



Self-Reflection and Open-Mindedness Critical Thinking Dispositions as Predictors of Students' Procedural Fluency Skills in Mathematics in Cross River State

Bassey, Ferdinand Ele, Agah, John Joseph & Nnaji, Anayo David
Department of Science Education, University of Nigeria, Nsukka
Corresponding Author: anayo.nnaji.92400@unn.edu.ng

Abstract

The study sought to predict students' procedural fluency skills in Mathematics by their self-reflection and open-mindedness critical thinking dispositions in Cross River State, Nigeria. three research questions guided the study, while three hypotheses were tested at 0.05 alpha level of significance. The predictive correlational research design was used in the study. The population of the study comprised 4,420 SS2 students in Ikom Educational Zone, Cross River State. The sample for this study was 367 SS2 students drawn by multistage sampling procedure. Self-reflection and Open-mindedness Critical Thinking Disposition Scale (SOCTDS) and Mathematical Procedural Fluency Scale (MPFS), developed by the researchers were used for data collection. SOCTDS and MPFS showed internal consistency of 0.87 and 0.86, respectively using Cronbach alpha statistic. Data were analyzed by simple and multiple linear regression analyses. Findings showed that students' self-reflection and open-mindedness critical thinking dispositions predict 28% and 36%, respectively, and jointly predict 50% of their procedural fluency skills in Mathematics. It was concluded in the study that self-reflection and open-mindedness critical thinking dispositions are crucial predictors of students' procedural fluency in Mathematics in Cross River State, Nigeria. It was recommended, among others, that teachers should encourage students to develop self-reflection and open-mindedness critical thinking dispositions for improved students' procedural fluency skills in Mathematics.

Keyword: Procedural Fluency, Critical Thinking, Dispositions, Self-reflection, Open-mindedness

Introduction

Procedural fluency has emerged as a crucial construct, and a key index in assessing students' ability in Mathematics. Although, it is often ignored by most teachers, its impact is undeniably important in Mathematics education. The National Council of Teachers of Mathematics (NCTM, 2023) opines that student require mathematical proficiency to perform well in mathematics. Its importance for mathematical success has promoted it to the front burner of research interests, especially due to the groaning stakeholders' concern for the lingering unsatisfactory achievement of students in Mathematics (Anyor & Amo, 2017; Ibrahim, Yew & Razak, 2020; Nnaji, et al., 2023).

Procedural fluency connotes students' ability to carry out mathematical procedures accurately and efficiently. According to Laswadi, Kusumah, Darwis and Afgani (2016), procedural fluency entails understanding mathematical processes, knowing when and how to employ them, and having the flexibility, accuracy and efficiency to

use them. Awofala (2017) defined procedural fluency as the efficiency, accuracy and generalizability of methods and algorithms with which a student computes based on well defined, understood relationship. In this study, procedural fluency describes students' ability to follow established mathematical procedures in an accurately flexible, efficient and time-effective manner. Empirical evidences suggest that procedural fluency fosters improved academic achievement in Mathematics (Paredes & Mendoda, 2019). Procedural fluency has been identified as key among the five strands of mathematical proficiency (Nuraida, Kusumah & Kartasasmita, 2019), and positively correlates with adaptive reasoning (Andal & Andrale, 2022). This shows a link between students' procedural fluency and their disposition to thinking, which is crucial for academic success in Mathematics.

Critical thinking for problem solving is a major requirement for academic success in

Mathematics. As an essential attribute for problem solving, critical thinking connotes the ability to analyze and interpret the relevance of an information towards a required solution especially in Mathematics (Ozel & Karakus, 2021). Interestingly, studies suggest that critical thinking can be ignited by the disposition to do so. The innate potentials that facilitate critical thinking refers to critical thinking dispositions (Ojewole & Thompson, 2014). Lai, Whittaker and Holding (2019) defined critical thinking disposition as a faculty of constructs that supports and sustains students to reason deeply. Critical thinking dispositions, encapsulate students' inclination to engage with information, ideas, arguments, and evidence along learning paths in search for the required solution (Facione & Facione, 2019). In this study, critical thinking dispositions are the affective dimension of reasoning, including attitudes, habits and inclinations which shapes student's routine ways of thinking in response to mathematical stimulus and life challenges.

Critical thinking dispositions are crucial for Mathematics problem solving. Critical thinking dispositions enhances students' propensity to think critically for problem solving. Aizikovitsh-Udi and Cheng (2015) asserted that critical thinking dispositions has been associated with problem solving. Ennis (2019) argued that with effective self-reflection, as a disposition to critical thinking, one can effectively navigate challenging situations. Furthermore, Eversen and Hmelo-Silver (2020) pointed out that open-mindedness is key to effective reflection. Drawing from both views, it is deducible to note that self-reflection and open mindedness are basic dispositions for critical thinking which can be key for mathematics problem solving. However, clarity is still needed on the predictive role of self-reflection and open-mindedness on students' procedural fluency skills in mathematics. Hence, the present study investigated self-reflection and open-mindedness critical thinking dispositions as predictors of students' procedural fluency in mathematics.

Self-reflection is a key disposition to critical thinking which is essential for initiating reasoning. Makri, Kosslyn and Berant (2020) believes that self-reflection is the intellectual humility to recognize the limitations of one's own knowledge and beliefs, and allows the individual to approach new ideas with an open mind and a willingness to revise their viewpoints based on new information. Al Adawi and Al Ajmi (2023) defined self-reflection as the disposition to inwardly review a process with new facts which may differ from one's original views. In this study, self-reflection connotes students'

readiness to take a second look to review what they think they know in line with the new mathematics knowledge encountered. Self-reflection triggers the mind to reexamine information, draw analogies, evaluations and explore deep understanding for transformation. Although Cavilla (2017) believed that self-reflection insignificantly correlates with academic performance, recent studies such as Chikhalsouk, Al Hajjar, El-Okda and Adref (2019); Akpur (2020); Sahasrabudhe (2022); and Al Adawi and Al Ajmi (2023) reveal that self-reflection improved students' academic achievement. More so, Nurhayati, Widodo, Purwianingsih and Samsudin (2025) pointed out that self-reflection correlated with students' open-mindedness. Open-mindedness can significantly facilitate students' self-reflective think disposition for insights on the solution to a mathematical problem.

Open-mindedness has been widely described as a facilitator for change. Open-mindedness entails welcoming and having respect for others' opinions (Bossér & Lindahl, 2020). According to Nurhayati, Widodo, Purwianingsih and Samsudin (2025), it is the alertness to alternatives, inadequacies, the consequences of decisions and willingness to reasoning from other standpoints, which requires respect, patience and tolerance for new information, irrespective of the source. Open-mindedness is conceptualized in this study as the willingness of students to consider and evaluate different ideas and perspectives without prejudice or bias to accept a more superior mathematical knowledge that is based on facts. Empirical evidences from the studies of Tamban and Maningas (2017); Gatzka (2020); Bossér and Lindahl (2020); Majeed and Rashid (2022); and Obilor and Sakpege (2022) revealed that open-mindedness can positively predict academic achievement through intellectual growth and reduced cognitive distortions.

The theoretical foundation for this study rests on the Three-Part Theory of Critical Thinking by Cohen (2000) which postulates that effective critical thinking is a combination of knowledge acquisition, skill development, and the cultivation of appropriate attitudes or dispositions to enable individuals to navigate complex situations thoughtfully and make reasoned judgments. The study validated the tenets of the theory by elucidating the predictive potency of students' critical thinking dispositions, which are internal constructs as students query on the reliability of new information from an external environment towards solving the problem situation, on students' procedural fluency in Mathematics. Solving problems often require engaging an efficient

procedure which is mostly lacking in Mathematics education literature. Several studies have investigated the impact of self-reflection and open-mindedness critical thinking dispositions on students' achievement in different fields of study, but literature appears to be vague on the predictive role of these critical thinking dispositions on students' procedural fluency in Mathematics in Cross River State, Nigeria. Hence, the present study sought to fill this gap by determining the predictive potency of self-reflection and open-mindedness critical thinking dispositions on students' procedural fluency skills in Mathematics in Cross River State. Specifically, the study sought to address the following research questions:

1. What is the predictive power of self-reflection on students' procedural fluency skills in Mathematics?
2. What is the predictive power of open-mindedness on students' procedural fluency skills in Mathematics?
3. What is the joint predictive power of critical thinking dispositions (self-reflection and open-mindedness) on students' procedural fluency skills in Mathematics?

The null hypotheses postulated and tested at 0.05 level of significance in the study are:

H0₁: There is no significant predictive power of self-reflection on students' procedural fluency skills in Mathematics.

H0₂: There is no significant predictive power of open-mindedness on students' procedural fluency skills in Mathematics.

H0₃: There is no significant predictive power of self-reflection and open-mindedness on students' procedural fluency skills in Mathematics.

Materials and Methods

The study adopted the predictive correlational research design. According to Nworgu (2015), a correlational research design seeks to establish the strength and direction of the relationship between predictor and criterion variables. The study sought to determine the extent self-reflection and open-mindedness critical thinking dispositions can predict students' procedural fluency skills in mathematics. The study was carried out in Ikom Educational Zone of Cross River State, Nigeria, comprising six local government areas (Abi, Boki, Obubra, Etung and Ikom). The area was chosen for the study due to students' unsatisfactory performance at external

examinations over the years in this area, and this may be due to their low critical thinking disposition.

The population of the study was 4420 senior secondary school two (SS2) students offering Mathematics in the 2023/2024 academic session in Ikom Educational Zone of Cross River State. The sample for the study comprised 367 SS2 students determined using the Taro Yamane formula and drawn by a multistage sampling procedure from the population. In the first stage, four local government areas were sampled from the six local governments areas (LGAs) that make up the educational zone using a simple random sampling technique. From each of the sampled four LGAs, a disproportionate sampling technique was used to draw three senior secondary schools (12 schools in all). A simple random sampling technique was used to draw the 367 SS 2 students from the 12 sampled schools who participated in the study.

The data for the study was collected using two instruments developed by the researchers, namely: Self-reflection and Open-mindedness Critical Thinking Disposition Scale (SOCTDS) and the Mathematical Procedural Fluency Scale (MPFS). Both instruments have two sections, Section A captured respondents' identification number and gender while Section B contained the item statements designed to capture responses on the trait of concern. Section B of the SOCTDS contained 18 item statements, nine in each of two clusters (Cluster A - self-reflection and Cluster B - open-mindedness) which captured information on critical thinking disposition. Section B of the MPFS is a single cluster 14 item statements which captured data on students' mathematical proficiency. The response options on both instruments were on the 4-point Likert scale response type, Strongly Agree (SA), Agree (A), Disagree (D) and Strongly Disagree (SD) which were rated as 4, 3, 2, and 1 respectively. The instruments were face-validated by three experts from the Faculty of Education (Measurement and Evaluation, Mathematics Education and Psychology Education Units), University of Nigeria, Nsukka. The reliability of SOCTDS and MPFS were determined using the Cronbach Alpha measures of internal consistency. For the SOCTDS, the overall reliability coefficient of 0.87 was obtained, while Clusters A and B of SOCTDS were determined as 0.78 and 0.85 respectively. For the MPFS, the reliability coefficient of 0.86 was determined for the instrument.

The data collection process commenced after obtaining clearance from the school authorities and informed consent of the students. The instruments for data collection were administered

directly to the sampled students by their regular mathematics teachers (12 research assistants) in each of the sampled schools and retrieved on-the-spot after completion to ensure a high return rate. The research assistants were properly briefed on the purpose and modalities, including guiding the students to minimize error ticking, administration and retrieval of the instruments. The data collected in the study were analysed using simple and multiple linear regression analysis in Statistical Package for Social Sciences (SPSS) version 25. Precisely, the

coefficient of determination (r^2) was used to determine the predictive power of critical thinking dispositions on students' procedural fluency in mathematics. Hypotheses 1 and 2 were tested using regression t-test, while hypothesis 3 was tested using regression F-test, all at 0.05 level of significance. The interpretation of correlation coefficient followed the criteria of Schober and Boer (2018). Also, if an exact probability value less than 0.05 was obtained, the null hypothesis was rejected, otherwise, the hypothesis was not rejected.

Results

Table 1

Regression analysis of the predictive power of self-reflection on students' procedural fluency skills in Mathematics **n = 367**

Variable	r	r ²	Adjusted r ²
Self-reflection	0.53	0.28	0.28
Procedural Fluency			

Key: n = Number of respondents, r = Correlation coefficient, r² = Coefficient of determination

The result in Table 1 shows that students' scores from their responses on self-reflection critical thinking disposition correlated with responses on procedural fluency. The result shows a correlation coefficient of 0.53. This result shows a moderate relationship between self-reflection critical thinking

disposition and students' procedural fluency. The result also shows a coefficient of determination of 0.28. This indicates that students' self-reflection critical thinking disposition predicts 28% of procedural fluency in mathematics.

Table 2

Regression test of significance for the predictive power of self-reflection on students' procedural fluency skills in Mathematics

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	26.26	1.78		14.76	0.00
	Self-reflection Critical Thinking Disposition	0.71	0.06	0.53	11.84	0.00

a. Dependent Variable: Procedural Fluency

The result in Table 2 shows a t-value of 11.84 with an exact probability value of 0.00 for the predictive power of self-reflection on students' procedural fluency skills in Mathematics. Compared with the a priori 0.05 significance level, the exact probability value of 0.00 is less than 0.05. Therefore, the null hypothesis one (H₀₁) which states that there

is no significant predictive power of self-reflection on students' procedural fluency skills in Mathematics was rejected. Hence, the inference drawn was that there is a significant predictive power of self-reflection on students' procedural fluency skills in Mathematics.



Table 3

Regression analysis of the predictive power of open-mindedness on students' procedural fluency skills in Mathematics **n = 367**

Variable	r	r ²	Adjusted r ²
Open-mindedness Procedural Fluency	0.60	0.36	0.36

Key: n = Number of respondents, r = Correlation coefficient, r² = Coefficient of determination

The result in Table 3 shows that students' scores from their responses on open-mindedness critical thinking disposition correlated with responses on procedural fluency. The result shows a correlation coefficient of 0.60. This result shows a moderate relationship between open-mindedness

critical thinking disposition and students' procedural fluency. The result also shows a coefficient of determination of 0.36 which indicates that students' open-mindedness critical thinking disposition predicts 36% of procedural fluency in mathematics.

Table 4

Regression test of significance for the predictive power of open-mindedness on students' procedural fluency skills in Mathematics

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	28.14	1.34		20.96	0.00
	Open Mindedness Critical Thinking Disposition	0.67	0.05	0.60	14.36	0.00

a. Dependent Variable: Procedural Fluency

The result in Table 4 shows a t-value of 14.36 with an exact probability value of 0.00 for the predictive power of open-mindedness on students' procedural fluency skills in Mathematics. Compared with the a priori 0.05 significance level, the exact probability value of 0.00 is less than 0.05. Therefore, the null hypothesis two (H₀₂), which states that there

is no significant predictive power of open-mindedness on students' procedural fluency skills in Mathematics was rejected. Hence, the inference drawn was that there is a significant predictive power of open-mindedness on students' procedural fluency skills in Mathematics.

Table 5

Regression analysis of the joint predictive power of critical thinking dispositions on students' procedural fluency skills in Mathematics **n = 367**

Variable	r	r ²	Adjusted r ²
Joint of Critical Thinking Dispositions Procedural Fluency	0.71	0.50	0.51

Key: n = Number of respondents, r = Correlation coefficient, r² = Coefficient of determination

The result in Table 5 shows that students' scores from their responses on the joint predictive power of critical thinking dispositions (self-reflection and open-mindedness) correlated with responses on procedural fluency. The result shows a correlation coefficient of 0.71. This result shows a strong relationship between the joint of students'

critical thinking dispositions (self-reflection and open-mindedness) and students' procedural fluency. The result also shows a coefficient of determination of 0.50 which indicates that the joint of students' critical thinking dispositions (self-reflection and open-mindedness) predicts 50% of procedural fluency in mathematics.

Table 6

Regression test of significance for the joint predictive power of critical thinking dispositions on students' procedural fluency skills in Mathematics

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3029.44	1	3029.44	239.48	.00
	Residual	1846.91	365	5.06		
	Total	4876.35	366			

a. Dependent Variable: Procedural Fluency

Result in Table 6 shows an F-value of 239.48 with an exact probability value of 0.00 for the joint predictive power of critical thinking dispositions (self-reflection and open-mindedness) on students' procedural fluency skills in Mathematics. Compared with the a priori 0.05 significance level, the exact probability value of 0.00 is less than 0.05. Therefore, the null hypothesis three (H_{03}) which states that there is no significant joint predictive power of critical thinking dispositions (self-reflection and open-mindedness) on students' procedural fluency skills in Mathematics was rejected. Hence, the inference drawn was that the joint of critical thinking dispositions (self-reflection and open-mindedness) has a significant predictive power on students' procedural fluency skills in Mathematics.

Discussion

The finding of the study showed that an increase in students' self-reflection will lead to a moderate increase in procedural fluency in mathematics. The findings of the study show that self-reflection predicts students' procedural fluency in mathematics. Also, this moderate relationship that predicts students' procedural fluency in mathematics by their self-reflection was found to be significant. Therefore, self-reflection can be used to forecast students' procedural fluency in mathematics. The reason for this result could be due to the interconnectedness of mathematical concepts which inspire deep reflection so in the process students take a self-reflection alongside the mathematical concepts. In the process, they regurgitate the instructional contents exposed to them thus privately interacting with the learning materials, which helps them to remember and better understand the procedures for tackling such mathematical problems. This result is in line with the thoughts of Makri, Kosslyn and Berant (2020) to reevaluate viewpoints based on new experiences and drawing from experiences. The findings of this study agree with those of Chikhalsouk, Al Hajjar, El-Okda and Adref (2019); Akpur (2020); and Sahasrabudhe

(2022) who found that self-reflection correlates significantly with students' academic achievement, and is beneficial to student learning, and disagree with the findings of Cavilla (2017) who found no statistically significant relationship between self-reflection and students' academic performance.

The findings of the study showed that an increase in open-mindedness will lead to a moderate increase in students' procedural fluency in mathematics. The findings of the study show that open-mindedness predicts students' procedural fluency in mathematics. Also, this moderate relationship that predicts students' procedural fluency in mathematics by their open-mindedness was found to be significant. Therefore, open-mindedness can be used to forecast students' procedural fluency in mathematics. This could be because opening ones' mind is the gateway to receptive information for learning engagements with the mathematical concepts. This makes it easier to print the learning materials in their minds of the students, minimize stress and maximize their receptibility in line with the views of Facione (2015), to enhance the students' procedural fluency in mathematics. The findings of this study agree with those of Tamban and Maningas (2017); Gatzka (2020); Majeed and Rashid (2022); and Obilor and Sakpege (2022) who revealed that open-mindedness significantly improves academic achievement among students.

The findings of the study showed that an increase in joint critical thinking disposition (self-reflection and open-mindedness) will lead to a strong increase in students' procedural fluency in mathematics. The findings of the study show that students' critical thinking dispositions jointly predicts students' procedural fluency in mathematics. Also, this strong relationship which predicts students' procedural fluency in mathematics by their joint critical thinking dispositions was found to be significant. Therefore, joint critical thinking dispositions can be used to forecast students' procedural fluency in mathematics. This result may have turned out so because critical thinking

dispositions empowers critical thinking for sound judgements and habitually propel individuals to engage in self-regulated activities for mastery in response to mathematical problems. The findings of this study agree with that of Gürol, Uslu, ErolPolat, Yiğit and Yüce (2013); and Aizikovitsh-Udi and Cheng (2015) who showed that critical thinking disposition facilitated learning. However, the finding disagreed with the findings of Azar (2010); and Ojewole and Thompson (2014) who showed that there is no significant difference between the students' critical thinking dispositions and nursing students' achievement.

Conclusion

The study investigated the predictive power of self-reflection and open-mindedness critical thinking dispositions on students' procedural fluency skills in Mathematics in Cross-Rivers State, Nigeria. Based on the findings of this study the researcher concluded that self-reflection and open-mindedness critical thinking dispositions predict students' procedural fluency skills in Mathematics, both separately and jointly. Implying that students' procedural fluency in Mathematics increases proportionately with an increase in their disposition reflect and apply open minds in receiving Mathematics learning content.

Recommendations

Based on the findings and conclusion of the study, the researchers recommended that:

1. Teachers should encourage students to develop self-reflection and open-mindedness critical thinking dispositions for improved students' procedural fluency skills in Mathematics.
2. Teachers should encourage students to receive mathematical instructional content with open minds to improve their procedural fluency in Mathematics.
3. Government should organize trainings and workshops for teachers to develop their capacities to help students develop self-reflection and open-mindedness critical thinking dispositions to foster improved students' procedural fluency in Mathematics.

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