



Critical Thinking Ability as a Correlate of Students' Mathematics Achievement: A Focus on Ability Level

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Article Info	Abstract
Received April 8, 2023	This study investigated the correlation between critical thinking ability and academic achievement in mathematics among 200 Senior Secondary School Two (SS2) students in Orlu Education Zone in Imo State, Nigeria. The researchers utilized a correlational design and employed a multi-stage but simple random sampling technique to select the sample. Data were collected using two instruments: the Watson-Glaser Critical Thinking Appraisal (WGCTA) and the Mathematics Achievement Proforma (MAP). The validity of the WGCTA instrument was ensured through expert suggestions and guidance. The study addressed three research questions and tested three null hypotheses using the Pearson Product Moment correlation coefficient at a significance level of 0.05. The findings of the study indicated a low positive and significant correlation between critical thinking ability and academic achievement in mathematics for all students. However, there was no significant relationship between critical thinking ability and achievement among high achievers, while there was a significant but negligible positive relationship between critical thinking ability and achievement among low achievers. The study recommended that mathematics teachers should incorporate critical thinking development in their classroom instruction to enhance the critical thinking ability of students, which can lead to improved academic achievement, especially among low achievers.
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INTRODUCTION

In the current era, there is an urgent need to emphasize on actualization of scientific and technological developments because of their global advancement. As a result, students are being encouraged to develop an interest in and pursue science-related subjects and courses since they will exponentially increase the level of growth in these critical fields in the near future. At all educational levels, mathematics is a fundamental prerequisite for learning any science discipline. Mathematics has significantly helped the development of science and technology for thousands of years and will continue to do so now (Algani, 2022). Students must have at least a credit in mathematics on their Senior Secondary School Certificate Examination in

order to be admitted to a tertiary institution. These days, mathematics is used in practically every sphere of human endeavor, and it is essential to a nation's economic growth.

As Nigeria matches to prioritize economic growth, we need nothing short of good academic achievement in mathematics at all educational levels. The good academic performance of students at the senior secondary school is of paramount importance in every educational system (Brew, Nketiah, & Koranteng, 2021). Despite the importance of mathematics, observations and reports from West African Examination Council Chief Examiners revealed that Nigeria Secondary Students continue to perform poorly in mathematics examinations. According to the 2021 West African Examinations Council (WAEC) May/June results, only 32.03% of Nigerian secondary school students obtained credit passes in Mathematics (WAEC, 2021). The low performance in mathematics has been a persistent problem in Nigeria, as highlighted by the National Examination Council (NECO) which reported that only 26.01% of candidates obtained credit passes in Mathematics in 2020 (NECO, 2020). The students' poor performance indicates that they are either not being taught mathematics correctly in schools or are having problems understanding the ideas and skills or may have learning difficulties in acquiring mathematics though-processes, concepts and inability to think critically

In terms of critical thinking, Adebisi and Akintoye (2020) found a positive correlation between students' critical thinking skills and their performance in mathematics. The study, which was conducted among senior secondary school students in Ogun State, Nigeria, recommended that mathematics teachers should incorporate critical thinking into their instructional strategies to enhance students' performance in the subject. Similarly, another study by Olanrewaju and Ogundipe (2021) examined the effects of a critical thinking instructional model on senior secondary school students' achievement in mathematics and found that the model significantly improved students' performance. The study recommended the adoption of the model in mathematics instruction in Nigerian schools.

The problem with ability level in critical thinking and mathematics achievement is that not all students possess the same level of critical thinking ability, and this can impact their academic performance in mathematics. Some students may struggle to apply critical thinking skills when solving mathematical problems, while others may excel in this area. This can lead to disparities in academic achievement based on students' ability level in critical thinking, particularly in a subject like mathematics that requires strong problem-solving skills. This issue highlights the need for mathematics teachers to incorporate critical thinking development into their instructional strategies to support students' learning and enhance their academic achievement, regardless of their ability level (Ogunniyi, Jegede, & Ogundipe, 2019). By doing so, teachers can help students develop the necessary skills to excel in mathematics and other subjects, and prepare them for success in higher education and beyond

The ability to think critically, analyze, solve problems and make decisions has been the foundation for the success and progress of the human race. For students to perform and contribute successfully in the society they have to possess competencies on these abilities. Educational institutions have a major responsibility to provide the tools and learning opportunities that enable students to develop these abilities. One major school subject through which critical thinking ability could be

inculcated to students is mathematics, which is in conformity with the National Educational Policy goals to imbibe the ability to make rational decisions. Similarly, the STEM framework does have objectives that correspond with the characteristics of 21st century-education, among which are critical thinking skills, or thinking that is always curious about the information available in order to achieve a thorough understanding (Setyawati et al., 2022). Since mathematics is a subject that is also based on logic and one has to make sense of concrete as well as abstract problems, then it can be argued that it can enhance critical thinking ability where logic is one of its components.

The concept of critical thinking and its development over centuries of literature is well documented. John Dewey defined critical thinking as "reflective thinking," emphasizing active and persistent consideration of beliefs and knowledge in light of evidence (Dewey, 1933). Fisher further elaborated on Dewey's definition, highlighting the importance of reasoning and implications of reasoning in shaping one's beliefs (Fisher, 2001). Edward Glaser expanded on Dewey's definition, emphasizing the need for evidence and a disposition to use critical thinking skills (Glaser, 1984). Ennis took Dewey's definition further by including decision-making as a component of critical thinking (Ennis & Norris, 1990), while Paul considered metacognition as a crucial element (Paul, 1995). Overall, critical thinking involves thoughtful consideration of problems and evidence to arrive at logical conclusions, with a disposition to use critical thinking skills and remain cognizant of one's own thinking process. (Dewey, 1933; Fisher, 2001; Glaser, 1984; Ennis & Norris, 1990; Paul, 1995).

The most crucial aspects of critical thinking and intellectual standards were presented by Michael Scriven and Richard Paul in the Annual International Conference on Critical Thinking and Education Reform. They describe critical thinking as the intellectual process of actively conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action. In its exemplary form, it is based on universal intellectual values that transcend subject matter divisions: clarity, accuracy, precision, consistency, relevance, sound evidence, good reasons, depth, breadth, and fairness (Scriven & Paul, 1987).

According to the above literatures, critical thinking involves logical reasoning and ability to separate facts from opinion, examine information critically with evidence before accepting or rejecting ideas and questions in relation to the issue at hand. In other words, it encourages people to reflect, raise doubts about things, challenge preconceived notions, come up with answers to situations, and make wise choices when faced with difficulties. For this study critical thinking requires a certain mindset which is essentially evaluative in nature. It is the ability to think clearly and rationally.

Critical thinking is connected to mathematics, scientific problem solving and physical science among other fields. In mathematics, critical thinking is referred to as the ability to evaluate the presented mathematical problems and think about vital skills that allows one to tackle the problems efficiently. The vital skills include; clarity of thought, intellectual integrity, problem identification and solution, respect for evidence, internal coherence, intellectual standards, meta-cognition, questioning, deductive and inductive reasoning, argument mapping and ethical

reasoning, to name a few (Ennis, 1993; Fisher, 2001; Paul & Elder, 2004; Scriven & Paul, 1987). Mathematics is also the logical language for expressing ideas of shapes, quantities, size, order, change and dynamism in systems and for explaining the complexities of modern society in the business, economic, academic, engineering, medical settings and other fields. The teachers are responsible to equip students with these skills and generate interest in learning mathematics as a means of acquiring effective tools for problem solving in life.

Mathematics education is a field of study that focuses on teaching methods, curriculum development, and instructional strategies to promote mathematical learning. It also involves the study of how students learn mathematics, the development of assessment tools, and research on enhancing problem-solving and critical thinking skills in mathematics (National Council of Teachers of Mathematics, 2021). The story of mathematics education in Nigeria is the story of our inherited western education system. To teach mathematics in an understandable way to our students has always been a problem and so different methods are investigated and practiced for better achievement by students in mathematics in the past years. Critical thinking is considered important in the academic fields especially in mathematics because it enables one to analyze, evaluate, explain and restructure their thinking, thereby decreasing the risk of adopting, acting on or thinking with, a false belief (UKEssays, 2021). If mathematics teachers incorporate critical thinking teaching techniques, teaching and learning may be improved which will transcend to students' academic achievement in mathematics.

Academic achievement represents performance outcomes that indicate the extent to which a person has accomplished specific goals that were the focus of activities in instructional environments, specifically in school, college, and university (Kane, 2017). In the school setting, it is referred to as evaluation of students' learning outcomes as quantified on the basis of marks or grades in school subjects. Kane further stresses that School systems mostly define cognitive goals that either apply across multiple subject areas (e.g., critical thinking) or include the acquisition of knowledge and understanding in a specific intellectual domain (e.g., numeracy, literacy, science, history). Academic achievement is commonly measured by examinations or continuous assessment. In this study, academic achievement was defined according to how well a student accomplished work in the school setting in mathematics. It was assessed by mathematics teachers and represented by students' cumulative grade for the terms. The marks or scores assigned by teachers could be high or low (ability level), which means that academic achievement, could either be good or bad.

There is a common saying that an examination is not a true test of knowledge. This implies that where the evaluation of students lacks validity and prejudice it does not guarantee that high achievers could exhibit high critical thinking ability. Students are divided into groups according to their performance on a test or examination, which determines their ability level. Ability level relates to a student's demonstration of skill, attitudes, and knowledge in relation to learner outcomes for the grade level. Regarding a teaching-learning setting, there are three different types of ability levels: low achievers, medium or average achievers, and high achievers (Talca, 2007). In categorization of students' academic ability levels, Talca (2007) grouped students with (0-49%) scores as low ability, (50-64%) scores as medium ability and (65-100%) as high ability level.

Low achievers are individuals whose academic potentials are estimated to be below average while their performance is characterized as poor, and they need constant study, assessment, and assistance in order to improve their situation. Medium or average achievers are individuals whose academic performance are estimated to be average, not a reflection of their competency, but rather, in part, a reflection of their inability to put up the additional work required to get better results. As a result, they limit their learning to the classroom and refrain from seeking out other sources of information. Higher achievers are individuals whose performance is deemed to be good and whose academic potential is above the class average. In the context of this study however, ability level was classified as high achievers (65-100%) and low achievers (0-49%) only, in mathematics cumulative grade for the terms. The ability level classification into high achievers (65-100%) and low achievers (0-49%) is based on the grading system used by the National Examinations Council (NECO) and the West African Examinations Council (WAEC) in Nigeria. Scores of 65% and above are considered distinctions, while scores below 50% are failing grades. This classification is widely recognized and used in Nigeria

Students categorized as higher achiever may or may not exhibit higher critical thinking skills than those students categorized as lower achiever. Looking into secondary school classroom settings, mathematics in secondary schools is mainly characterized by a high percentage of low achievers as evidenced by the poor achievement of the students in mathematics examinations in public secondary schools. According to a study conducted by Adeyemi and Adeyemo (2019) in Nigeria, mathematics education in secondary schools is characterized by a high percentage of low achievers. The study found that many students performed poorly in mathematics examinations in public secondary schools, with some even failing the subject. Findings indicate moderate positive correlation between academic achievement and critical thinking ability in undergraduate students (Braun, & Clark, 2021). Findings have proved that critical thinking is significantly and positively correlated with academic achievement (Chiketa & Okigbo, 2021; Fitriani et al., 2020; Nur'Azizah, Utami, & Hastuti, 2021; Nwuba, Ekwu, & Osuafor, 2022). Studies that assess students' critical thinking ability reveal that students often fail in tasks that require critical thinking (Fadhlullah & Ahmad, 2017; Flores et al., 2012; Yasir & Alnoori, 2020).

The body of literature related to critical thinking continues to grow, there continues to remain disagreement of factors that are associated with the ability to think critically. The current research may differ from previous studies in terms of the specific research questions, sample population, research design, and data analysis methods. This study aims to provide a better understanding of this relationship and identify specific critical thinking skills associated with academic achievement. The results of this research can inform the design of effective interventions and strategies, guide targeted interventions, and inform educational policies to prepare students for success in the modern world. The research can achieve new things such as providing a better understanding of critical thinking and academic achievement in mathematics, identifying critical thinking skills that need improvement, and increasing awareness of the importance of critical thinking skills in mathematics education. All of these can help develop better educational interventions and policies and prepare students for success in the modern world.

It is against this background that this study sought to establish the extent of correlation between critical thinking ability and students' academic achievement in mathematics focusing on ability level.

Research Questions

The study was guided by three research questions. Firstly, what is the correlation between critical thinking ability and students' achievement in mathematics? Secondly, what is the relationship between critical thinking ability and achievement among high achievers in mathematics? Finally, what is the relationship between critical thinking ability and achievement among low achievers in mathematics?

Null Hypotheses

The following null hypotheses were tested at 0.05 level of significance: Firstly, there is no significant correlation between critical thinking ability and students' achievement in mathematics. Secondly, there is no significant relationship between critical thinking ability and the achievement of high achievers in mathematics. Finally, there is no significant relationship between critical thinking ability and the achievement of low achievers in mathematics.

RESEARCH METHODS

The study used correlational survey research design, which aimed at correlating critical thinking and students' academic achievement in mathematics. It seeks to establish the relationship that exists between two or more variables. The population of the study comprised all four thousand eight hundred and fifty-four (4854) senior secondary school class two (SS2) in forty (40) government owned secondary schools in Orlu Education zone one (1) in Imo State, Nigeria. The participants consisted of two hundred (200) SS2 students. The researchers adopted the multi-stage but simple random sampling technique to draw the sample. Two instruments were used to collect data for this study. They include: Watson-Glaser Critical Thinking Appraisal (WGCTA) and Mathematics Achievement Proforma (MAP). The WGCTA is a widely used standardized instrument of critical thinking ability that measures the ability to think critically across five cognitive domains: inference, recognition of assumptions, deduction, interpretation, and evaluation of arguments. The WGCTA consists of 40 test questions that assess critical thinking ability across the five cognitive domains. MAP was used to collect data on students' achievement scores in mathematics. It includes the cumulative scores of students' first and second term mathematics results. Two experts validated and modified the instrument (WGCTA) to ensure the appropriateness of the language used and coverage content is suitable in eliciting the required information. A single-administration reliability and Kuder-Richardson formula 21 (KR-21) reliability coefficient of 0.83 was obtained, WGCTA was deemed reliable. Mathematics Achievement Proforma (MAP) of high achievers (65-100%) and low achievers (0-49%) in mathematics cumulative grade for first and second terms were used. The data obtained were analyzed using Pearson Product Moment correlation coefficient in answering research questions and *t*-test in testing null hypothesis at 0.05 level of significance with aid of statistical package for Social Sciences (SPSS) version 20. Decision rule

for correlation coefficient was adopted from Best and Kahn (2013) who provided the following rules for judging the strength of correlation between two variables.

Table 1. Relationship Category	
Correlation (<i>r</i>)	Relationship
.00 to .20	Negligible
.20 to .40	Low
.40 to .60	Moderate
.60 to .80	Substantial
.80 to 1.00	High to very high

The decision to reject or accept a null hypothesis was based on the probability value (*p*-value) and the 0.05 significance level. Where the *p*-value is less than 0.05 alpha level, the null hypothesis is rejected, if otherwise not rejected.

RESEARCH RESULTS

The results are presented in the order of the research questions and hypotheses raised.

Table 2. Correlation between Critical Thinking Ability and Students' Achievement in Mathematics

Variable	<i>N</i>	<i>R</i>	<i>R</i> -square	<i>Sig.</i>	Decision
WGCTATEST	200	.260**	0.068	.000	Significant
Achievement	200				
**correlation is significant					

The results in Table 2 from the correlation analysis, the correlation coefficient (*r*) of 0.260 was obtained and the null hypothesis (H_{01}) is rejected because *p*-value (*Sig.*=0.000) is less than the 0.05 level of significance. This shows a low positive and significant correlation between critical thinking ability and students' academic achievement in mathematics. By squaring the correlation coefficient and multiplying by hundred (100), we obtained 6.8%. This also shows that only 6.8% of variation in critical thinking ability. That is, critical thinking ability influences achievement in mathematics to the tune of 6.8%.

Table 3. Relationship between Critical Thinking Ability and Achievement of High Achievers in Mathematics

Variable	<i>N</i>	<i>R</i>	<i>R</i> -square	<i>Sig.</i>	Decision
WGCTATEST	41	.169	0.0286	.292	Not Significant
Achievement	41				
**correlation is significant					

The results in Table 3 revealed that the correlation coefficient (*r*) is 0.169, which is positive but negligible and null hypothesis (H_{02}) is accepted because *p*-value (*Sig.*=0.292) is greater than the 0.05 level of significance. Therefore, there is negligible positive and no significant relationship between the critical thinking

ability and achievement of high achievers in mathematics. The result also shows that critical thinking ability of high achievers influences their mathematics achievement to turn of 2.86%.

Table 4. Relationship between Critical Thinking Ability and Achievement of Low Achievers in Mathematics

Variable	N	R	R-square	Sig.	Decision
WGCTATEST	159	.161**	0.0259	.043**	Significant
Achievement	159				

**correlation is significant

In table 4, the results of the correlation analysis revealed that the correlation coefficient (r) is 0.161, which is negligible positive and null hypothesis (H_{O3}) is accepted because p -value ($Sig.=0.043$) is less than the 0.05 level of significance. Therefore, there is negligible positive and significant relationship between the critical thinking ability and achievement of low achievers in mathematics. Further computation shows that 2.59% of the variation in mathematics achievement of low achievers could be explained by variation in their critical thinking.

DISCUSSION

The result indicates that the knowledge of critical thinking ability of students could not accurately correlate their achievement in mathematics. The result also shows that critical thinking ability and mathematics achievement change in the same direction. This is an indication that increase in critical thinking ability leads to increase in mathematics achievement and vice versa. This is in agreement with the findings of the previous studies (Chiketa & Okigbo, 2021; Fitriani et al., 2020; Nur'Azizah et al., 2021; Nwuba et al., 2022). The previous studies also found a significant positive relationship between critical thinking ability and academic achievement, this study found a low correlation between the two variables while Braun, and Clark (2021) found a moderate relationship. The findings further revealed that critical thinking ability uniquely contributed only 6.8% of the variance in mathematics achievement. This is not comparable with the report of 18% by Scott and Bryan (2006). This is an indication that there is an inconclusive result on the extent of correlation between critical thinking ability and academic achievement. Therefore, the critical thinking ability does not absolutely influence achievement in mathematics as suggested by the findings.

The findings also showed there is negligible positive and no significant relationship between the critical thinking ability and achievement of high achievers in mathematics. while there is negligible positive and significant relationship between the critical thinking ability and achievement of low achievers in mathematics. This also supports earlier submission that knowledge of students' critical thinking ability could not accurately predict their achievement in mathematics, irrespective of whether the students are classified as high or low achievers. Further computation also revealed that 2.86% and 2.59% of the variation in mathematics achievement of high and low achievers respectively, could be explained by variation in their critical thinking ability. The remaining 97.1% and 97.4% respectively, is accounted for by chance. Therefore, one can rightly say that

students' critical thinking ability does not account for their achievement in mathematics. The implication for these results is that students have not yet developed the critical thinking ability to handle mathematical problems. This is true for both high and low achievers. Scott and Bryan (2006) found that students categorized as high achievers exhibit higher critical thinking skills than those students categorized as low achievers. These findings are not in accordance with the findings of the study as related to their achievement in mathematics. Thus, critical thinking ability plays little or no role in the mathematics achievement of the high achievers.

CONCLUSION

Based on the discussion of the findings, the following conclusions were drawn that there is a low positive and significant correlation between critical thinking ability and achievement of students in mathematics; the knowledge of critical thinking ability of the students could not accurately predict their achievement in mathematics; the critical thinking ability plays little or no role in the mathematics achievement of high achievers.

The following recommendations were made: (1) Mathematics teachers should strive to incorporate critical thinking development in their classroom presentation, (2) Education practitioners should facilitate the development of critical thinking ability through seminars, and workshops.

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