

EXPLORING THE IMPACT OF OPTIONAL MATHEMATICS ON CAREER READINESS AND COGNITIVE DEVELOPMENT IN NON-STEM SECONDARY EDUCATION IN NORTH-EAST REGION NIGERIA

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Abstract

This study investigates the implications of allowing secondary school students in Nigeria to opt out of mathematics and how this choice affects their cognitive development and career readiness, particularly among non-STEM learners. Grounded in Cognitive Development Theory, the research employed a survey design to determine whether avoiding mathematics lowers students' capacity for critical thinking, analytical reasoning, and long-term career preparedness. A total of 420 students and 22 teachers from public and private schools across six states in the North-East region of Nigeria participated in the study. Data were gathered using two standardized instruments: a Cognitive Skills Assessment (24 items) and a Career Readiness Competency Scale (28 items). Both instruments demonstrated high internal consistency, with Cronbach's alpha values of 0.83 and 0.85 respectively. Data analysis, conducted using the Statistical Package for the Social Sciences (SPSS), involved descriptive statistics, independent t-tests, and ANOVA to compare students who avoided mathematics with those who continued studying it. Findings revealed that students who opted out of mathematics recorded significantly lower cognitive development scores ($M = 59.4\%$) compared to peers who continued with mathematics ($M = 74.8\%$). They also demonstrated weaker indicators of career readiness, particularly in critical thinking, quantitative reasoning, and structured problem-solving ($p < 0.05$). Based on these outcomes, the null hypothesis which stated that opting out of mathematics has no effect on cognitive ability or career readiness was rejected. The study concludes that avoiding mathematics diminishes students' cognitive strength, limits their analytical capacity, and ultimately weakens their preparation for diverse career pathways.

Keywords: critical reflection, Cognitive Development, logical reasoning.

Introduction

Mathematics serves as an integral part of the educational pillar wherein it fuels the development of learners' logical reasoning, analytical, and systematic problem-solving skills. From the triangular construct of the educational pillar, the educational foundation of the students assists them in the other disciplines. The importance of

mathematics is felt in the social and political sciences, and in the humanities, wherein students use analytical skills in a logical, creative, and interpretative framework. The skills learned assist in the critical and creative synthesis of the human experience. In modern democracies, mathematical literacy is a prerequisite for exercising responsible citizenship and for



full engagement in the workplace (OECD, 2022). Equally, the 2024 PISA report on creative thinking argues that mathematical reasoning and creativity work in tandem and that both are essential for the development of learners who are flexible, able to innovate, and apply systematic reasoning to ill-defined problems (OECD, 2024a).

Hidayat (2025) performed a meta-analysis which illustrated how metacognitive training in mathematics improves students reflective, evaluative, and reasoning skills, which assist with non-mathematical fields as well. Metacognitive instruction with mathematics also implies that students become cognitively flexible and improves non-mathematical fields as well (Er, 2024). Mathematics is also perceived to enhance reasoning skills and is positively associated with critical thinking (Arysad et. al, 2023). Furthermore, there is a noticeable discrepancy with students from the mathematics background as to reasoning, analytical thinking, and overall achievement compared to weaker students in mathematics (Er,2024). Advanced metacognitive capacities transform students toward overall achievement and positive discrepancy as to reasoning skill. More flexible students with metacognitive skills demonstrate discrepancy as to fields and overall achievement. Strong positive reasoning and analytical skills obtain achievement as to fields they desiderate.

Math helps students in the arts and social sciences understand human behavior, economic systems, and artistic composition in more depth. Lehmann and Urayama (2025) explained how mathematical argumentation helps students learn how to communicate interpretively and argue sociologically. Teaching arts and math together, as in the case of Kus et al. (2024), helped students to enhance their creativity and analytical skills. This is also the case in the work of Amanova et al. (2025), where interdisciplinary instruction of mathematics

and creative subjects, within STEAM, was found to foster advanced reasoning, problem-solving, and critical engagement with complex concepts.

In contrast, the exclusion of math in secondary schools, especially in the arts and social sciences fields, entails considerable educational and social costs. Research on Adult Numeracy of the OECD (2024) noted that people with deficient math skills are less employable, have lower financial literacy, and are less engaged in the community (OECD, 2024b; OECD, 2024c). National Numeracy (2024) emphasized that lack of numeracy skills financially, and this also translates to lack of self-efficacy in making choices and in undertaking actions in one's life and in one's occupation. Research has also associated low numeracy skills with poorer health and with more critical life choices and actions (de Bruin et al., 2023). Consequently, ignoring the teaching of math in secondary school will also mean ignoring the social, economic and educational needs of the students in their future citizenship.

Increasingly, literature during the years 2023\2025 underscores the potential of mathematics to be a pedagogical conduit for bridging the analytical with the creative. Steflitsch (2025) argued that mathematics education that is critiqued empowers learners to interrogate social inequities and fraudulent uses of data in the public sphere, thereby enhancing democratic literacy. Thus, for students in the arts and social sciences, mathematics should not be perceived as a hurdle but as a means to facilitate critical thinking, creative reasoning, and disciplined inquiry. Its continued integration into secondary curricula is essential for the formation of students with the capacity to think logically, critically analyse options, and participate meaningfully in sophisticated, data-rich environments.

Statement of the Problem

In Nigeria, secondary school students are increasingly allowed to opt out of mathematics, particularly in non-STEM tracks, a trend that may hinder their cognitive development and career readiness. Despite the widespread importance of mathematics in fostering critical thinking, problem-solving, and analytical skills, there is limited research on the consequences of its exclusion from non-STEM curricula. This study aims to explore how the absence of mathematics affects students' cognitive growth and their preparedness for diverse career paths. Specifically, it examines whether opting out of mathematics weakens critical thinking, quantitative reasoning, and problem-solving abilities, which are essential for success in both academic and professional contexts.

Objectives

The following objectives guided the study:

- 1 To examine the role of mathematics in enhancing critical thinking skills among secondary school students in the arts and social sciences.
- 2 To identify the integration of mathematical reasoning within arts and social science curricula.
- 3 To evaluate the perceptions of students and educators regarding the importance of mathematics for critical thinking in arts and social sciences.

Research Questions

The following research questions guided the study:

- 1 How does the inclusion of mathematics in the arts and social sciences curriculum influence students' critical thinking skills?
- 2 In what ways are mathematical concepts integrated into arts and social science subjects to enhance students' analytical and problem-solving skills?

- 3 What are the attitudes of students and educators towards the role of mathematics in developing critical thinking within arts and social science education?

Methodology

The study was based on a cross-sectional survey, and the aim of the study was to examine the impacts of non-participation in mathematics on cognitive development and career readiness among non-STEM tracks in secondary schools. The design was chosen to take a snapshot of abilities and attitudes of students at a particular moment in time, which will offer useful information about the possible effects of the decision to omit mathematics off the curriculum. The survey design was suitable to collect the data systematically using a diverse sample, which helped to identify the patterns and relationships between the variables of interest.

The study population was a sample that comprised of secondary school students and teachers in the North-East of Nigeria, both in the public and the privates. In particular, the students attending non-STEM academic streams (including the arts and social sciences) were targeted, where avoiding mathematics is more prevalent. There were 22 teachers and 420 students participating in the study. The students came out of the six states in the region in order to have representation of the region but the teachers were those who were directly involved with the students in these non-STEM track.

The stratified random sampling method was also used to make sure that the sample represented the varied features of the population especially in gender and academic stream. Students were grouped into two categories; the ones who did not show interest in mathematics and the ones who proceeded with mathematics. Students in these groups were further stratified by their academic stream (arts/social sciences) to make the representation balanced. The

teachers were chosen according to their participation in the non-STEM mathematics education.

Two standardized data collection instruments were used to collect data, each aimed at evaluating the important constructs of the study:

Cognitive Skills Assessment (CSA) - It is a 24-item tool that assessed critical thinking, analytical reasoning, and problem-solving abilities among the students.

Career Readiness Competency Scale (CRCS) - A 28-item scale that predicts the readiness of students in their future career based on their performance in such areas as quantitative reasoning, decision-making, and communication.

The two instruments proved to be very high in their internal-consistency with Cronbach alpha of CSA at 0.83 and 0.85 in CRCS, which implies that the tools were consistent in reliability in measuring the constructs of interest.

In a bid to guarantee validity of the instruments, subject-matter specialists in mathematics education and cognitive psychology made the evaluations. These professionals checked them on the content criteria and suitability in the framework of the educational system of Nigeria. There was also a pilot study to make refinements of the instruments and ensure that they are applicable to the target population.

Cronbachs Alpha was used to measure reliability and the CSA and CRCS had a value of 0.83 and 0.85 respectively thus showing high levels of internal consistency. This implies that the measures are always capturing the constructs of interest and can be known to have the same results in various settings.

The data were collected during a period of three weeks in the form of structured surveys that were conducted in the

classroom. The teachers were informed about the aim of the study and given the responsibility of administering the surveys to the students. The volunteer participation was given and students were also told that their replies would not have any impact on their grades. Participants were fully informed and parental consent was requested in children who were below 18 years. Each school had research assistants to help in the administration of survey questionnaires, consistency in data collection, and respondent queries.

Thereafter, the data obtained after the completion of the survey were coded and analyzed through the Statistical Package of the Social Sciences (SPSS). The analysis procedures that were used are as follows:

The means, standard deviations, and frequency tables were computed to give a summary of data and profile the perceptions of students and teachers concerning the role of mathematics in cognitive development and career readiness.

Inferential Statistics: ANOVA and the independent t-tests were employed to find out how significantly different were the cognitive abilities and career readiness of the students, who both did not take mathematics and the ones who did. In the analysis, gender, academic stream, and academic achievement were also taken into account as miscellaneous variables to determine the possible confounding variables.

Results

Data from the survey was collected and analyzed using the methods of descriptive analysis and inferential analysis which are contained in the tables. The following tables have been prepared to assist in answering the research questions.

Research Question 1: To what extent does the incorporation of mathematics in the curriculum of the arts and social sciences impact students' critical thinking skills?



Table 1: Mathematics and Critical Thinking Development

Item	Mean	SD	Decision
Mathematics helps me think critically in arts/social science subjects	4.12	0.89	Agree
Mathematical reasoning aids my ability to analyze social or artistic phenomena	3.95	0.92	Agree
I apply mathematical methods (logic, patterns, structures) to solve problems in other subjects	4.03	0.76	Agree
Mathematics improves my ability to evaluate arguments and evidence	4.18	0.84	Agree
I am confident about how mathematics develops critical thinking	3.80	1.10	Agree
Mathematics enhances my ability to analyze issues in arts/social sciences	3.60	1.20	Agree
Mathematics instruction strengthens my general problem-solving skills	3.50	1.00	Agree
I frequently apply mathematical thinking across non-STEM subjects	3.20	1.00	Neutral
Mathematics is important for my future career readiness	3.90	0.80	Agree
Grand Mean	3.92	0.94	Agree

Grand Mean = 4.07

Respondents' responses on how they see mathematics as an aid in their arts and social science subjects' critical thinking skills have been addressed in this table. The results are indicating that math helps students in their critical thinking skills in arts and social science subjects obtaining an average of 4.07. The students also widely agreed to that math helps in social or artistic phenomenon (mean = 3.95) and in logical problem solving (mean = 4.03). The students have their grand mean of 4.07 demonstrates that they see math as an important domain in the further development of students' critical thinking and problem solving skills. Although students have high levels of agreement regarding the need of math for the workforce despite having a neutral response to the application of math in non-STEM fields at 3.20 for frequency as seen in the

importance of math for workforce preparedness (mean = 3.90), students also made complaints concerning the non-STEM fields to have low levels of math engagement.

Statistical Tool: Data gathered from the Likert scales answers provided by the students were analysed using descriptive statistics (mean and standard deviation). The explanation of the mathematics pertaining to critical thinking was derived from the mean average and the dispersion of the answers from the students were explained by the standard deviation.

Research Question 2: In what ways are mathematical concepts integrated into arts and social science subjects to enhance students' analytical and problem-solving skills?



Table 2: Integration of Mathematical Reasoning in Arts and Social Sciences

Item	Mean	SD	Remark
Frequency of teachers integrating mathematical reasoning in lessons	3.44	1.10	Neutral
Students are taught to apply mathematics to real-world problems in non-STEM subjects	3.76	0.88	Agree
Integration of mathematics enhances problem-solving abilities	4.12	0.83	Agree
Understanding mathematical models improves ability to interpret social or artistic trends	3.95	0.76	Agree
Grand Mean	3.83	—	Agree

Grand Mean = 3.83

The second table analyzes the extent to which abstract mathematical concepts are incorporated in the arts and social sciences. The data suggests that students feel that the mathematical reasoning to some degree adds to their ability to solve social or artistic data (mean = 4.12) and helps them recognize the patterns (mean = 3.95). However, there is still an uneven degree of transdisciplinary integration of mathematics, as reflected in the neutral mean of 3.44, which suggests that arts and social science teachers do not frequently integrate mathematical reasoning into their lessons. The overall mean of 3.83 indicates that the level of integration, though still meaningful, can be enhanced.

Statistical Technique: The level of mathematical integration in the units of study in the curriculum is best reflected by the mean and standard deviation of the scores. The data also provide evidential support for the need of greater consistency in the integration of the mathematical concepts.

Research Question 3: What are the attitudes of students and educators towards the role of mathematics in developing critical thinking within arts and social science education?

Table 3: Students' and Teachers' Attitudes Toward the Role of Mathematics in Developing Critical Thinking.

Attitude Indicator	Students' Mean	Students' SD	Educators' Mean	Educators' SD	Overall Interpretation
Mathematics is essential for developing critical thinking in non-STEM subjects	4.12	0.89	4.25	0.71	Both groups strongly agree; educators show slightly stronger conviction.
Mathematical reasoning improves analytical skills in arts/social sciences	3.95	0.92	4.10	0.81	Consensus that mathematics enhances analytical ability.
Mathematical reasoning is frequently integrated in lessons	3.44	1.10	3.32	0.94	Both groups report limited frequency;



Confidence in applying/using mathematical reasoning within non-STEM subjects	3.60	1.20	3.45	0.88	integration is inconsistent. Students feel slightly more confident than teachers.
Mathematics enhances the ability to evaluate arguments and interpret evidence	4.18	0.84	4.18	0.77	Perfect alignment: both strongly agree.
Curriculum supports cross-disciplinary mathematical integration	3.20	1.00	3.20	1.02	Both groups agree the curriculum provides insufficient support.
Grand Mean	3.75	—	3.75	—	Overall positive attitudes from both students and educators.

Grand Mean = 3.5

This table showcases the difference in outlook on the importance of mathematics in the development of students' critical thinking skills on the part of students themselves as opposed to teachers. Results of the analysis show that students (mean=3.75) and educators (mean=3.75) both lean toward the view that mathematics contributes significantly to the development of students' analytical abilities. However, both educators and students remain neutral in the position that their classes incorporate and use mathematical reasoning (mean=3.44 for students, 3.32 for educators). Also, both educators and students deeply believed that mathematics contributes significantly to the students' skills in evaluating and analyzing arguments and evidence (mean=4.18), which shows that there is common understanding regarding the centrality of mathematics in critical thinking skills.

Statistical Tool: As in this table, descriptive statistics (mean, standard deviation) were used for this statistical analysis. The

comparison of means for students and educators shows that both groups appreciate the role of mathematics in critical thinking, yet there is a gap in its application.

Discussion

The findings of this research show beyond a doubt that, when mathematics are incorporated in the course curriculum, it facilitates the conduction of critical thinking due to retaining of higher-order thinking skills like analysis and evaluation as illustrated by the high grand mean of 4.07. There was a positive attitude that students showed when applied mathematics enhanced their ability to solve problems in non-STEM disciplines. Despite the indication of a value that is close to the neutral value (mean = 3.44), to show the inconsistent frequency of such integration by the teachers, the overall results indicate the importance of mathematics in improving cognitive flexibility and problem-solving skills.



This is in line with the works of Hidayat (2025), who conducted a meta-analysis study that showed that metacognitive training on mathematics plays an important role in reflective and evaluative thinking that are essential in non-mathematical areas. Moreover, Arysad et al. (2023) also discovered a beneficial correlation between mathematics education and critical thinking, which supports the idea that mathematical reasoning is what adds greater rigorousness to analytical abilities.

Besides, there was a positive attitude regarding the integration of mathematics in students and teachers with a mean of 3.52 (grand mean). This reflects Lehmann and Urayama (2025) that introduced a rationalization of mathematics into the curriculum as students could become more creative and analytical particularly in the disciplines that are historically non-STEM. The fact that mathematical problem solving is reasonable in the number of occurrences during the lessons, however, implies incomplete curriculum coverage. The results are also echoed by OECD (2024a) which underscored that although integration of creative thought and mathematical reasoning is a key to driving innovation, it has not been applied in consistency in other subjects.

Additionally, the research states that even the students who are conscious of the possible advantages of mathematics, particularly in arts and social sciences, are encountering the lapses in actual cross-disciplinary integration. This feeling of inferiority is in line with Steflitsch (2025), who suggested that the students and teachers acknowledge the necessity of mathematical reasoning, but there is a practical issue in implementing these abilities in non-STEM programs completely.

Overall, the research highlights that the phenomenon of non-STEM not only

deprives students of their cognitive growth but also makes them less ready to solve complicated problems in different professions. The findings can be justified by the OECD (2024b) study, which concluded that less skilled people in math are less likely to have jobs and earn less, as well as have poorer financial literacy and struggle to make informed choices in their life both personal and professional.

Conclusion

The case study aims to examine the problem solving, analytical, and critical thinking skills to see how these skills are enhanced when math is integrated into the arts and social sciences curriculum at the secondary school level. The results indicate that students see a positive relationship between the integration of these skills and the enhancement of critical and reasoning skills, as they had high grand means in these areas (4.07). However, student responses indicated their understanding surrounding their ability to think critiques the social, art, and argumentative components. There was a moderate understanding, grand means of 3.83, in the positive integration of math into the arts and social sciences curriculum. The positive attitude that students had towards math, was not reflective of the integration of math that teachers presented, which indicates that students are aware of the math concepts applicable to social arts and sciences, but teachers are not structuring their teaching in a way that math is viewed as relevant to the non-STEM subjects. The results of the study find that math is a key cognitive skill the is needed in on the non-STEM subjects, and it is not being fully explored, due to minimum inter-subject teaching practices.

Recommendation

Based on the findings of this study, several recommendations are proposed to enhance the integration of mathematics in non-STEM secondary education and improve

students' cognitive development and career readiness:

- 1 Measure the Impact of Interdisciplinary Teaching Models: The impact on the application of mathematical understanding when arts and social science curricula are integrated with mathematics through and interdisciplinary teaching approach would make for an interesting area of scholarship.
- 2 Explore Attitude Towards Mathematics Across Different Sectors: The attitudes of students across various socio-economic and academic divisions towards math as a foundation for critical thinking would assist to improve the instructional design of disengaged students.
- 3 Assess Outcomes of Specialized Teacher Training: The extent to which arts and social science education achieves the goals of mathematical reasoning is a function of the confidence and instructional methods of the educators. How specialized training of these educators impacts outcomes becomes an interesting area of research.

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