics education are different according to the course that becomes research case. Some learning models, strategies, or media can be applied during this pandemic to enhance the critical thinking of mathematics education students. Google meets and online Geogebra based on scaffolding, given E-Academic integrated online-based collaborative learning model, Javascript Geogebra, PDEODE learning strategy, and newspaper article example.

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