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Intelligence Quotient And Academic Achievement In Physics: A Component-Based Empirical Analysis Among Secondary School Students In Nigeria

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Article:
Background: *Intelligence Quotient (IQ) as a measure of one's general intelligence and cognitive ability comprises of components such as Fluid Intelligence (FI), Quantitative Reasoning (QR), and Executive Functioning (EF) which are importantly capable of influencing student's academic achievement in abstract subject like physics. This examines the relationship between students' IQ and academic achievement, and how the IQ components (FI, QR, EF) contribute to achievement in Physics.*
Methodology: *The study adopted an ex-post facto descriptive survey design, using a sample of 250 physics students randomly selected from public secondary schools within the study area. Academic achievement and IQ data were obtained using the students' result broad sheet and IQ test, respectively; and analyzed using descriptive and inferential statistics at 0.05 level of significance.*
Results: *Findings showed a significantly (i) moderate positive relationship between IQ and achievement among all students ($r = 0.42$ at $p < 0.001$), with a slightly weaker relationship among female students ($r = 0.37$ at $p < 0.001$), compared to male students ($r = 0.46$ at $p < 0.001$); (ii) positive joint relationship {$R = 0.646$, $F(3, 246) = 58.25$ at $p < 0.001$, $R^2 = 0.417$} between students' IQ components (FI, QR, EF) and achievement with FI, QR, and EF jointly influencing achievement to about 41.7%; (iii) positive contributions of FI ($\beta = 0.21$, $p = 0.002$, 21%), QR ($\beta = 0.45$, $p < 0.001$, 45%) and ($\beta = 0.19$, $p = 0.002$, 19%) to achievement in Physics.*
Conclusion: *IQ is a significant determinant of academic achievement in Physics, indicating that cognitive ability such as reasoning ability, numerical and analytical competence, and executive control skills enhances students' understanding and performance in Physics.*
Key Words: *Intelligence Quotient; Fluid Intelligence; Quantitative Reasoning; Executive Functioning; Physics.*

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I. Introduction

Physics is a basic science subject generally studied at the senior secondary school levels in Nigeria, requiring abstract reasoning, ability to apply concepts and solve numerical problems coupled with high level concentration and motivation for learners to really excel in it. In essence, physics has the ability to equip learners with critical and analytical thinking skills which are useful in many science, technology, engineering and mathematics (STEM) career courses. Assem et al. (2023) opined that students learn physics by experience, giving them the chance to observe and experiment, apply knowledge, solve theoretical and practical problems, discover, and explore their environment, and further develop their talents. Scholars have stated that good foundation in physics develops in students higher degree of precision and accuracy when approaching new problems and are able to reason both deductively and inductively (Coffie et al., 2020). Consequently, students' success in Physics depends heavily on their cognitive capacities and higher-order reasoning skills.

Academic achievement can be explained as certain measurable learning outcomes in a teaching-learning systems obtained through demonstration of learners' knowledge, skills and abilities, and measured by standardized tests and examinations. Ahmead (2025) defines academic achievement as success measured through grades, tests, and learning outcomes. Other researchers have define academic achievement as the extent to which a student succeeds in their studies (Mahnaz & Kiran, 2024). So, basically academic achievement is an indicator of a learner's learning success, often influenced by the learners' cognitive abilities (such as intelligence quotient, fluid intelligence, quantitative reasoning, etc) as well as the non-cognitive factors such as classroom engagement, motivation, quality of teaching-learning techniques and assessment, self regulation, learning resilience, family and other school factors.

Intelligence Quotient (IQ) is an academic construct in form of a score, that reflect an individual's general intelligence levels and cognitive ability, such as logical thinking, reasoning, problem-solving, sensible decision-making, understanding new concept, thought and ideas organization, multidimensional visualization and understanding of knowledge from experience, and adaptation to novel situations. Tolibas et al. (2024) defines IQ as as a general mental capability involving reasoning, problem-solving, planning, abstract thinking, complex idea comprehension like reading and vocabulary, and learning from experience. According to Ilo & Onyejesi (2021), Intelligence quotient (IQ) is the number value gotten from administering an intelligence quotient test and reflects an individual's intellectual capacity, potential or natural capability. Further empirical evidence indicates that IQ is a robust predictor of academic achievement across educational levels and subject domains (Akubuilo et al., 2020; Ilo & Onyejesi, 2021; Tolibas et al., 2024; Lozano-Blasco et al., 2022; Schneider & Preckel, 2017). Contemporary models of intelligence conceptualize IQ as a multidimensional construct comprising of interrelated cognitive components that jointly support learning. Among these are, fluid intelligence, quantitative reasoning, and executive functioning which have been identified as relevant to academic achievement in STEM disciplines, including physics (Peng et al., 2020). These components underpin students' ability to reason abstractly, apply mathematical knowledge, and regulate cognitive processes during complex learning tasks.

Fluid intelligence (Gf) refers to the capacity to reason and think logically, detect patterns, and solve novel problems independently of prior knowledge, acquired knowledge or specific learned content. Contemporary cognitive models describe fluid intelligence as a central higher-order ability supporting reasoning across domains, particularly under conditions of complexity and novelty (McGrew et al., 2023). Contemporary empirical evidence shows that fluid intelligence cannot be reduced to working memory alone but reflects a broader system of controlled reasoning processes that support novel problem solving (Hagemann et al., 2023). It is particularly important in physics education, where students frequently encounter unfamiliar problem situations that require conceptual reasoning rather than rote application of formulas. Researches from the past years have demonstrated that fluid intelligence is a strong, consistent predictor of academic achievement across developmental stages and multiple domains, even in mathematics and science subjects, as it supports conceptual understanding, transfer of learning, and complex problem solving (Peng et al., 2020; Ren et al., 2015; Green et al., 2017; Tikhomirova et al., 2020). Other studies have shown a positive relationship between fluid intelligence and academic grades (including mathematics and physics), and that its relationship strengthens with task complexity, reinforcing that fluid reasoning contributes and is linked with higher academic achievement in cognitively demanding academic domains (Romero et al., 2023; Semeraro et al., 2023; Niazi & Adil, 2021). Li & Shi (2019) found that fluid intelligence predicted math and language performance but that trait emotional intelligence sometimes explained additional variance, particularly among average-ability children, highlighting the multifaceted contributors to achievement.

Quantitative Reasoning (QR) represents another essential component of IQ and involves the ability to understand, analyze, interpret, and apply numerical and mathematical information to solve problems. Richland & Zhao (2023) from a cognitive perspective opined that QR relies on relational reasoning processes that allow individuals to compare quantities, evaluate proportional relationships, and integrate numerical information under task demands. Physics learning is inherently quantitative, requiring students to manipulate equations, analyze graphical data, and reason proportionally about physical quantities. Contemporary educational research increasingly recognizes quantitative reasoning as a key cognitive factor influencing students' academic achievement across educational levels (Schneider & Preckel, 2017). Studies conducted in diverse cultural and educational contexts consistently demonstrated a strong association between quantitative reasoning and academic achievement, emphasizing that students with stronger quantitative reasoning skills achieve higher in mathematics and related subjects (Rosemary & Ibibo, 2019; Peng et al., 2020; Hamdan & Aldhafiri, 2024). Other studies have demonstrated that QR skills are strongly linked to academic achievement in mathematics and science, and they play a crucial role in students' ability to solve physics problems meaningfully rather than algorithmically (Peng et al., 2020). Nguyen & Tran (2024) further showed that quantitative reasoning significantly enhances mathematical modelling competencies among pre-service teachers, which are strongly associated with academic success in advanced mathematics. Other studies have shown that QR mediates the relationship between general intelligence and academic achievement, especially in numerically intensive subjects (Roth et al., 2015). Stadler et al. (2016) demonstrated that reasoning abilities measured in early adolescence significantly contributed to later achievement in mathematics, even after controlling for general intelligence. These findings underscore the importance of integrating quantitative reasoning development into instructional practices to enhance students' academic achievement and overall cognitive growth.

Executive function (EF) refers to a set of higher-order cognitive processes such as working memory, inhibitory control, and cognitive flexibility that are essential for goal-directed behaviour (Best & Miller, 2016; Diamond & Ling, 2016), including planning, and self-regulation. Executive reasoning enables individuals to monitor progress, suppress irrelevant responses, and adapt strategies during problem solving, thereby supporting effective reasoning under high cognitive demand (Zelazo, 2020). Research shows that executive reasoning plays a central role in everyday problem solving by enabling individuals to manage complex reasoning tasks through executive control and relational integration (Richland & Zhao, 2023). Executive function is vital in physics learning, where students must manage multiple representations, sustain attention during problem solving, inhibit misconceptions, and plan multi-step solutions. Empirical studies indicate that executive functions significantly predict academic achievement across domains and mediate the relationship between intelligence and learning outcomes (Best & Miller, 2016; Ahmed et al., 2019; Perpiñá Martí et al., 2023). Longitudinal and cross-sectional studies consistently show that executive function contributes to mathematics, reading, and general academic performance, even after accounting for intelligence, socioeconomic status, and prior achievement (Allan et al., 2019; Ahmed et al., 2019; Cirino et al., 2018; Fuhs et al., 2018; Willoughby et al., 2019). Begum et al. (2021) found those with high EFs were found to have high academic achievement than those with low EFs, and there is high correlation between EFs and academic success. McClelland & Cameron (2019) emphasized that executive function supports academic success by enabling students to regulate behavior and attention in classroom settings. Studies have also shown that executive functions (working memory, inhibition, flexibility) are consistent predictors of academic achievement, reliably predicting STEM-related achievement and enhance predictions when combined with general reasoning measures (Cortés-Pascual et al., 2019; Iglesias-Sarmiento et al., 2023).

Moreover, evidence suggests that interactions among cognitive components matter for academic achievement, as emerging work has indicated that executive functioning and fluid intelligence may interact in predicting growth in early mathematics learning, where strong executive skills can partly compensate for lower fluid intelligence and vice versa (Vasilyeva, et al., 2025). Another research demonstrates that IQ components such as fluid intelligence and executive function, significantly correlates with achievement in cognitively demanding subjects such as mathematics and science (Peng et al., 2020; Shadwell et al., 2023). Research in cognitive development shows that updating and inhibition (executive processes) significantly contribute to both fluid intelligence and higher-order thinking skills, suggesting overlapping and joint mechanisms that influence achievement-related reasoning (Liu et al., 2024). This interaction underscores how multiple cognitive components jointly shape students' ability to tackle complex academic tasks, including those encountered in physics.

Statement of the Problem

Students' academic achievement in Physics continues to generate concern among educators and researchers due to persistently low performance observed in school-based and standardized examinations, basically because of its abstract and cognitively demanding nature. A wide range of factors has been shown to influence academic achievement, including instructional strategies, teacher competence, learning resources, and students' motivation. However, comparatively less attention has been given to learners' cognitive characteristics, particularly Intelligence Quotient (IQ), despite being a strong predictor of academic performance across educational levels as revealed by several researchers. Besides, few studies have examined how learners' IQ influence achievement in Physics, and the relative contributions of different IQ components to success in physics remain underexplored (Ajadi & Amoo, 2024; Ghosh & Bhat, 2025), particularly in developing educational system like that of Nigeria. Addressing this gap is essential for developing effective instructional strategies and targeted interventions, that can support learning systems toward improving students' academic achievement in Physics.

Therefore, this study seeks to examine students' Intelligence Quotient, its relationship to academic achievement in Physics, including how the different components of IQ relate and contribute to academic achievement in Physics. Understanding how IQ interact and relates to academic achievement in Physics will provide empirical evidence to support educational policies and practices that can enhance students' success in science education.

Research Hypotheses

1. There is no significant relationship between students' Intelligence Quotient (IQ) and Academic Achievement (AA) in Physics as a whole and based on gender differences.
2. There is no significant joint contribution of students' Intelligence Quotient, IQ components (Fluid Intelligence, FI; Quantitative Reasoning, QR; and Executive Function, EF) to Academic Achievement (AA) in Physics.
3. There is no significant relative individual contribution of students' Intelligence Quotient (IQ) components (Fluid Intelligence,FI; Quantitative Reasoning, QR; and Executive Function, EF) to Academic Achievement (AA) in Physics.

II. Methodology

Study design and Location: This study used an ex-post facto descriptive survey design method, conducted in Abeokuta area, specifically within Odeda Local Government area, Abeokuta, Ogun state, Nigeria.

Population and Sample: The target population consists of all Senior Secondary School II and III (SS II and III) Physics students in all public senior secondary schools in Odeda Local Government area, Abeokuta, Ogun state, Nigeria. The study samples consist of Two hundred and fifty (250) Physics students (made up of 146 boys and 104 girls) drawn from five randomly selected secondary schools within the local government area. Fifty (50) students each, were picked from each of the selected five secondary schools (25 students each from SS II and SS III) in the Local Government area. SS II and III students were used in this study because of their schooling experience.

Study Instrument: The instruments used for data collection are (i) SS II-First Term Result Broad Sheet (FTRBS-II), (ii) SS III-Academic Report Broad Sheet (FTRBS-III), and (iii) Intelligence Quotient Test (IQT). The FTRBS-II and FTRBS-III are result sheets containing first term examination scores of SS II and SS III Physics students, respectively, representing students' academic achievements. The IQT is an intelligence quotient test designed by the researchers to measure students' IQ based on the IQ components - Fluid Intelligence (FI), Quantitative Reasoning (QR), and Executive Function (EF). The IQT is made up of sections A and B. Section A contains bio-data information of the sample students while sections B consists of part I, II, and III, containing twenty (20) items each, that measures students' IQ components. Part I, II, and III contains items that measure students' fluid intelligence, quantitative reasoning, and executive function, respectively. Each correctly answered item of the IQT has a maximum of one (1) mark, making up an obtainable maximum total of 60 marks. The IQT was validated by education experts in test and evaluation, and then subjected to Cronbach alpha reliability test to obtain a reliability coefficient value of 0.79.

Data Collection and Statistical Analysis: The IQT was administered to the sample students and allowed to answer under strict examination conditions to avoid sharing of ideas among one another. Data obtained from the instruments were subjected to descriptive and inferential statistics such as mean, standard deviation, pearson product moment correlation, and multiple regression analysis at 0.05 level of significance. The SS II and SS III First term examination scores (academic achievements) were reported on over 100 (i.e maximum score of 100), while the IQT which was on over 60 (i.e maximum score of 60) was converted and reported on over 100 (i.e maximum score of 100) to help easy analysis and consistency of reported data.

III. Results And Discussion

Research Hypothesis 1: There is no significant relationship between students' Intelligence Quotient (IQ) and Academic Achievement (AA) in Physics as a whole and based on gender differences.

Table 1: Pearson correlation result for gender relationship between students' IQ and AA

		Intelligence Quotient		**Academic Achievement**		**Correlation Analysis**	
Sample	**N**	**MS**	**SD**	**MS**	**SD**	**r (IQ - AA)**	**Sig.**
All students	250	32.17	11.25	52.46	13.77	0.42**	0.000
Male	146	34.05	10.84	53.32	13.22	0.46**	0.000
Female	104	30.29	11.66	51.60	14.31	0.37**	0.000

MS = Mean Score, SD = Standard Deviation, r = correlation coefficient, **p < 0.001, 2-tailed, Source: Fieldwork, 2025.

Table 1 showed the correlation analysis result for the relationship between students' overall intelligence quotient and academic achievement by gender. The result indicated a moderate positive significant relationship between intelligence quotient and academic achievement among all students as a whole (**r = 0.42** at $p < 0.001$ level of significance), among male students (**r = 0.46** at $p < 0.001$ level of significance), and among the female students (**r = 0.37** at $p < 0.001$ level of significance), even though a closer observation indicated a slightly weaker relationship among the female students. With these results, the null hypothesis is rejected. This implies that higher IQ scores are generally associated with higher AA, and lower IQ scores are associated with lower AA; but the relationship between IQ and AA appears to be stronger among male students (**r = 0.46**) than among female students (**r = 0.37**).

These findings support previous studies which found a significant positive relationship between IQ and academic performance in their study, implying that learners with higher IQs typically perform academically better than their colleagues with lower IQ (Akubuilo et al., 2020; Ilo & Onyejesi, 2021; Tolibas et al., 2024). Lozano-Blasco et al. (2022) in their findings highlight the significant, positive and moderate relationship between intelligence and academic performance ($r = 0.367$; $p < 0.001$), while Sharma et al. (2024) though found a direct relationship between IQ and academic performance of the students, they also observed that males had a better IQ than females in their study which reflected in their Academic performance.

Research Hypothesis 2: There is no significant joint contribution of the components of the students' Intelligence Quotient, IQ (Fluid Intelligence, FI; Quantitative Reasoning, QR; and Executive Function, EF) to Academic Achievement (AA) in Physics.

Table 3a: Model summary of MLR analysis for joint contribution of IQ components to achievement

Model	R	R^2	Adjusted R^2	Standard Error of Estimate
1.	0.646	0.417	0.412	9.94

Predictors: (Constant), Fluid Intelligence, Quantitative Reasoning, Executive Function, Source: Fieldwork, 2025.

Table 3b: ANOVA result of MLR analysis for joint contribution of IQ to achievement

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	17256.32	3	5752.11	58.25	0.000
Residual	24318.71	246	98.91		
Total	41575.03	249			

Dependent Variable: Academic Achievement; Predictors: (Constant), Fluid Intelligence, Quantitative Reasoning, Executive Function, Source: Fieldwork, 2025.

Table 3a shows the summary of multiple regression analysis conducted to examine the joint contribution of students' IQ components (FI, QR, EF) to academic achievement in Physics. This table showed a regression coefficient, R = 0.646 which indicates the existence of a significant positive joint relationship between the students' IQ components (FI, QR, EF) and academic achievement in Physics. Likewise, $R^2 = 0.417$ in the result table indicates that both FI, QR, and EF jointly contributed and influenced academic achievement in physics to about 41.7%, while the remaining 58.3% may be due to other factors not included in this study. Table 3b shows the ANOVA results of the regression analysis. The table result shows $F(3, 246) = 58.25$ at $p < 0.001$ significant level, indicating a statistically significant joint relationship between students' IQ components (FI, QR, EF) and academic achievement in Physics. In essence, this result shows that the three IQ components (FI, QR, EF) can collectively and significantly predict academic achievement in Physics.

The above findings align with previous studies such as that of Große et al. (2025), Rosemary & Ibibo (2019), Tikhomirova et al. (2020), Vasilyeva et al. (2025), among others. Große et al. (2025) in a recent work observed that executive functions and fluid intelligence are robust predictors of learning outcomes and strategy knowledge relevant to achievement, compared to fluid intelligence. Tikhomirova et al. (2020) in a structural modeling study showed that fluid intelligence, and related cognitive abilities (e.g., working memory and number sense) significantly predicted general academic achievement across school subjects, indicating domain-general cognitive processes correlate with achievement outcomes. Vasilyeva et al. (2025) found interactive effects between fluid intelligence and executive function components in predicting math learning, where both cognitive processes jointly explained variance in academic outcomes, consistent with a joint predictive model where EF moderates the impact of fluid reasoning. Rosemary & Ibibo (2019) reported a significant positive relationship between students' QR ability and mathematics achievement among junior secondary school students, indicating that learners with stronger QR skills demonstrate superior performance in mathematical problem-solving tasks.

Research Hypothesis 3: There is no significant relative individual contribution of students' Intelligence Quotient, IQ components (Fluid Intelligence, FI; Quantitative Reasoning, QR; and Executive Function, EF) to Academic Achievement (AA) in Physics.

Table 4: Coefficients of MLR analysis for IQ Components contributing to achievement

	Unstandardized Coefficients		standardized Coefficients		
Model (Predictor)	B	Std. Error	Beta (β)	t	Sig.
Constant	12.48	2.31	-	5.40	0.000
Fluid Intelligence	0.28	0.09	0.21	3.11	0.002
Quantitative Reasoning	0.61	0.08	0.45	7.63	0.000
Executive Function	0.37	0.12	0.19	3.08	0.002

Dependent Variable: Academic Achievement, Source: Fieldwork, 2025.

Table 4 shows the coefficients of the multiple regression analysis carried out to determine the relative contribution of IQ components (FI, QR, EF) to academic achievement. As shown by the table, quantitative reasoning ($\beta = 0.45$, $t = 7.63$, $p < 0.001$), fluid intelligence ($\beta = 0.21$, $t = 3.11$, $p = 0.002$) and executive function ($\beta = 0.19$, $t = 3.08$, $p = 0.002$) made statistically significant positive contributions to academic achievement. In other words, quantitative reasoning, fluid intelligence and executive function contributed about 45%, 21% and 19% respectively to students academic achievement in Physics, with quantitative reasoning being the strongest contributor compared to other components. These results implies that students with higher scores in quantitative reasoning, fluid intelligence, and executive function are more likely to achieve higher academic achievement in Physics.

These results are in line with previous research studies such as that Peng et al. (2020) which reported that numerical and quantitative reasoning skills were strong predictors of mathematics achievement across grade levels, highlighting the enduring influence of QR on academic development. Similarly, Hamdan & Aldhafiri (2024) found that mathematical reasoning significantly predicted mathematics achievement and overall academic excellence among senior secondary school students. Tilkhomirova et al. (2020) in their study found that fluid intelligence to significantly predicted general academic performance, including mathematics and language success, across a broad age range of schoolchildren. Likewise, Green et al. (2017) in their longitudinal study showed that fluid reasoning (intelligence) predicted future mathematics performance across ages 6 to 21, above and beyond, suggesting fluid intelligence scaffolds both early and later math learning. Ramos-Galarza et al. (2020) in their regression analysis study showed that executive functions explain 31% of the variance of academic performance (χ^2 (25) = 43.81, $p < 0.001$). Alhwaiti (2025) in a multi-analysis study found executive functions and intelligence have a significant linear relationship with mathematics achievement, executive functions explaining 41.7% and 43.7% of the variance of mathematics achievement.

IV. Conclusion

This study concludes that students' Intelligence Quotient (IQ) and its specific cognitive components are significant determinants of academic achievement and academic success in Physics, indicating that cognitive ability such as reasoning ability, numerical and analytical competence, and executive control skills each play distinct and meaningful roles in enhancing students' understanding and performance in Physics irrespective of gender differences. These results, therefore provide empirical evidence emphasizing the need for instructional strategies and assessment practices that support the development of fluid reasoning, quantitative skills, and executive functioning among students.

V. Recommendations

Based on the findings obtained from this study, it is recommended that:

1. School authorities should organize training workshops and seminars to train Physics teachers on how to design instruction that strengthens higher-order reasoning, numerical analysis, and executive control skills relevant to Physics learning.
2. Physics teachers should deliberately incorporate learning activities that enhance fluid intelligence, quantitative reasoning, and executive functioning, such as problem-based learning, inquiry-driven experiments, and multi-step problem-solving tasks, to improve students' academic achievement in Physics.

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