DOI: 10.56773/bj.v4i1.57
E-ISSN: 2809-8528

Brillo Journal
Volume 4, Issue 1, December 2024, pp. 1-14

CRITICAL THINKING SKILLS: COMPARATIVE ASSESSMENT OF FURTHER MATHEMATICS AND NON-FURTHER MATHEMATICS STUDENTS IN PUBLIC AND PRIVATE SCHOOLS

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Abstract

Critical thinking skills, essential for daily progress and academic success, are rarely studied in relation to Further Mathematics. This study compared the critical thinking skills of further mathematics and non-further mathematics students in Alimosho, Lagos, Nigeria. A total of 310 participants, including 153 further mathematics and 157 non-further mathematics students, were purposively selected from public and private secondary schools. Data were collected using a valid and reliable questionnaire (r=0.82) and analyzed using descriptive and inferential statistics, including frequency, mean, standard deviation, and t-test at a 0.05 significance level. The results revealed a significant difference in critical thinking skills between further mathematics and non-further mathematics students in public secondary schools. Similarly, a significant difference was found in the critical thinking skills of public and private school students, regardless of whether they studied mathematics. No significant difference was observed in the critical thinking skills of students taking further mathematics compared to those who did not, across both types of institutions. The study recommended that mathematics teachers focus on fostering critical thinking skills beyond problem-solving in further mathematics to support students' overall development.

Keywords: Critical thinking skills, Further mathematics, Gender, Public school, Private school.

Abstrak

Keterampilan berpikir kritis, yang penting untuk kemajuan sehari-hari dan kesuksesan akademik, jarang dikaji dalam kaitannya dengan Matematika Lanjutan. Penelitian ini membandingkan keterampilan berpikir kritis antara siswa Matematika Lanjutan dan non-Matematika Lanjutan di Alimosho, Lagos, Nigeria. Sebanyak 310 peserta, terdiri dari 153 siswa Matematika Lanjutan dan 157 siswa non-Matematika Lanjutan, dipilih secara purposif dari sekolah menengah negeri dan swasta. Data dikumpulkan menggunakan kuesioner yang valid dan reliabel (r=0,82) dan dianalisis dengan statistik deskriptif dan inferensial, meliputi frekuensi, rata-rata, simpangan baku, dan uji-t pada tingkat signifikansi 0,05. Hasil penelitian menunjukkan adanya perbedaan signifikan dalam keterampilan berpikir kritis antara siswa Matematika Lanjutan dan non-Matematika Lanjutan di sekolah menengah negeri. Demikian pula, ditemukan perbedaan signifikan dalam keterampilan berpikir kritis antara siswa sekolah negeri dan swasta, terlepas dari apakah mereka mempelajari matematika atau tidak. Namun, tidak ada perbedaan signifikan dalam keterampilan berpikir kritis antara siswa Matematika Lanjutan dan non-Matematika Lanjutan di kedua jenis institusi tersebut. Penelitian ini merekomendasikan agar guru matematika lebih menekankan pengembangan keterampilan berpikir kritis yang melampaui pemecahan masalah dalam Matematika Lanjutan untuk mendukung perkembangan siswa secara keseluruhan.

Kata kunci: *Kemampuan berpikir kritis, Matematika tingkat lanjut, Jenis kelamin, Sekolah negeri, Sekolah swasta.*

How to Cite: Etuk-Iren, O. A., Bakre, O. F., & Lawal, R. F. (2024). Critical Thinking Skills: Comparative Assessment of Further Mathematics and Non-Further Mathematics Students in Public and Private Schools. *Brillo Journal, 4*(1), 1-14.

INTRODUCTION

Contemporary innovations and challenges have given rise to modern-day skill requirements by which the 21st century is acclaimed to be driven. Communication, collaboration, critical thinking, creativity, and problem-solving are part of these abilities required for success in the present century. Education of students in general and mathematics education in specific should therefore not be void of this important skill development lest the products of our curriculum become globally uncompetitive and obsolete. Corroborating the importance of critical thinking, researchers Evendi et al. (2022) adjudged it as a core graduate competency that occurs as one of the most important skills in the 21st century and should be instilled in learners through intensive tasks.

Critical thinking has been defined in varying ways. Syafril et al. (2020) defined critical thinking as the careful application of reason in the determination of whether a claim is true. To Holmes et al. (2015), critical thinking is perceived as active thinking in which it assesses and analyzes information in order to determine the best course of action based on reason whereas Alwehaibi (2012), explains that the tools for the mind generally needed to think through issues for study and daily life is provided by critical thinking. Clearly, developing students' ability to think critically is not only a major objective of secondary school mathematics but also an essential means of enhancing academic dynamism to help students adapt, stay updated with current trends, and contribute to the advancement of scientific societies.

In the process of developing this skill, students acquire other abilities that are useful for achieving future goals (Alwehaibi, 2012). In Figure 1, Sarigoz (2012) highlighted five strands of critical thinking: reasoning, problem-solving, analysis, decision-making, and evaluation. These strands are further supported as cognitive strengthening, the achievement of investigation, analysis, inference, conception, and appraisal by Awofala and Lawal (2022).

A closer look at the strands of critical thinking includes reasoning—a skill that involves using cognitive thinking through a logical approach, which enables students to solve mathematical problems using the fundamentals of the subject. In mathematics education, the four types of reasoning include deductive, inductive, abductive reasoning,

and reasoning by analogy (Kollosche, 2021). Problem-solving is an activity that bridges the gap between an undesirable situation (problem) and its solution. As a dominant activity in mathematics, problem-solving is a component of critical thinking, engaging knowledge, facts, and data to solve problems, even outside the classroom (NCTM, 2000). Problem-solving is essential in life and the mathematics learning process, as it connects students with real-world situations (Jacob, 2012; Putri & Wutsqa, 2019) and significantly impacts a learner's critical thinking skills (Çelik & Özdemir, 2020). Analysis involves breaking down a concept into its components for deep consideration, identifying its basis, connections, and potential solutions.

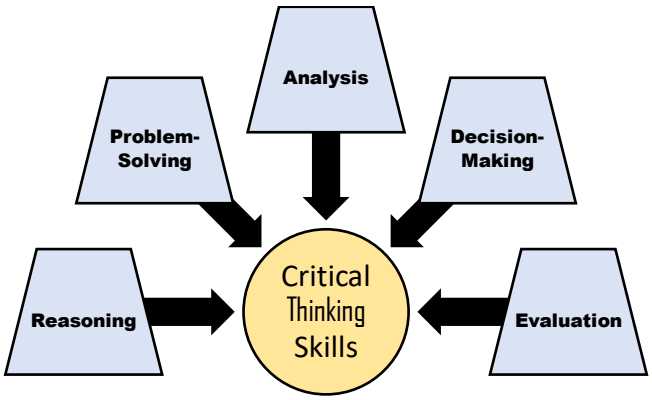

Figure 1. Strands of critical thinking (Sarigoz, 2012)

Decision-making is the process of identifying problems and existing alternatives, then providing solutions to these problems. This construct can also be seen as the identification and determination of a given situation and deciding what actions to take in such a context. Evaluation involves the appraisal of issues in an objective manner. It includes scrutinizing information to make judgments. This construct is also considered one of the higher-order thinking skills within Bloom's taxonomy of the cognitive domain (Anderson & Krathwohl, 2001).

Students who develop as good critical thinkers are meticulous, attentive to details, and engage in resourceful attempts of mathematical exercise leading to a productive disposition to the study of the subject (Awofala & Lawal, 2022). Such learners make reasoned decisions and do not resort to guesses being mindful of the process and not just the product, hence they portray determination to get a goal by making correct choices amid various alternatives (Sarigoz, 2012).

Jacob (2012) established that the development of critical thinking skills can improve

mathematics achievement among students. Chukwuyenum (2013) found a significant relationship between critical thinking and higher-order thinking, reasoning, mathematical thinking skills and problem-solving sub-dimensions. As well, significant predictors of critical thinking were found to have reasoning, mathematical thinking skills, and problem-solving sub-dimensions.

Firdaus et al. (2015) in a quasi-experimental study found positive effects of the use of mathematical learning modules based on Problem-based Learning on critical thinking skills in mathematics students. Sherafat and Murthy (2016), in a comparative study of private and government school students in India, found that students from private schools outperformed their government school counterparts on the critical thinking scale used to assess ability, although poor critical thinkers accounted for more than half of the sample. Hananto and Kusmayadi (2018), exploring the critical thinking skills of junior high school students, concluded that students' critical thinking process in solving geometry problems was below satisfactory. Orhan and Tekin (2022) observed that high school students scored high on each critical thinking skills subscale; however, a significant difference was observed in the possession of these skills based on gender and parents' educational background. Furthermore, neither age nor class level had a significant influence on participants' scores on the subscales or the overall scores. Awofala and Lawal (2022) correlational study showed statistically significant relationships between critical thinking strands and students' achievement. The five strands examined were found to be predictors of quantitative reasoning achievement among the participants.

Studies found in literature repeatedly focused on the use of different methods to foster critical thinking skills, appraisal of students' critical thinking skills in a branch of mathematics, and attempts to determine the association between critical thinking skills and other skills or constructs. As well, the studies concentrated on mathematics and quantitative reasoning as a subject conspicuously leaving out further mathematics. This indicates a paucity of literature on studies that focus on further mathematics and critical thinking skills in secondary schools, which is the gap this study intends to fill.

Mathematics as an important component in the education of secondary school students, is a symbol for improving logical reasoning and developing useful skills. To complement the concepts presented in mathematics, further mathematics as a subject was introduced into the Nigerian education curriculum in response to a recommendation at a

national workshop on policies and strategies for the improvement of the teaching and learning of mathematics at all levels (Odili & Asuru, 2011). Further mathematics exposes senior secondary school students to topics in advanced-level mathematics to enhance students' level of mathematical thinking.

Further Mathematics, however, is a tool for insight into the application of science and technology by playing the vital role of introducing students to the concepts needed for technological and national development in a deeper and wider form leading to the development of nations across the globe (Kang'ahi et al., 2012). While mathematics holds a compulsory status within the Nigerian educational system, further mathematics is offered by students who find it suitable or are willing to explore advanced concepts in mathematics at their level (Lawal, 2019). The Federal Ministry of Education stipulates that Further mathematics as a subject is intended for students who wish to study science, engineering, and mathematics. This accounts for why the number of students offering the subject is limited and mostly made up of science students.

Further mathematics introduces a wide range of pure and applied content such as matrices, complex numbers, and some topics in the mathematics curriculum presented at a slightly advanced level such as sets and circles. This may explain why further mathematics students were found to excel better than their colleagues who do not offer the subject (Oluwatusin & Dele-Rotimi, 2017). The subject is aptly described as one which requires problem solving and could be affected by sentiments (Ozturk & Guven, 2016).

Students' offer of further mathematics may be influenced by demographic variations such as gender as earlier identified in the studies of Sherafat and Murthy (2016) and Orhan and Tekin (2022). Ownership of the school (public or private) is another factor in this category that may influence, to some extent, class size, availability of instructional resources, and the overall learning environment. Public secondary schools in Nigeria are usually more populated than private ones due to the more affordable access they provide to education, allowing citizens with lower socioeconomic status to take advantage of academic opportunities. The importance of these variables for a clearer understanding informed their inclusion in the investigation of senior secondary school students' critical thinking skills, based on students' enrollment in further mathematics.

From the foregoing, the study is targeted at examining the critical thinking skills of

students based on their offer of further mathematics, gender, and school ownership (private and public). An assessment of students' ability on the five constructs that make up critical thinking skills was also conducted.

Research questions

(RQ1) What is the level of critical thinking skills possessed by further mathematics and non-further mathematics students?; (RQ2) What is the level of critical thinking skills possessed by male and female students?; (RQ3) What is the difference in the critical thinking skills of further mathematics and non-further mathematics students in private schools?

Hypotheses

(H01) There is no significant variance in the critical thinking skills of further mathematics and non-further mathematics students; (H02) No significant difference exists in the critical thinking skills of public and private school students; (H03) The difference in the critical thinking skills of further mathematics and non-further mathematics students in public schools is not significant.

RESEARCH METHODS

The study adopted the survey research design while the population of study was the Alimosho local government area which is the largest local government area in Lagos State. The local government houses 25 public schools comprising 15,394 male and 16,071 female senior secondary students. Within the local government, are 709 private schools attended by 19,236 male and 18,490 female students. Using the purposive sampling technique, 157 students who offered further mathematics were selected whereas 153 who did not offer further mathematics were randomly selected from three public and four private senior secondary schools in the local government area.

The instrument used for data collection is a 35-item critical thinking skills questionnaire adapted from Sarigoz (2012) and validated by two experts. Upon pilot testing, the reliability coefficient of the questionnaire was found to be 0.824 using Cronbach alpha statistics. Descriptive data were analyzed using frequency, percentages, mean, and standard deviation, while hypotheses were tested at the 0.05 level of significance (α=0.05) using *t*-test statistics. Data was collected manually in a face-to-face

manner after due permission was obtained from the school administrator.

RESULTS AND DISCUSSION

The study involved 310 senior secondary school students whose demographic profiles are shown in Table 1.

Table 1. Respondents' profile

Variable	Profile	Frequency	Percentage
Gender	Male	170	54.8%
	Female	140	45.2%
School Ownership	Private	115	37.1%
	Public	195	62.9%
Offer of Further Mathematics	Yes	157	50.6%
	No	153	49.4%

Table 1 showed the respondents' profile in this study based on gender, school ownership, and the offer of further mathematics. In terms of gender, the majority of the respondents were male, with 170 individuals (54.8%), while female respondents totaled 140 (45.2%). Regarding school ownership, most respondents attended public schools, with 195 individuals (62.9%), while only 115 individuals (37.1%) attended private schools. In terms of the offer of further mathematics, the respondents were almost equally divided, with 157 individuals (50.6%) taking the subject, while 153 individuals (49.4%) did not. Overall, this table showed a fairly balanced distribution of respondents by gender, with a larger number from public schools and nearly half of the respondents taking further mathematics.

The distribution of respondents, as shown in Table 1, indicated a relatively equal split between students who took further mathematics and those who did not, with a larger proportion from public schools. This balance set the stage for exploring how the offer of further mathematics might have influenced the development of critical thinking skills. To address this, we turned to the first research question, (RQ1): What was the level of critical thinking skills possessed by students based on the offer of further mathematics? Table 2 provided an overview of students' scores on the strands of critical thinking skills, segmented by their enrollment in further mathematics.

In Table 2, except for the reasoning strand on which further mathematics students' mean (M=6.28) was lower than non-further mathematics students (M=7.44); further

mathematics students had higher points on the skills scale than non-further mathematics students although the margins are close. Further mathematics students' mean scores on the problem solving, analysis, decision-making, and evaluation strands of the critical thinking scale (22.23, 22.85, 23.23, and 22.24, respectively) were higher than those of non-further mathematics students (22.58, 22.28, 22.91, and 22.23, respectively).

Table 2. Students' critical thinking scores by further mathematics enrollment

Offer of Furthermath		Reasoning	Problem Solving	Analysis	Decision Making	Evaluation
Yes	Mean	6.28	22.23	22.85	23.23	22.24
	N	157	157	157	157	157
	SD	2.268	3.348	2.748	2.539	2.575
No	Mean	7.44	20.58	22.28	22.91	22.23
	N	153	153	153	153	153
	SD	2.431	3.470	3.020	3.195	3.242
Total	Mean	6.85	21.41	22.56	23.07	22.24
	N	310	310	310	310	310
	SD	2.417	3.502	2.899	2.885	2.917

The analysis revealed that the standard deviation values for further mathematics students were consistently lower than those of non-further mathematics students across all strands, indicating that the former group exhibited greater consistency and higher homogeneity in their critical thinking skills. Building on this observation, the second research question explores whether gender plays a role in shaping the level of critical thinking skills among students, (RQ2): What is the level of critical thinking skills possessed by students based on gender?

Table 3. Participants' scores on the strands of critical thinking skills based on gender

Sex		Reasoning	Problem Solving	Analysis	Decision Making	Evaluation
Male	Mean	6.76	21.52	22.48	23.17	22.25
	N	170	170	170	170	170
	SD	2.109	3.445	2.896	2.622	2.667
Female	Mean	6.97	21.27	22.64	22.95	22.22
	N	140	140	140	140	140
	SD	2.755	3.580	2.912	3.179	3.214
Total	Mean	6.85	21.41	22.56	23.07	22.24
	N	310	310	310	310	310
	SD	2.417	3.502	2.899	2.885	2.917

As presented in Table 3, regarding students' gender, the mean scores of male students

on the problem solving, decision-making, and evaluation strands (21.52, 23.17, and 22.25, respectively) were higher than those of females (21.27, 22.95, and 22.22, respectively). However, females had slightly higher mean scores on the reasoning and analysis strands (6.97 and 22.64, respectively) compared to their male counterparts (6.76 and 22.48, respectively).

As presented in Table 3, the analysis of students' gender showed that male students had higher mean scores on the problem solving, decision-making, and evaluation strands (21.52, 23.17, and 22.25, respectively), while female students scored slightly higher on the reasoning and analysis strands (6.97 and 22.64, respectively). This provides insight into how gender may influence students' performance across various critical thinking strands. Building on this, the third research question examines whether school ownership has an impact on the level of critical thinking skills possessed by students, (RQ3): What is the difference in the level of critical thinking skills possessed by students based on school ownership?

Table 4. Strands of critical thinking skills based on school ownership

Type of school		Reasoning	Problem solving	Analysis	Decision making	Evaluation
Public schools	Mean	7.14	21.68	23.01	23.24	22.24
	N	195	195	195	195	195
	SD	2.628	3.492	2.928	2.990	3.087
Private schools	Mean	6.40	20.95	21.78	22.80	22.23
	N	115	115	115	115	115
	SD	1.960	3.486	2.690	2.696	2.628

A comparison of students' critical thinking skills by school ownership (public and private), as displayed in Table 4, shows that, overall, public school students consistently outperformed private school students across the strands, based on the mean values. This prompts a deeper examination into the impact of the offer of further mathematics on critical thinking skills, leading to the first hypothesis test, (H01): There is no significant variance in the critical thinking skills of further mathematics and non-further mathematics students. Table 5 presents the results of the *t*-test conducted to explore this hypothesis.

Inferential statistical analysis of the critical thinking ability of the general pool of further mathematics and non-further mathematics students, regardless of school ownership, as presented in Table 5, reveals no statistically significant difference between

both categories, with a *Sig.*>0.05.

Table 5. *t*-test of critical thinking skills based on offer of further mathematics

Variable	Offer of Further Maths	N	*df*	Mean	SD	*t*	*Sig.*
Critical Thinking	Non F/M	153	308	96.255	7.161	0.662	0.509
EVA	F/M	157		95.660	8.567		

This leads to the second hypothesis, which examines whether school ownership affects critical thinking skills, (H02): No significant difference exists in the critical thinking skills of public and private school students.

Table 6. *t*-test of students' critical thinking skills based on school ownership

Variable	School Ownership	N	*df*	Mean	SD	*t*	*Sig.*
Critical Thinking	Public	195	308	97	8.153	3.079	0.002
EVA	Private	115		94.179	7.133		

Investigation into the critical thinking ability of further mathematics students from public and private schools through self-assessment reveals no significant difference, with a *Sig.*>0.05. However, further analysis indicates that public school students exhibit statistically significant higher critical thinking skills than their private school counterparts. As a result, the hypothesis is rejected, confirming that a significant disparity exists between the critical thinking skills of private and public school students. This leads to the third hypothesis, which examines whether the difference in critical thinking skills between further mathematics and non-further mathematics students in public schools is significant, (H03): The difference in the critical thinking skills of further mathematics and non-further mathematics students in public schools is not significant. Table 7 presents the results of the *t*-test for public school students' critical thinking skills based on their offer of further mathematics.

Table 7 shows the Equal Variances Assumed (EVA) analysis of further mathematics and non-further mathematics students' critical thinking skills based on whether they offer further mathematics or not. The *Sig.*=0.017<0.05 established the significance of the difference in the critical thinking ability of students offering the subject as better than their colleagues who do not in public schools.

Table 7. *t*-test of public school students' critical thinking skills by further mathematics enrollment

Variable	Offer of Further Mathematics (Public school students)	N	*df*	M	SD	*t*	*Sig*.
Critical Thinking (EVA)	Yes	68	193	98.897	6.869	2.407	0.017
	No	127		95.984	8.618		

Discussion of findings

Critical thinking skills, as a 21st-century skill, are clearly fostered by secondary school students' enrollment in further mathematics, as evidenced by the higher mean scale points of further mathematics students compared to their non-further mathematics peers, except for the Reasoning strand. This is supported by Moneva et al. (2020), who stated that students' critical thinking ability is essential in problem-solving and analyzing mathematical problems. The study of the subject could have far-reaching effects on the overall development of students, providing them with deeper insights into creativity and personal innovation through the rigorous concepts presented in the curriculum. Both male and female students scored highly on the scale, which aligns with the findings of Orhan and Tekin (2022), who also observed high scores across the strands. However, in this study, the mean values for male students were slightly higher in the reasoning and analysis components of critical thinking, while males outperformed females in problem solving, decision-making, and evaluation.

Inferential statistics however revealed that the difference observed in students' scores on the critical thinking scale may not be generalizable as it was found to lack statistical significance. This could be due to the lumping of students from private and public schools within the overall sample although public school students consistently displayed higher mean along the critical thinking strands when compared with the private school counterparts. On a closer analysis of critical thinking skills between further and non-further mathematics students in the public schools, a significant difference was found to the benefit of further mathematics students buttressing the impact of the more rigorous and intensive concepts presented to such students as confirmed by Awofala et al. (2020) and Chukwuyenum (2013). Nigerian public school students are known to be a lot more independent, displaying some element of native intelligence (a form of reasoning) due to their socio-economic background which may impact their critical thinking skills as they

are more prone to seeking means of survival as opposed to private school students who bear a relatively higher socio-economic status on this part of the globe. This however contrasts with Sherafat and Murthy (2016) who found that private school students had better critical thinking skills than government learners. Mostly modern parents as well, do not help private school students as they get overprotective and in the process attempt to do all the thinking for their wards, hence these wards lack more of problem-solving, decision-making, and evaluation skills. Also worthy of note is the advantage of a relatively higher chronological age among public school students, which may be one of the factors accounting for the significant disparity observed although Orhan and Tekin's (2022) study stated otherwise for a different clime.

CONCLUSION

The study concluded that offering further mathematics indicates better critical thinking skill possession and development in public secondary schools. However, in comparison with private school students, other factors beyond the scope of the present study may also interplay in this development of the skill. Public school students' critical thinking skill is significantly greater than private school students' possession of the ability within the local government examined.

Based on the findings of the study, the following are suggested: (1) Mathematics teachers should not just focus on students' problem solving skills but other aspects of critical skills to build students up in all aspects; (2) Teachers should engage further mathematics students more in exercises requiring reasoning not only with questions requiring calculations; (3) All senior secondary school students should be encouraged to offer further mathematics in schools as it is found to significantly influence critical thinking ability which is a 21st century skill; (4) Further studies can be conducted in this regard to investigate other factors apart from further mathematics which account for level of critical thinking in private school students.

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