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A Meta-analytic Review of the Relationship between Mathematics Anxiety and the Mathematical Thinking of Africa Students

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Authors' contributions

This work was carried out by both authors. Author AOM designed the study conception. Both authors collected data. ASB performed the analysis and both authors interpreted the results. Author AOM reviewed the results. Both authors read and approved the final manuscript.

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ABSTRACT

The development of mathematical thinking is a crucial component of Mathematics education. Mathematics is needed for students to have the ability to manage, acquire, and make use of information to survive in competitive, uncertain, and ever-changing circumstances. Mathematical thinking is the primary goal of learning Mathematics. Despite the relative importance of Mathematics, it is highly disheartening to see that, due to Mathematics anxiety, students' mathematical thinking has remained persistently subpar in Africa. Mathematics anxiety, which is the feeling of worry, stress, and trepidation when people engage with mathematics, has long been a topic of concern in education. This study investigated the relationship between Mathematics anxiety and the mathematical thinking of students in Africa. A meta-analysis method was used to

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statistically analyze the results of studies yielding 1789 samples that examined the relationship between Mathematics anxiety and the mathematical thinking of students. These studies were conducted from 2005 to 2021. The findings showed a strong negative correlation between Mathematics anxiety and the mathematical thinking of students in Africa. This study's statistical findings demonstrate how the problem-solving ability of students and the reasoning of students are affected by Mathematics anxiety. These results can help education stakeholders to create environments that will enhance students' mathematical reasoning abilities. This study recommends that curriculum developers should come up with strategies for incorporating fresh perspectives into the Mathematics curriculum that will make it engaging for African students and boost their thinking to become better not just in their academics but also in their day-to-day living.

Keywords: Mathematics anxiety; mathematical thinking; mathematics education; mathematical reasoning abilities; problem-solving abilities.

1. INTRODUCTION

The role of Mathematics in the life of any nation is closely related to its development [1]. No country that seeks to advance scientifically and technologically ignores the importance of Mathematics in its educational system [2]. Students should be able to link and understand mathematical concepts, reason mathematically, communicate mathematically, and solve mathematical problems, according to school mathematics objectives. Mathematics is receiving more and more attention which originates from the fact that without Mathematics there is no science, without science modern technology might not exist, and without modern technology modern society might not be in place. In general, mathematics plays a vital part in many aspects of life, but its greatest impact can be seen in the area of education [3]. All students take mathematics to develop their capacity for analytical, logical, critical, systematic, and creative thought as well as their interpersonal and cooperative skills.

Mathematical thinking is understood as a mode of thinking that is related to mathematical processes [4]. A key objective of education is to develop students' capacity for mathematical thinking and their ability to apply it to problem-solving. In this way, mathematical thinking will help with science, everyday life, technology, and economic growth [5] Mathematical thinking is essential to education. The development of mathematical thinking is a crucial component of Mathematics education. The capacity to answer mathematical puzzles is known as mathematical thinking. To find meaning in some situations, they might need to solve the problem through the use of mathematical context, which might be represented by numbers, symbols, forms, or mathematical concepts [6]. The development of mathematical thinking is the primary goal of mathematical teaching. To solve an issue, a person must first think, critically evaluate the formulation, look at the evidence supporting the formulation, and use problem-solving techniques [7]. Despite the relative importance of Mathematics, it is highly disheartening to see that, due to Mathematics anxiety, students' mathematical thinking has remained persistently subpar most especially in Africa [8]. Daniel (2016) in Ghana found that out of 200 participants, 47.5% have severe anxiety about mathematics which affects their thinking. Also, according to Arigbabu, Tobih, and Arigbabu [9], 72.5% of all participants in the research conducted in Nigerian school have higher levels of Mathematics anxiety and it affects their thinking. Furthermore, Olatunde [10] emphasized that 61.5% of Nigerian secondary school students exhibited greater levels of Mathematics anxiety impeding their thinking ability in Mathematics.

The emotional response of fear, stress, helplessness, and mental disarray when handling a mathematical issue is known as Mathematics anxiety [11]. This unfavorable emotional response or mood can also be directed at Mathematics in general. Thus, it's possible to think of Mathematics anxiety as a bad attitude toward Mathematics or the idea of performing Math [1]. Globally, the issue of anxiety in Mathematics has been a major concern [12] as indicated by Trends in International Mathematics and Science Study (TIMSS) indicated that students in many countries experienced Mathematics anxiety. Mathematics anxiety impacts students at alarming rates, regardless of whether they are in elementary school, primary school, secondary school, or higher institution [13].

Students who are anxious about Mathematics might suffer significant physical, psychological, and academic consequences. Any math-related question might make students who struggle with Mathematics anxiety feel exceedingly anxious. To solve a mathematical problem, some people may experience a variety of negative emotions, including stress, aversion, fear, and, in some cases, pain. This condition is known as mathematical anxiety [3]. Increased student apathy, overcrowded classrooms, student misconduct, budgetary constraints, lack of infrastructural support, expanding administrative loads, demanding or unsupportive parents, inadequate salaries, the negative public opinion are part of what contributes to Mathematics teachers' burnout, and burnout teachers exacerbate Mathematics anxiety in students. Geist [8], Sharma & Rao [14], and Young & Young, [15] among others found that high levels of anxiety have a negative impact on students' working memory, distraction, and reasoning. The fear of Mathematics makes it hard for them to think coherently because Mathematics Anxiety blocks their access to their working memory. According to Vitasari, Herawan, Wahab, Othman, & Sinnadurai [16], students who struggle with Mathematics anxiety are often quite critical of themselves and operate under the damaging and incorrect presumption that being successful at Mathematics means the ability to produce mathematical answers quickly whenever needed either academically or in everyday activity. These assumptions and ideas are rather restrictive. Students suffering from Mathematics anxiety have negative thoughts about the subject and their abilities. Much of this thinking may happen in their heads, making it difficult to understand any mathematical concept [17,18].

Students in a classroom setting develop mathematical thinking that helps them to make the right decision and give systematic, correct, precise, and concise meaning to issues [12]. The capacity to think mathematically is thought to have an impact on how Mathematics anxiety develops. It is believed that students' anxiety about Mathematics would decrease as their mathematical thinking abilities grow [1].

However, many students do not care to think mathematically since they believe it is very difficult to do and they concluded that it is not important to their individual growth [19]. Problem-solving offers several chances for the development of mathematical thinking and Mathematics teachers can design lessons to foster Mathematical thinking [20]. Therefore, children can develop positive reasoning skills toward Mathematics and solve all mathematical problems with less fear when their mathematical thinking is at a high level. Additionally, mathematical thinking strengthens students' ability to estimate and round, measure and construct, handle data, represent and analyze data, recognize and mathematically depict relationships, use algorithms and relationships, solve issues, and make decisions.

As affirmed by Mason, Burton, and Stacey [21], it is possible to enhance students' capacity for mathematical thinking. Secondary school students' mathematical thinking abilities can be improved by practicing with reflection in problem-solving and reasoning. The wrong impression about Mathematics being a difficult subject is one of the ways Mathematics anxiety develops in students and thereby impairs their ability to engage in mathematical thinking and can lead to teachers' burnout.

In line with the study of Maryam, Rohani and Sahar [21], they indicated that there was a negative moderate correlation between mathematical thinking and Mathematics anxiety. Likewise, Sharma [22] indicated that the technique for encouraging mathematical thinking as a result of creativity was more suited to students with low Mathematics anxiety than to individuals with high Mathematics anxiety. This work is relevant because poor mathematical thinking in Mathematics is seen as a barrier to achieving economic and social development. In this regard, it is important to find ways to improve the mathematical thinking of African students. The results will provide teachers, students, parents, and other education stakeholders with information that will help to develop strategies to improve students' mathematical thinking. The study's techniques, tools, findings, and recommendations may prompt teachers to explore early intervention strategies for students who are struggling with Mathematics anxiety.

1.1 Research Aim

The importance of Mathematics for students and the economy globally cannot be over-emphasized hence; there is a need to study the effect of Mathematics anxiety of students on Mathematics thinking. To this end, the focus of this research will be on the impact of Mathematics anxiety on the mathematical thinking of students in Africa. The ability of

African students to think mathematical will be examined from different angles such as their problem-solving ability, creativity, and reasoning. This paper will investigate the effect of mathematics anxiety on the mathematical thinking of students using meta-analysis to shed light on the issue. There have been previous meta-analyses on Mathematics anxiety, but they tended to concentrate on the relationship between Mathematics anxiety and Mathematics performance [23,24,25] or the effectiveness of Mathematics Teaching Strategies [13] or the efficacy of Technology [26]. The research titled “Do games reduce Mathematics Anxiety?” by Dondio, Gusev, and Rocha [27] is the closest meta-analysis to this current study. To date, no meta-analysis has been done on the effect of mathematics anxiety on the mathematical thinking of students. The findings of this study can offer teachers an understanding of the damage Mathematics anxiety can do to students' reasoning, creativity, and problem-solving abilities.

1.2 Research Objectives

To find out the relationship between Mathematics anxiety and mathematical thinking (the problem-solving ability and reasoning of students).

1.3 Literature Review

For decades, the subject of Mathematics has been plagued with fear and anxiety by some students. Researchers and educators started to notice the importance and prevalence of children who had unfavorable attitudes toward Mathematics as early as the 1950s [28]. Number anxiety was defined by Blazer [29] as unfavorable emotional reactions to Mathematics. Mathematics anxiety is characterized by Yakubu, Bisandu&Datiri [30] as stress that results in unfavorable physical reactions and impairs the manipulation of numbers and problem-solving in both academic and non-academic contexts. All definitions contain a profoundly unpleasant response to Mathematics on the physical, emotional, and cognitive levels that impairs a person's capacity to learn about and engage in Mathematics activities [2,12,17].

According to Jeannotte and Kieran [31], mathematical thinking skills are among the life skills that must be acquired, particularly in light of the more congested information age and competitive environment. The ability to think Mathematical is, therefore, crucial for students to be able to adapt to change and create new things in the future. The inability to think mathematically is caused by several reasons, including students' characteristics, teachers' methods of instruction, the relationships between learning settings, and most importantly Mathematics anxiety [32].

In general, students who think critically about mathematical concepts tend to be highly curious, have a broad range of interests, and appreciate creative pursuits [33]. Also, Marson, Burton and Stacey [34] believed that students who think mathematically tend to be extremely independent and self-assured, which results in a low level of anxiety. More than other students, they are more prone to take chances in life, demonstrating that they do not worry too much about what other people think of them when they accomplish something essential, relevant, and likable to them [35]. In other words, students who can think mathematically do not have anxiety; instead, they can reason, solve problems, and attain mathematical success because mathematical thinking develops their confidence in Mathematics.

Due to the complexity of the Mathematics materials and how they interact with one another, Mathematics education must be planned in a way that might help students improve their mathematical reasoning [36]. It is necessary to keep fostering and honing this aptitude for Mathematics. One of them is using knowledge in a way that allows students to freely express and develop their thoughts while yet being guided by teachers acting as facilitators [37].

The Transactional Model of Test-Related Emotions theory by Smith and Ellsworth [38] affirmed that worry and emotions are the two main causes of Mathematics anxiety. According to these researchers, the worry factor includes the cognitive aspects of Mathematics anxiety that cause the student to have pessimistic expectations, to be forgetful, to criticize themselves, and to come to irrational conclusions, all of which have been shown to have a negative impact on mathematical thinking.

Yakubu, Bisandu, and Datri [31] evaluate the link between Mathematics test anxiety and the thinking of Senior Secondary School 3 students in Kafanchan Educational Zone, Kaduna state. They noted that there was no significant difference in the mean scores of male and female students, and there was a negative association between test anxiety and students' mathematical thinking. This was gotten from 420 senior secondary students, 210 male students, and 210 female students. Aremu and Taiwo [39] demonstrated that emotional freedom and numerical cognition have a substantial impact on lowering anxiety and improving performance in Mathematics. Maryam, Rohani & Sahar [40] indicated that the level of Mathematics anxiety is related to mathematical thinking and Mathematics attitude.

2. METHODOLOGY

The meta-analysis approach will be used to conduct this research. The meta-analysis adheres to the PRISMA-P [41] Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols.

2.1 Research Strategy

The Boolean operators were combined with keywords in searching for publications. The researchers used a set of keywords related to mathematical thinking (such as, "Mathematical reasoning" OR "creativity" OR "Mathematical literacy"), the second set of keywords related to Mathematics anxiety (e.g., "Mathematics anxiety" OR "Math anxiety" OR ""Maths anxiety" " "Fear of Mathematics", the literature search was restricted to the English language and to research published between 2005-2021.

2.2 Information Sources

The researchers independently searched for publications at first. Between April and June of 2022, a preliminary literature search was conducted, and it was updated in October of 2022. The following online bibliographical databases were used for the search: Google Scholar, EBSCOHost, SAGE Journal, JSTOR, Science Direct, Web of Science, Taylor & Francis Online, ProQuest, and a dedicated database for grey literature.

2.3 Techniques of Data Collection

Data collecting techniques are methods for gathering, measuring, and analyzing data from various pertinent sources. The collection of data can be done in a variety of ways when it comes to research methods. These include using questionnaires, conducting interviews, holding focus groups, etc [41]. However, in collecting the data for this study, there are various steps involved. The articles chosen for the current meta-analysis came about as a result of a screening selection procedure. Two separate researchers independently evaluated each article to determine its eligibility, and any discrepancies were settled through discussion until agreement was obtained. Each study's full text was screened.

The literature on the research topic was rigorously searched by the two researchers from different sources such as Google Scholar, EBSCOHost, SAGE Journal, JSTOR, ScienceDirect, Web of Science, Taylor & Francis Online, and ProQuest. Materials were examined based on some search collections and compilations such as Mathematics anxiety, Mathematics thinking, and the impact of Mathematics anxiety on the mathematical thinking of students, amongst many others after which the whole collated paper was checked to ensure that each of the statistical data needed for inclusion within the meta-analysis was reported within the paper. All the collated papers were thoroughly studied to examine the features of the test, the statistical analysis used, the study area, and the duration. The aforementioned search techniques turned up 318 studies. The abstracts were initially screened, after which favorable papers were read and appraised in light of the study's goal.

Initially, 375 studies were originally sourced by the two researchers, and 219 studies were preliminarily screened after the duplicated publications had been removed. After the application of the inclusion and exclusion criteria, the researcher excluded 126 studies and 5 peer-reviewed publications and conference papers were included in the meta-analysis.

2.4 Criteria Inclusion and Exclusion

A survey and/or quasi-experimental study that met at least the following inclusion criteria were included in the present meta-analysis. The inclusion criteria are: the study must be published in English; it must be related to Mathematics anxiety; would have measured students' mathematical anxiety and thinking; Mathematics problem-solving skills and reasoning; would have been carried out between the period of 2005-2021. Furthermore, any study that was devoid of these inclusion criteria was excluded from the study. The inclusion criteria were developed to create a pool of representative studies that addressed the research questions and moderators [42]. According to Pigott [43], setting inclusion criteria and modifiers beforehand lowers the possibility of obtaining erroneous results. Therefore, a priori research important to the goals of this investigation was used to guide this approach.

2.5 Coding of Studies

In this study, meta-analysis was used to incorporate the results of primary research regarding the impact of Mathematics anxiety on the mathematical thinking of respondents. The publications chosen were properly coded according to subsequently explain the variety displayed by the effect sizes, the selected studies were categorized based on the general features of the study. Numerous coding elements were extracted to support the study's validity, including research authors, year, country, sample sizes, and so on.

The two researchers coded each of the 40 studies using the coding scheme and variables listed in Table 1. To achieve agreement, studies were coded while the researchers were in constant discussion. Additionally, disagreements were discussed in weekly consultation sessions with the researchers and the researchers to find a solution even when there was disagreement. The information for each study was coded by the researchers in the manner shown in Table 1. It was precisely mentioned for which mathematical thinking was devised in this meta-analysis. One performance outcome measure is coded for each study included in the meta-analysis so that the number of outcome measures does not result in disproportionate weightings between studies [44].

2.6 Method of Data Analysis

2.6.1 Effect size calculation

For the meta-analysis, the effect size was measured using Pearson's *r*. [45,46], given the benefits of using *r* as an effect size metric. The researchers converted inference test statistics (t-value, F-value, or chi-square) from studies that did not directly report Pearson's *r* to those studies' Pearson's *r*. The conservative effect size was determined if only individual studies were statistically significant, presuming a p-value of 0.05. Cooper et al. [47] state that the researcher used Fisher's z transforms to make sure the sample distribution was stabilised. Once again converted into correlations with effect sizes and confidence intervals, these values were then. Each r would then undergo the Fisher z transformation as follows:

$$Z = \frac{1}{2}.\ln\left(\frac{r+1}{r-1}\right)$$

To calculate the effects in the current study, this study used the random-effects model. The random-effects model assumed that different populations may have produced different samples for various studies and samples and that each population would have its sampling distribution [48,49].

2.6.2 Bias analysis of publication sensitivity

The five steps of publication bias analysis are used to determine the data's accuracy.

- Examining the funnel plot and determining whether the findings are asymmetric using a linear regression test created by Egger.
- Fill and Trim tests ought to be performed.
- Measuring impact size.
- Calculating the number of “null” effect studies necessary to move from an average effect to a 95% confidence level using the fail-safe Rosenthal process estimate.
- Examine the results' sensitivity by using the "One study deleted" option in the Comprehensive Meta-Analysis tool to identify any odd sources of the data effect size.

3. ANALYSIS AND INTERPRETATION

The focus of the meta-analysis was to investigate the relationship between Mathematics anxiety and mathematical thinking among school students and to pinpoint potential moderators and underlying mechanisms of such a relationship, including problem-solving and reasoning.

According to Table 2, the samples from the five (5) studies consist of one (1) research that focused on junior high school students, two (2) studies focused on senior secondary school students, and two (2) studies focused on tertiary school students. 5 (100%) papers of the investigations in total were published (N = 5). One (1) conference paper and four (4) journals were among the 5 studies that examined the influence and connection between Mathematics anxiety and mathematical thinking. Three (3) of the studies are related to problem-solving while two (2) of the studies are related to reasoning as variables for mathematical thinking.

3.1 Effect Sizes

In investigating the relationship between Mathematics anxiety and mathematical thinking, Pearson's *r*, was used to calculate the effect size. As long as the sample for each effect size was independent, studies might contribute multiple effect sizes. Using the random-effects robust standard error estimator, it was possible to account for the statistical dependence of various effect sizes inside a single sample (i.e., effect sizes nested within samples). The correlations between the effect sizes from the same sample are taken into account when the standard errors are corrected.

The 95% confidence intervals for the association between anxiety and mathematical thinking are shown in Table 3. Values of *r* in the current meta-analysis ranged from -0.20 to 0.97. The coefficient of variance also ranges from -0.03 to 1.40. The mean average value across the effect size board and coefficient of variance were 0.244 and 0.59 respectively. The information in Table 3 illustrates the size and accuracy of the effect sizes and coefficient of variance used in the current study. The findings imply that there is some variance in the precision levels and point estimates of the effect size. From the 5 studies conducted that the problem-solving ability and reasoning have a moderate effect size.

The null hypothesis test results from the random-effect model in Table 4 show that the p-value is less than 0.05, which indicates from 5 studies conducted that the problem-solving ability and reasoning have a moderate effect size. The weighted average of the two variables for mathematical thinking is -0.40 (problem-solving)

Table 1. Variables from the coding scheme used for the meta-analysis

Category	Coded information
General information	Title Authors' name Publication year Journals' name
Characteristics of mathematical thinking	Mathematical reasoning Creativity Problem-solving ability
Characteristics of the sample	Level of education (Primary, secondary and tertiary) Number of students The ability of the sample (High, Mixed, low, Mathematics ability)
Design	Research objectives/aims Survey versus quasi-experimental design Standardized or researcher-developed test
Outcomes	Main outcomes A performance measure used in the meta-analysis Alternative outcomes (i.e. correlation, effect size)

Table 2. Characteristics of sample studies

Authors/Year	Sample Size (n)	Methodology
Nkechi et.al., (2013)	26	Paired-Samples T-test and Independent t-test Report
Afusat & Sabainah (2020)	446	Mathematics Anxiety Inventory and Multi-Dimensional Personality
Joseph (2005)	621	Descriptive statistics and correlation analysis
Wang et.al., (2015)	493	Descriptive and correlational analyses
Maryam et.al., (2010)	203	Correlation analysis

Table 3. Result of pearson's effect sizes

Authors/Year	N	Effect Size	Coefficient of Variance
Nkechi et.al., (2013)	26	r= 0.78	1.40
Afusat & Sabainah (2020)	446	r= 0.97	0.33
Joseph (2005)	621	r= -0.20	0.30
Wang et.al., (2015)	493	r= 0.25	0.94
Maryam et.al., (2010)	203	r = -0.58	-0.03

and -0.61 (reasoning). The finding of this study supports the findings of Rusyda et.al [50] where it was indicated that there was a negative correlation between mathematics anxiety and mathematical problem-solving. This finding contradicts the study of Joseph [51] which found that test anxiety had almost no relationship with the mathematical problem-solving test. The findings regarding the reasoning ability of students have a negative correlation with Mathematics anxiety. The study of Ellianawati et.al, [52] indicated that students' reasoning abilities and feelings of mathematical anxiety are significantly improved.

In determining the effect size model used, a heterogeneity test is performed. The results of the heterogeneity effect size test calculations from the studies conducted are shown in Table 5. The heterogeneity test is not complete without getting the value for *p*. Based on the results of the heterogeneity analysis in Table 5 the *p*-value (0.016) is less than 0.05, which indicates that the overall mathematical problem-solving ability and mathematical reasoning have significant differences. With a *p*-value of less than 0.05 in the heterogeneity, analysis indicates that the random-effect rather than fixed-effect model is the best fit for this study.

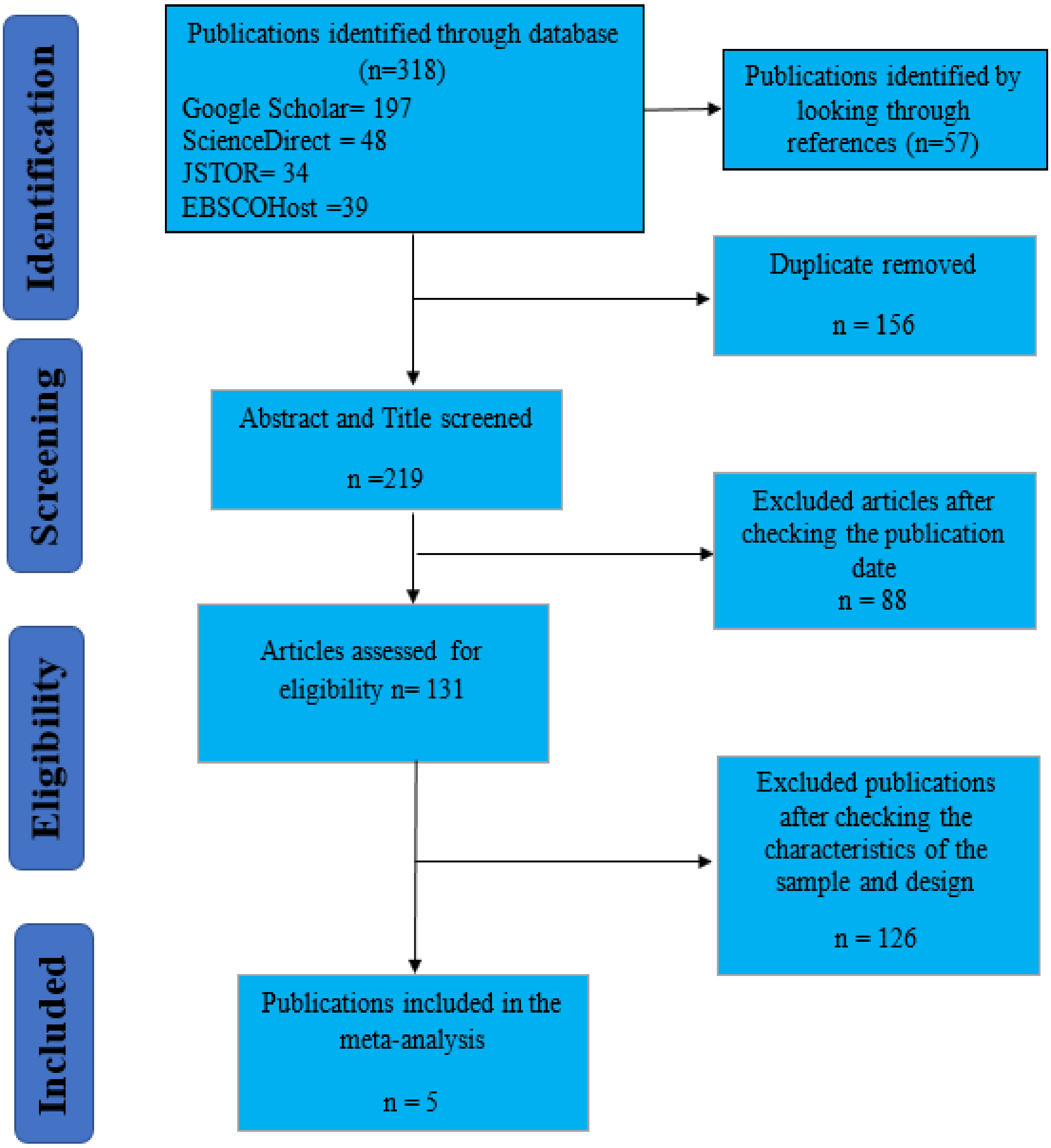

Fig. 1. Systematic search strategy for meta-analysis
Source: Author's compilation

Table 4. Comparison of meta-analysis results based on the weighted average

Variables	Model	N	Weighted Average	Df	P
PS	Random Effect	3	-0.40	2	0.00
R	Random Effect	2	-0.61	1	0.00

Note: PS: Problem Solving; R: Reasoning; RE: Random Effect. WA: Weighted Average

Table 5. The heterogeneity (Q) test results

Heterogeneity Value (*Q*)	Degree of Freedom (*df*)	*p*
12.24	4	0.016

As a result of the heterogeneity test, the effect sizes of Mathematics anxiety and mathematics thinking studies were found as statistically significant. In the heterogeneity test, a *p*-value (0.016) smaller than 0.05 means that meta-analysis has a heterogeneous structure, and the random effects model should be used in this case. Therefore, the random effects model was used in the current study to calculate the effect sizes regarding the relationship between mathematics anxiety and Mathematics thinking.

3.2 Result of Random Effects

The below random effect was calculated in relationship with the effect size.

The typical mean effect size is 0.244 in value. The effect size's lower and upper limits in the 95% confidence range are -0.742 and 0.780, respectively. Statistical significance is indicated by the value p=0.016. The random effects of pooled d is valued at 0.019. These results indicate a positive and somewhat strong link between math thinking and math anxiety. In addition, considering the *p*-value, it is statistically significant.

Of the 5 studies included in the meta-analysis, one (1) is a conference paper and four (4) are journals. The effect size regarding the publication types revealed that there was a significant medium-level positive (*r*=0.78) relationship between Mathematics anxiety and mathematics thinking with respect to the conference paper and this relationship was significant. Similarly, there was a significant medium-level positive (*r*=0.44) relationship between Mathematics anxiety and mathematics thinking with respect to journals. However, at a 95% confidence level, the lower limit for conference and journal papers is -1.439 and -2.55 respectively. The upper limit on the other hand for the conference and journal is 2.659 and 1.516 respectively.

3.3 Results of the Moderator Analyses

Considering the heterogeneity that emerged in this meta-analysis study, it is important to identify the possible sources of this heterogeneity. Therefore, the variables of publication type and publication year, sample level and research method given in Table 5 were determined as moderator variables.

As indicated above, regarding the publication type, the 5 studies used are 100% published. The sample level consists of one (1) study on junior school with 20%, and 2 studies on senior high school and tertiary school with 40% respectively. On the research methods, 4 of the studies are experimental in nature with 4 (80%) of the total studies, while 1 (20%) of the studies is non-experimental in nature.

3.4 Analysis of Publication Bias and Sensitivity

To check publication bias, a funnel plot was used and assess the expected relationship between effect sizes and standard research errors. Funnel plots are often used to assess the presence of bias. The distribution of effect size data from this study is presented in Fig. 2.

The black diamond sign in the funnel plot shows the combined virtual effect size and the blank points show the distribution of study effect size that appears to be spread majorly on the left side of the symmetry axis, meaning that it does not need to be added or subtracted due to publication bias. In other words, no publication bias was found in this study. Then three quantitative assessment methods are used: trim and fill, Egger regression tests, and Fail-safe N. Neither method proves the presence or absence of publication bias. N Rosenthal's fail-safe method helps determine the probability of publication bias because distribution channel plots are not fully symmetrical. From the analysis of data, N Rosenthal's fail-safe value is 600. According to the formula, N/(5k+10) with k is the number of studies, which is 600/(5×5 +10), and the calculation result is 17.142.

According to these calculations, it can be identified that the studies included in this analysis are resistant to publication bias because when the calculation results> 1 show sufficient tolerance to publication bias. Thus it is stated that the results of the meta-analysis in this study are reliable. The funnel plot in Fig. 2 provides an overview of the effect size distribution in a vertical line in which the effects are combined. Here, there is no publication bias found when the distribution of effect size is symmetrical toward the combined effect size. In the presented funnel plot, it can be seen that the dots which represented the effect size is located symmetrically high enough toward the combined effect size. Besides, there is no study that shows the effect size is too far from the vertical line. Thus, it can be argued that no studies need to be excluded or added as a result of the impact of publication bias.

As explained in Fig. 2, the effect size is spread almost symmetrically on the left side of the funnel plot, but there is 1 datum on the horizontal line of the funnel plot. However, based on the Fail Save N (FSN) calculation, the N Rosenthal value is 334. According to the formula N / (5K + 10) with a k value of 5, it is obtained 334/(5×5 +10) = 3.941. According to this calculation, because the statistical calculation result is 9.54>1, this meta-analysis is resistant to publication bias, and this research is reliable.

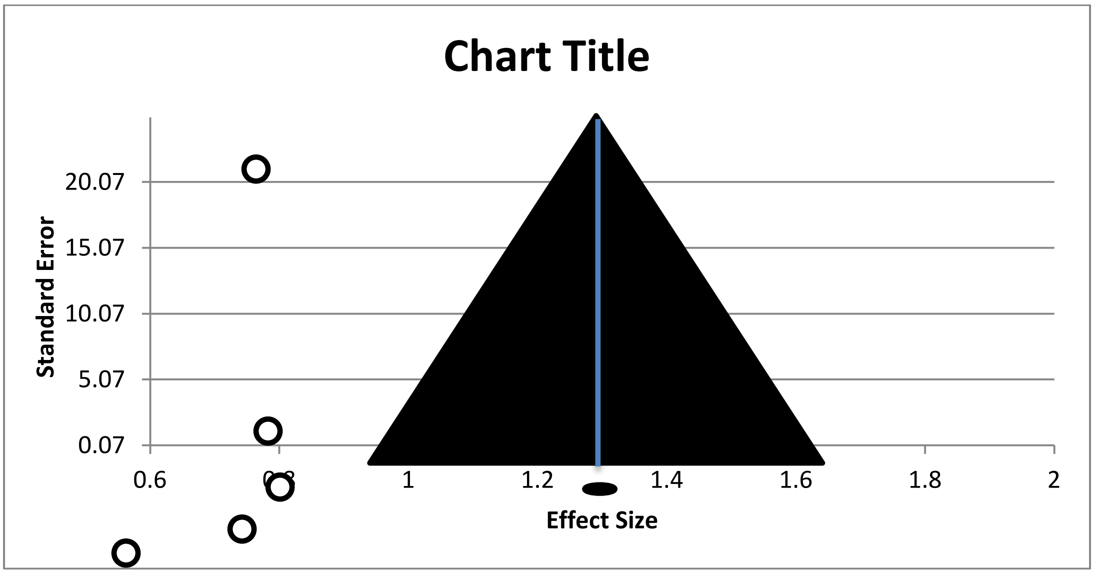

Fig. 2. Funnel plot of effect size

Table 6. Effect sizes of the studies based on random effects model random

Mean effect size	Random effects of pooled d	Variance of pooled d	Df	95% confidence interval		p
				Lower 95% C.I	Upper 95% C.I	
0.244	0.019	0.151	4	-0.742	0.780	0.016

Table 7. Effect size values of the studies in terms of the publication type variable

Publication type	Freq (*n*)	Effect size	95% Confidence interval for effect size	
			Lower limit CI	Upper limit CI
Conference	1	0.78	-1.439	2.659
Journals	4	0.44	-2.515	1.516
Within groups total	5	1.22	-3.954	4.175

Table 8. Characteristics of moderators

Variables	K	%
Publication Type (*k*= 5)		
Unpublished	0	0
Published	5	100
Sample Level (*k*= 5)		
Junior School	1	20.0
Senior High School	2	40.0
Tertiary School	2	40.0
Research Method (*k*= 5)		
Experimental	4	80.0
Non- Experimental	1	20.0

4. CONCLUSION

The current study aimed to examine the relationship between Mathematics anxiety and mathematical thinking. The study also explored if, when taking into account problem-solving and logical reasoning, the effect sizes of the association between Mathematics anxiety and mathematical thinking varied according to publication types. The heterogeneity test revealed that the effect sizes of the studies on Mathematics anxiety and mathematical thinking were statistically significant. The association between Mathematics anxiety and mathematical thinking was strong (r=0.78) and significant at 0.05, according to the moderator analysis of the publication kinds. The connection between Mathematics anxiety and mathematical thinking with regard to journals was also significant and moderately unfavourable (r=0.44). This shows that there is a relationship between Mathematics anxiety and mathematical thinking. The random effects of pooled d is valued at 0.019. lower and upper limits in the 95% confidence range are -0.742 and 0.780 with statistical significance indicated by the value *p*=0.016. These results indicate a strong link between mathematical thinking and Mathematics anxiety. In addition, considering the *p*-value, it is statistically significant. The aforementioned leads to the conclusion that Mathematics anxiety affects mathematical thinking negatively.

Based on the findings of this paper, it is recommended that:

1. The Government, through the ministry of education in African countries, should direct teachers to help identify Mathematics anxiety among students and develop means of helping them overcome anxiety for effective mathematical thinking.
2. Curriculum developers should come up with a strategy for incorporating fresh perspectives into the Mathematics curriculum that will make it engaging for students and boost their thinking in order to become better not just in their academics but also in their day-to-day living.

CONSENT

This is a Meta-Analysis and systematic literature review; the research is well referenced.

ETHICAL APPROVAL

No confidential, sensitive or deeply personal information was collected from participants.

COMPETING INTERESTS

Authors have declared that no competing interests exist

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