META-ANALYSIS: THE RELATIONSHIP BETWEEN SELF-REGULATED LEARNING AND MATHEMATICAL CRITICAL REASONING

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Abstract. *Self-regulated learning and critical reasoning are two important dimensions in government policies to improve the quality of education which is manifested in the form of the Pancasila student profile. These two dimensions are able to describe the character and competencies of students that must be possessed in the Industrial Revolution 4.0. This research is a meta-analytic study that aims to analyze the relationship between self-regulated learning and mathematical critical reasoning abilities. Data were collected through searching scientific articles that have been published in scientific journals and proceedings in the period 2018-2020. There were 10 research samples that matched the exclusion and inclusion criteria. The data were analyzed using the JASP V-0.11. The results of heterogeneity test with a value of Q=111.610 and p=0.001<0.05. The effect size model used was the random effect model. The results showed that the mean effect size was 0.72 in the moderate effect category and the results of the Funnel Plot and Egger's Test with a value of z=1.368 and p=0.171>0.05 indicated that there was no publication bias. In conclusion, self-regulated learning is strongly correlated with mathematical critical reasoning.*
Keywords: *Mathematical Critical Reasoning, Meta-analysis, Self-regulated Learning.*

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Introduction

One of the important educational policies in Indonesia to face the Industrial Revolution 4.0 is strengthening the profile of Pancasila students (Zamjani et al., 2020). There are six main elements characteristic of the Pancasila student profile, namely (a) faith, fear of God, and noble character, (b) global diversity, (c) independence, (d) cooperate, (e) critical reasoning, and (f) creative. The six elements must be seen as aunit that is complementary and related to each other. Education must be able to improve learning outcomes in the form of cognitive and non-cognitive competencies so that each student is able to be competitive at the global level, but still base their behavior on the principles of Pancasila.

Mathematics aims to equip students with reasoning, analytical, logical, systematic, critical, innovative and creative thinking skills, as well as problem solving skills (Fauzan, et al., 2017). Mathematical skills are partof life skills that must be possessed by students, especially in developing reasoning, communication, and solving problems faced in everyday life (Sudiarta & Widana, 2019). Therefore, mathematics must be taught starting from basic education to higher education. Understanding mathematical concepts is the main foundation for students to build logical and systematic thinking skills. The hierarchy of mastery of concepts in mathematics has been organized in such a way that it is able to train logical thinking systematically and regularly in problem solving (Yunita et al., 2020).

Self-regulated learning is an activity carried out by a student to learn more actively that comes from his own desire or intention to achieve an ability or competence to deal with matters related to himself supported by knowledge in determining time, place, rhythm, tempo, method and evaluation of learning carried out by a student. Self-regulated learning shown in the behavior that is responsible for the learning process and results. Students who have self-regulated learning must have several key elements,including awareness of themselves and the situation at hand, as well as the ability to carry out self- regulation, namely regulating their thoughts, feelings, and behavior to achieve learning goals (Rovers et al., 2019). Self-regulated learning has three main elements, namely prior domain knowledge, self-efficacy, and the use of learning strategies. The three elements are positively correlated with students' critical thinking skills in mathematics (Sun, Xie, & Lynley, 2018). Thus, the development of students self-regulated learning should be an important concern for teachers and educational institutions.

There are nine indicators of self-regulated learning, namely: (a) having the initiative to learn, students learn on their own accord without being ordered by others; (b) identifying and determine learning needs independently; (c) setting learning targets and objectives, so as to determine the stages of the learning process to be carried out; (d) monitoring, regulating, and controling learning progress, as a form of self-evaluation of progress made it has achieved; (e) having the ability to see difficulties as challenges, students do not easily give up when facing learning difficulties, on the contrary, they are more enthusiastic to find the right solution; (f) seeking and utilizing relevant sources, is a form of independence to solve problems; (g) choosing and applying appropriate learning strategies, (h) evaluating learning processes and outcomes, and (i) having self-efficacy (Asmar & Delyana, 2020).

Reasoning is an activity or thought process to make conclusions or develop new statements based on previous statements where the truth has been proven (Fajriah, et al., 2019). Critical reasoning is the ability of students who are able to see things from various perspectives and are open to new evidence. To achieve this ability, students must be able to think systematically and scientifically, conclude from existing facts, and solve problems first (Widana, 2020). Several elements must be met to achieve this profile, including being able to obtain and process information and ideas, analyze and evaluate reasoning, reflect on thought processes, and make decisions (Hobri et al., 2020)). Parenting is one of the dominant factors that affect good critical reasoning abilities. Democratic parenting is the dominant factor that is able to build critical reasoning because it provides space for students to develop self-regulated learning (Boobphan et al., 2021).

Mathematical critical reasoning includes the ability to think critically and creatively so that it can be used to solve problems (Jablonka, 2020). Critical thinking is an individual's mental activity to make decisions in solving problems faced with various information that has been obtained through several categories (Aini et al, 2019). Critical thinking is a systematic thinking activity that allows a person to formulate and evaluate their own beliefs and opinions (Seventika et al., 2015). So, students in critical thinking use reasonable thinking to decide what to do according to their intellectual abilities. Creative thinking generally involves higher order thinking skills. Creative thinking is related to novelty that comes from one's innovation and creativity. Every individual has the ability to think creatively, therefore it is very important for teachers to develop factors that can improve creative thinking skills (Cenberci, 2018).

The characteristics of critical mathematical reasoning include: (a) interpretation is the ability to understand and express the meaning of a situation, data, judgment, rule, procedure, or various criteria; (b) analysis is the ability to clarify conclusions based on the relationship between information and concepts, with the questions in the problem; (c) evaluation is the ability to assess the credibility of a statement or other representation of someone's opinion or judge a conclusion based on the relationship between information and concepts, with the questions in a problem; (d) inference is a person's ability to identify the elements needed in making rational conclusions, by considering information relevant to a problem and its consequences based on available data; (e) explanation is a person's ability to state one's reasoning when giving reasons for justification of a proof, concept, methodology, and logical criteria based on existing information or data, where this reasoning is presented in the form of an argument (Lestari & Jailani, 2018).

Students who have critical reasoning are able to understand the case at hand, conclude what is given to the case, know how to use information to solve problems, and be able to find relevant sources of information to support problem solving. In the context of problem solving, mathematical critical reasoning consists of several stages containing several indicators. The stages of mathematical critical reasoning are formulated as follows (Biagioli, 2020).

Table 1 **Mathematical critical reasoning stages and indicators**

No.	Stages	Indicators
1.	Basic clarification	a. Analyzing a given situation b. Formulating questions c. Choosing a problem solving strategy
2.	Bases for the decision	a. Choosing information that is relevant to the problem b. Evaluating the credibility of the information obtained c. Analyzing the suitability of new information with previously owned information
3.	Inference	a. Making deductions and evaluating deductions b. Making inductions and evaluating inductions c. Evaluating and formulating conclusions
4.	Advanced clarification	a. Defining and formulating concepts b. Identifying assumptions
5.	Supposition and integration	a. Predicting, formulating hypotheses b. Blending, combining

Many correlational studies have been conducted relating to self-regulated learning and mathematical critical reasoning. However, the magnitude of the correlation between the two variables varies with the number of samples, resulting in various conclusions. This study aims to analyze the correlation of self- regulated learning and mathematical critical reasoning sourced from published journal articles and proceedings. The results of this study can provide answers to the doubts that arise due to the various conclusions obtained, regarding the correlation between self-regulated learning and mathematical critical reasoning.

Method

This study is a meta-analysis research using the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) method which is carried out systematically and analyzed quantitatively to obtains accurate conclusions. This meta-analysis research needs to be carried out because of the fact that there is no research that is free from errors in research even though researchers have tried to minimize errors in research using various statistical controls. This research was conducted from July to August 2021 in Denpasar. The steps of meta-analysis research can be grouped into 3, namely: (1) formulating research questions and collecting research results as meta-analysis material, (2) calculating effect sizes, and (3) compiling reports on analysis results (Retnawati et al., 2018).

Population were journal articles and proceedings that are similar and relevant to the title of research on the relationship between self-regulated learning and mathematical critical reasoning and have been published. Research data search using Google Scholar, SINTA, and DOAJ databases. The flow of browsing samples of articles and proceedings can be described as follows.

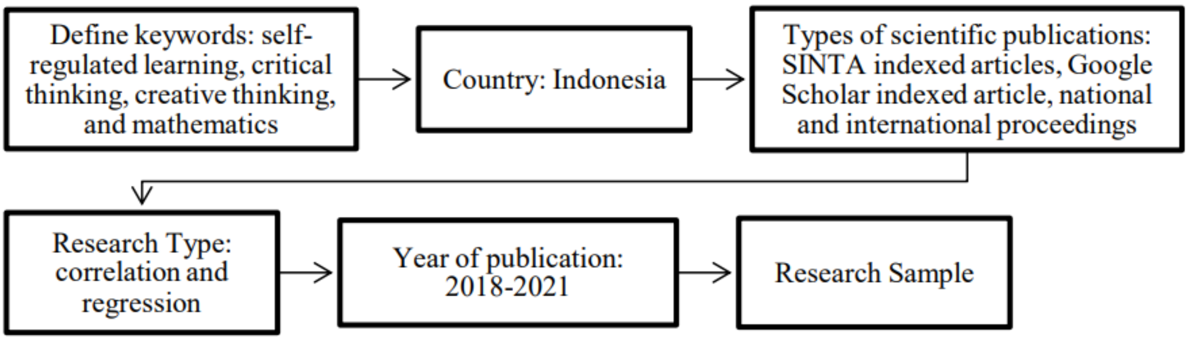

Figure 1 **Research Sample Tracing Flow**

The research data were processed and analyzed using the JASP V-0.11 software (Goss-Samspson, 2019). Furthermore, to determine the effect size merger model, heterogeneity test was carried out. If the p value > 0.05 then the effect size merger model uses a fixed effect model, while if the p value < 0.05 then the effect size merger model uses a random effect model [18].

There are 5 criteria of effect sizes that show the strength of the relationship between self-regulated learning and mathematical critical reasoning, as follows (Glass & Smith, 1981).

Table 2 **Effect Size (ES) Criteria**

No.	Criteria	Effect Size
1.	$ES \leq 0.15$	Can be ignored
2.	$0.15 < ES \leq 0.40$	Low
3.	$0.40 < ES \leq 0.75$	Moderate
4.	$0.75 < ES \leq 1.10$	High
5.	$1.10 < ES \leq 1.45$	Very high

Results and discussion

The results of the search for journal articles and proceedings are carried out in accordance with the steps and criteria that have been set. Data from the search results of journal articles and proceedings based onthe stages carried out are as follows.

Table 3 **Article search results data**

No.	Stages/Criteria	Total
1.	Define keywords: self-regulated learning, critical thinking, creative thinking, and mathematics	2.162
2.	Country: Indonesia	877
3.	Types of scientific publications: SINTA indexed articles, Google Scholar indexed article, national and international proceedings	121
4.	Research Type: correlation and regression	68
5.	Year of publication: 2018-2021	29
6.	Research Sample	10

Table 3 above shows the search result data according to the search stages and criteria that have been set. The number of samples according to the inclusion and exclusion requirements was 10 articles and proceedings, consisting of 5 articles indexed by SINTA, 2 articles indexed by Google Scholar, 1 national proceedings, and 2 international proceedings indexed by Scopus. The selected sample data are presentedin table 4 below.

Table 4 **Research Sample Data**

No.	Research Title	Author	Journal/Proceeding
1.	Hubungan Kemandirian Belajar terhadap Kemampuan Berpikir Kritis melalui Penggunaan *Software Geogebra*	1. Ali Asmar 2. Hafizah Delyana	AKSIOMA: Jurnal Program StudiPendidikan Matematika, Vol. 9, No. 2, (2020), pp. 221-230. SINTA 2
2.	The Influence of Self Regulated Learning to Mathematics Critical Thinking Ability on 3D-Shapes Geometry Learning using Geogebra	1. Destia Wahyu Hidayati 2. Lenny Kurniati	JIPM (Jurnal Ilmiah PendidikanMatematika) Vol. 7, No. 1, (2018), pp. 40-48. SINTA 3
3.	Kemandirian Belajar dan Kemampuan Penalaran Matematis pada Mata Kuliah Analisis Real	ıhamad Farhan	Prosiding Seminar Nasional danDiskusi Panel Pendidikan Matematika, Vol. 6, (2020), pp. 351-358.
4.	Hubungan antara Kemampuan Berpikir Kritis Matematis dan Kemandirian Belajar Siswa SMA Cimahi	1. A'ine Nurfalah 2. Dessy Prihatini 3. Wahyu Hidayat 4. Euis Eti Rohaeti	Journal on Education, Vol. 2, No.1, (2019), pp. 167-172. Google Scholer Indexed
5.	Pengaruh Kemandirian Belajar terhadap Kemampuan Penalaran Matematis Siswa pada Materi Perbandingan	1. Ghina Nurul Zannati 2. Aflich Yusnita Fitrianna 3. Euis Eti Rohaeti	Jurnal Pembelajaran Matematika Inovatif, Vol. 1, No. 2, (2018), pp. 107-112. SINTA 4
6.	Pengaruh Kemandirian Belajar Siswa SMP terhadap Kemampuan Penalaran Matematis	1. Lailatul Fajriyah 2. Yoga Nugraha 3. Padillah Akbar 4. Martin Bernard	Journal on Education, Vol. 1, No.2, (2019), pp. 288-296. Google Scholer Indexed
7.	Pengaruh Kemandirian Belajar Matematik Siswa terhadap Kemampuan Berpikir Kreatif Matematis Siswa SMA	1. Agil Maulana Akhdiyat 2. Wahyu Hidayat	Jurnal Pembelajaran Matematika Inovatif, Vol. 1, No. 6, (2018), pp. 1045-1054. SINTA 4
8.	The Logical Thinking Ability: Mathematical Disposition and Self-Regulated Learning	1. JS Ab 2. G. Margono 3. W. Rahayu	IOP Conf. Series: Journal of Physics: Conf. Series 1155 (2019) 012092 doi:10.1088/1742-6596/1155/1/012092 (Scopus Q3)
9.	The Relationship Between Self Regulated Learning and Mathematical Creative Thinking Ability	1. Runisah 2. F. Gunadi 3. D. Ismunandar	Journal of Physics: ConferenceSeries 1657 (2020) 012004 doi:10.1088/1742-6596/1657/1/012004 (Scopus Q3)
10.	Pengaruh Kecerdasan Emosional dan Kemandirian Belajar terhadap Kemampuan Berpikir Kreatif Siswa Kelas VIII SMP Negeri 2 Kota Jambi	1. Sarifah Yeni 2. Buyung 3. Sri Dewi	Jurnal Pendidikan Matematika Vol. 4, No. 1, (2020), pp. 49-54. SINTA 5

Furthermore, each research sample above recorded statistical data including correlation coefficient (r) and number of samples (N). The complete data is presented in table 5 below.

Table 5 **Sample Statistical Data**

Sample	Correlation coefficient (r)	Number of samples (N)
1.	0.412	40
2.	0.676	11
3.	0.515	25
4.	0.802	40
5.	0.757	30
6.	0.683	32
7.	0.935	31
8.	0.230	355
9.	0.610	56
10.	-0.080	70
	Total	690

Based on the statistical data in table 5 above, heterogeneity test was conducted to determine the effect size merger model. The results of the analysis are presented in table 6 below.

Table 6 **Heterogeneity Test Results**

	Q	**df**	**p**
Omnibus test of Model Coefficien	19.733	1	.001
Test of Residual Heterogenitas	111.610	9	.001

Note. p -values are approximate

Table 6 above shows the value of the Test of Residual Heterogeneity with a value of Q = 111.610 and p = 0.001 < 0.05. It means that the heterogeneity of the data is significant or the data was not homogeneous. Thus, the combined effect size model used was the random effect model.

Furthermore, the effect size of each article and the combined effect are shown by the Forest Plot image as follows.

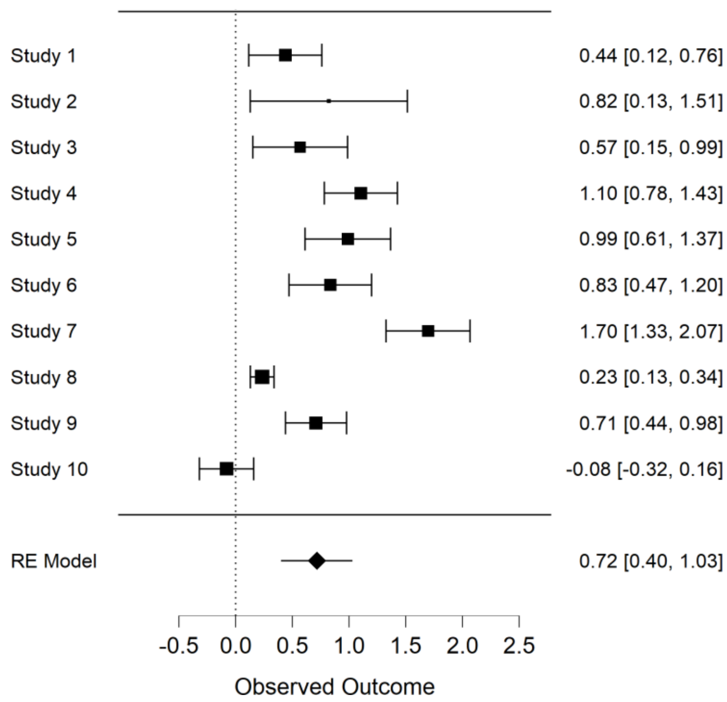

Figure 2 **Forest Plot**

Figure 2 above presents a summary of the effect size meta analysis, on the left shows there are 10 articles analyzed. The forest plot contains various elements, including the lower limit at the left end, the upper limit at the right end, and the middle part contains a square of different sizes whose width indicates the magnitude of the weighting, and the position indicates the location of the effect size of each study. At the bottom, there is a diamond whose area is the area of the total weight of each study, and its positionstates the magnitude of the effect size aggregation. The more to the right of the plot position, the greaterthe value of the effect size of the article. The effect size value seems to vary with the lowest value of - 0.08 in article no. 3 with intervals [-0.32, 0.16]. While the highest effect size value is found in article number 7 of 1.70 with an interval of [1.33, 2.07]. The total effect size value for all articles is indicated by a diamond-shaped box of 0.72 with an interval of [0.40, 1.03].

Hypothesis testing used the Wald test to determine the relationship between self-regulated learning and mathematical critical reasoning. The results of the analysis are presented in table 7 below.

Table 7 **Coefficients**

	Estimate	Standard Error	z	p
intercept	0.716	0.161	4.442	< .001

Note. Wald test.

Table 7 shows that the value of z = 4.442 and p-value = 0.001 < 0.05. Thus, it can be concluded that there is a positive and significant relationship between self-regulated learning and critical mathematical reasoning with an effect size of 0.716 ≅ 0.72 in the moderate effect category because it is in the interval $0.40 < ES \leq 0.75$ [20].

Furthermore, the Funnel Plot and Egger's Test were carried out to test publication bias in this meta-analysis. Publication bias can be seen from the shape of the Funnel Plot, if the Funnel Plot image is symmetrical, it can be concluded that there is no publication bias. On the other hand, if the Funnel Plot image is not symmetrical, it means that there is a publication bias. To increase the precision of the publication bias analysis using the Funnel Plot test, it was tested with the Egger's Test. If the p-value > 0.05 means that the Funnel Plot image is symmetrical, otherwise if the p-value < 0.05 means that the Funnel Plot image is not symmetrical.

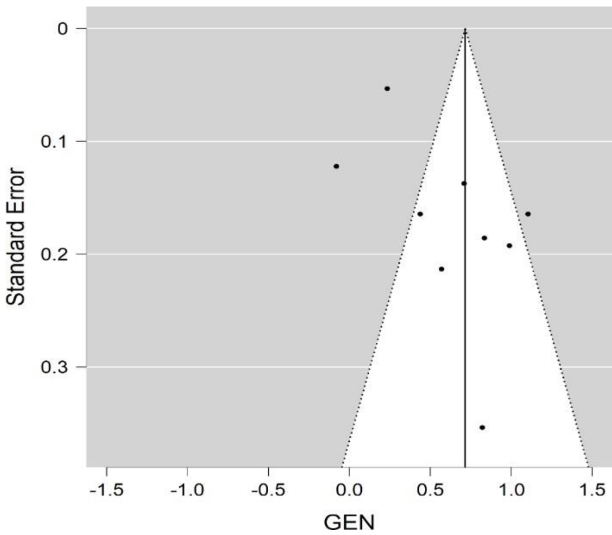

Figure 3 **Funnel Plot**

In Figure 3 above, it can be seen that the Funnel Plot image is symmetrical and the sample points for each article and proceedings are in a triangular area. To increase the precision of the Funnel Plot test results above, the Egger's Test was carried out as follows.

Table 8 **Egger's Test**

Regression test for Funnel plot asymmetry ("Egger's test")		
	z	p
sei	1.368	0.171

In table 8 of the Egger's Test test above, it can be seen that the value of p = 0.171 > 0.05 means that the Funnel Plot image is symmetrical. Thus, it can be concluded that there is no publication bias in this study.

After analyzing 10 research samples, it is seen that sample number 2 has the widest interval with a lower limit of 0.13 and an upper limit of 1.51 which indicates that the level of confidence in the research results is the lowest when compared to other samples. Sample number 2 with an effect size of 0.82 using N = 11 people and the value of r = 0.676 belongs to the category of a very small sample size, but statistically this study is significant. This can be seen from the very small effect size area but its position is to the right of the vertical line. In this study, it was stated that self-regulated learning contributed 45.7% to critical mathematical reasoning, while 45.3% of mathematical critical reasoning is influenced by other variables (Hidayati & Kurniati, 2018).

However, sample number 8 has the shortest range of intervals with a lower limit of 0.13 and an upperlimit of 0.34 indicating the highest confidence in the research results compared to other articles. The effect size value of 0.23 using N = 355 people with a value of r = 0.23 indicates that the effect size is the most precise compared to other samples. Although the effect size value is small, its position is to the right of the vertical line, meaning that statistically the results of the study in this sample are significant. In this study, it is stated that mathematical critical reasoning is not only influenced by self-regulated learning but is also influenced by other variables such as mathematical disposition, which is a positive attitude that views mathematics learning as important and meaningful. Likewise, intellectual intelligence is related to a number of abilities such as the ability to reason, solve problems, and develop ideas. Likewise, self-regulated learning is one of the important variables in learning as a form of responsibility to regulate and strive to achieve better learning outcomes (Ab, Margono, & Rahayu, 2019).

Sample number 7 has the largest effect size value of 1.70 with a lower limit interval of 1.33, an upperlimit of 2.07 with N = 31 people and a value of r = 0.935 and its position is far to the right of the vertical line. This shows that the relationship between self-regulated learning and mathematical critical reasoning is positively and significantly correlated. It was also explained that the self-regulated learning variable contributed 87.5% to critical mathematical reasoning, while 12.5% was influenced by other factors. In this study, mathematical critical reasoning is shown by the different ways students solve problems. Although the solution method is different, the end result remains the same. Creative thinking like this is strongly influenced by students' self-regulated learning (Akhdiyat & Hidayat, 2018).

Sample number 10 has the smallest effect size value of -0.08, has a lower limit of -0.32 interval andan upper limit of 0.16 with N = 70 people, the value of r = -0.08 and its position is slightly to the left of the vertical line. This means that the effect size in this study is very weak in the negligible category [18]. The relationship between self-regulated learning variables and mathematical critical reasoning is a negative correlation. This means that the higher the self-regulated learning, the lower the mathematical critical reasoning variable and vice versa. Only 2.8% of mathematical critical reasoning variables were influenced by self-regulated learning variables, while 97.2% were influenced by other variables not examined in this study. The sample used in this study was class VIII SMPN 2 Jambi City (Yeni, Buyung, & Dewi, 2018).

After conducting a study of 10 articles, it is seen that the number of samples used in each article varies greatly. Likewise, the magnitude of the correlation coefficient between the variables of self- regulated learning and critical mathematical reasoning varies widely with different directions. Of course, the results of these studies are very confusing for readers to make a conclusion on the relationship between self-regulated learning variables and mathematical critical reasoning. The important role of meta-analysis studies is to provide accurate answers to several studies that have been carried out by previous researchers. The meta-analysis study used a much larger sample than each of the studies conducted by previous researchers. In this meta-analysis study, the total number of samples used was 690 people. Thus the precision of effect size is much better compared to each study. The total effect size of the 10 samples analyzed is 0.72, which is in the interval with a lower limit of 0.40 and an upper limit of 1.03 and the direction of positive correlation.

In meta-analysis studies, publication bias can occur due to several factors, including: (1) there are articles that escape the search, (2) there is a tendency for researchers not to publish their research results because the results are not in accordance with the expected hypothesis, theory not supported by research data, (3) journal editorial teams refuse to publish research results that accept the null hypothesis, they tend to want to publish research results that accept alternative hypotheses, and (4) language bias that results in misperceptions or terms that different between researchers. Publication bias may result in inaccurate meta-analysis results. Therefore, to ensure the precision of the meta-analysis results in order to have high accuracy, it must first be proven that the meta-analysis studies are free from publication bias.

The results of the meta-analysis study show that there is no publication bias as evidenced by a symmetrical funnel plot, and supported by the results of the Egger's Test with a value of $z = 1.368$ and a value of $p = 0.171 > 0.05$ meaning that the funnel plot is proven to be symmetrical. Thus, the results of this meta-analysis study are proven to be free from publication bias, so that the findings in this study are unbiased and can provide accurate answers to doubts about the results of previous studies whose results are very diverse both in terms of effect size, length of funnel plot intervals, number of sample, the magnitude of the coefficient and the direction of the correlation.

The relationship between self-regulated learning variables and mathematical critical reasoning has been shown to be positively and significantly correlated. Mathematical critical reasoning is related to higher order thinking skills that involve the ability to analyze, evaluate, and create (Widana, et al., 2019). These abilities can develop optimally if a student has good self-regulated learning (Farhan, 2020). Self-regulated learning is characterized by a strong desire to learn from within a person so that individuals are able to carry out learning management properly according to their initial readiness, motivation, and learning style (Nurfalah, et al., 2019). Mathematical critical reasoning develops along with the development of self-regulated learning, meaning that the better a student's mathematical critical reasoning indicates that the student's self- regulated learning is also higher (Zannati, et al., 2018). Thus, self-regulated learning should be an important concern for teachers and education managers. The relationship between the two variables is in the moderate category, so to equip students with good mathematical critical reasoning, self-regulated learning must be conditioned by teachers in learning management (Runisah, et al., 2020).

Conclusion

Research on the correlation between self-regulated learning variables and mathematical critical reasoning has been done before. Searching was done through Google Scholar, SINTA, and DOAJ obtained 10 samples that met the exclusion and inclusion requirements. Based on the 10 articles used as research samples, each study reports the magnitude of the correlation coefficient and the direction of the relationship varies. Differences in research results in each study are caused by differences in the number of samples used. This difference has an impact on the emergence of doubts about the results of research that has been carried out. These doubts can be answered through meta-analysis research.

The results of the meta-analysis showed that there was a positive and significant relationship between the variables of self-regulated learning and mathematical critical reasoning. This means that if the self-regulated learning variable increases, the mathematical critical reasoning variable also increases. Conversely, if the self-regulated learning variable decreases, the mathematical critical reasoning variable also decreases. This study also proved to be free from publication bias which ensures that the results of this study are unbiased. The number of samples used in this study is much larger than the number of samples for each study. The large number of samples can increase the precision and accuracy of research results. The recommendation that can be conveyed from this research is that students' critical mathematical reasoning can be optimized through increasing students' self-regulated learning in the learning process. The selection of learning models and the use of information technology in learning arealternatives to encourage the improvement of students' self-regulated learning.

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