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A causal path analysis of students'-related factors on academic achievement in biology among secondary school students in Anambra State: The mediating role of test anxiety

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Abstract
This study examined the causal pathways linking student-related factors—academic goal orientation, self-regulated learning, academic resilience, and academic motivation—to academic achievement in Biology among secondary school students in Anambra State, Nigeria, with test anxiety as a mediating variable. A model-testing correlational design was adopted. The population comprised 2,154 Senior Secondary Two (SS2) students, from which a sample of 630 students was selected using a multi-stage sampling technique. Data were collected using six validated questionnaires and an academic achievement proforma. The instruments demonstrated acceptable reliability coefficients ranging from 0.72 to 0.91. Data were analyzed using path analysis with Maximum Likelihood Estimation. The findings revealed that all student-related factors had significant positive direct effects on academic achievement in Biology, with academic motivation emerging as the strongest predictor, followed by self-regulated learning, academic resilience, and academic goal orientation. The results further showed that student-related factors significantly and negatively predicted test anxiety, while test anxiety had a significant negative effect on academic achievement. This indicates that higher levels of motivation, resilience, self-regulation, and goal orientation are associated with lower levels of test anxiety and improved academic performance. The study also established that test anxiety significantly mediates the relationship between student-related factors and academic achievement in Biology. The findings highlight the importance of addressing both cognitive and emotional dimensions of learning in improving students' performance. It is recommended that educators adopt strategies that enhance students' motivation, self-regulation, and resilience while implementing interventions to reduce test anxiety. Overall, the study provides empirical evidence for a comprehensive model explaining academic achievement in Biology and offers practical implications for teaching and learning.

Keywords: Academic achievement, biology education, student-related factors, academic motivation, self-regulated learning, academic resilience, academic goal orientation, test anxiety, path analysis, secondary school students

Introduction

Biology continues to occupy a central position in secondary school education due to its relevance to everyday life, health, environmental sustainability, and scientific advancement. As a core science subject, it equips learners with essential knowledge required for careers in medicine, agriculture, nursing, and other science-oriented fields. In Nigeria, Biology is compulsory at the senior secondary school level, and students' performance in the subject plays a decisive role in their progression into higher education. However, students' academic achievement in Biology has remained inconsistent, particularly in states such as Anambra, where examination reports frequently highlight fluctuations in performance across years (Adewale, 2021; Okeke & Nwoye, 2022; Eze *et al*., 2023; Obi & Ezeudu, 2024) [1, 12, 26, 27]. This pattern has raised concerns among educators and stakeholders, prompting increased interest in understanding the factors that shape students' learning outcomes in Biology.

Academic achievement is widely understood as a product of multiple interacting factors rather than a single influence. Contemporary research emphasizes that students' performance is shaped by a combination of cognitive, motivational, emotional, and behavioral processes (Richardson *et al*., 2021; Schunk & DiBenedetto, 2020; Talsma *et al*., 2021; Putwain *et al*., 2022) [32, 33, 35, 37]. Among these, student-related factors have gained significant attention because they reflect internal dispositions that directly influence how students approach learning tasks (Zimmerman, 2020; Mega *et al*., 2021; Panadero, 2021) [10, 23]. These factors include academic goal orientation, self-regulated learning, academic resilience, and academic motivation, all of which play a crucial role in determining academic outcomes.

Academic goal orientation refers to the underlying reasons or purposes that drive students' engagement in learning activities. Students with mastery-oriented goals tend to focus on understanding and improving their competence, while those with performance-oriented goals may focus more on demonstrating ability or avoiding failure (Elliot *et al*., 2021; Murayama & Elliot, 2021) [11]. Research has shown that mastery goal orientation is positively associated with deeper learning strategies and higher academic achievement, particularly in science subjects such as Biology (Senko & Dawson, 2021; Hulleman *et al*., 2022) [36, 40]. In contrast, maladaptive goal orientations may lead to surface learning and reduced persistence when faced with challenging tasks.

Closely linked to goal orientation is self-regulated learning, which involves students' ability to plan, monitor, and evaluate their own learning processes. Self-regulated learners actively set goals, organize their study activities, and adjust strategies when necessary, thereby enhancing their academic performance (Zimmerman, 2020; Panadero, 2021; Broadbent & Poon, 2021) [5, 10, 28]. In Biology, where students must integrate theoretical knowledge with practical

application, self-regulation becomes particularly important. Studies have consistently shown that students who demonstrate strong self-regulation skills tend to achieve better academic outcomes compared to those who lack such skills (Dent & Koenka, 2020; Theobald, 2021) [5, 10].

Academic resilience is another critical student-related factor that has received increasing attention in recent years. It refers to the ability of students to overcome academic setbacks and persist despite challenges. In demanding subjects like Biology, students often encounter difficulties that require sustained effort and perseverance. Resilient students are better able to cope with these challenges, maintain their motivation, and continue striving toward their academic goals (Martin & Marsh, 2021; Cassidy, 2022; Ayala & Manzano, 2021) [3, 7, 22]. Research indicates that resilience not only supports academic performance directly but also enhances students' capacity to manage stress and adapt to academic demands (Turner *et al*., 2022; Agasisti *et al*., 2023) [2, 41].

Academic motivation, which refers to the drive that energizes and sustains students' engagement in learning activities, also plays a vital role in academic achievement. Motivated students are more likely to invest effort, participate actively in class, and persist in the face of difficulties (Ryan & Deci, 2020; Froiland & Worrell, 2021; Guay, 2022) [14, 15, 34]. In the context of Biology, motivation influences how students interact with instructional materials and whether they are willing to engage in deeper learning processes. Empirical evidence suggests that both intrinsic and extrinsic forms of motivation contribute to academic success, although intrinsic motivation is often associated with more meaningful learning outcomes (Howard *et al*., 2021; Cerasoli *et al*., 2022) [8, 18].

While these student-related factors are essential, emotional variables also play a crucial role in shaping academic outcomes. One such variable is test anxiety, which is widely recognized as a significant factor affecting students' performance in examination settings. Test anxiety is characterized by feelings of tension, worry, and apprehension that occur before or during tests (Zeidner, 2020; Putwain, 2021) [31, 44]. Although a moderate level of anxiety can enhance alertness and preparation, excessive anxiety can interfere with cognitive functioning and negatively affect academic performance (Pekrun & Perry, 2020; von der Embse *et al*., 2021; Thomas *et al*., 2022) [29, 39, 43].

Research has consistently demonstrated a negative relationship between test anxiety and academic achievement. Students who experience high levels of anxiety are more likely to have difficulty concentrating, recalling information, and performing effectively during examinations (Putwain *et al*., 2022; von der Embse *et al*., 2021; Pekrun *et al*., 2021) [11, 32, 43]. In science subjects such as Biology, which require critical thinking and problem-solving under time constraints, the impact of anxiety can be particularly detrimental (Trassi *et al*., 2022; Thomas *et al*., 2022) [39, 40]. Studies conducted in both international and Nigerian contexts have confirmed that test anxiety significantly predicts lower academic performance among secondary school students (Okeke & Nwoye, 2022; Eze *et al*., 2023; Adewale, 2021) [1, 12, 27].

Importantly, test anxiety does not function independently but is closely linked to other student-related factors. For instance, students with low self-efficacy or poor preparation are more likely to experience higher levels of anxiety (Usher & Pajares, 2022; Talsma *et al*., 2021) [37, 42]. Similarly, students who lack effective self-regulation strategies may feel overwhelmed during examinations, leading to increased anxiety (Panadero, 2021; Broadbent & Poon, 2021) [5, 28]. Conversely, students who demonstrate high resilience and strong coping skills are better able to manage anxiety and maintain their performance (Martin & Marsh, 2021; Cassidy, 2022) [7, 22]. These relationships suggest that test anxiety may act as a mediating variable through which student-related factors influence academic achievement.

Recent studies have increasingly highlighted the mediating role of test anxiety in academic settings. For example, research has shown that self-efficacy and motivation can influence academic achievement indirectly by reducing anxiety levels (Putwain *et al*., 2022; Pekrun *et al*., 2021; Howard *et al*., 2021) [18, 30, 32]. Similarly, resilience has been found to buffer the negative effects of anxiety, thereby enhancing students' academic performance (Turner *et al*., 2022; Agasisti *et al*., 2023) [2, 41]. These findings underscore the importance of examining both direct and indirect pathways when investigating the determinants of academic achievement.

Given the complexity of these relationships, there is a growing need for analytical approaches that can capture multiple interactions simultaneously. Causal path analysis provides a suitable framework for examining both direct and indirect effects within a single model. This approach allows researchers to test theoretical assumptions about how different variables are related and to identify the mechanisms through which they influence academic outcomes (Kline, 2021; Hair *et al*., 2022; Byrne, 2022) [6, 16, 21]. By adopting this approach, it becomes possible to develop a more comprehensive understanding of the factors that contribute to students' academic achievement in Biology.

Despite the increasing body of research in this area, there remains a notable gap in the literature, particularly within the Nigerian context. Many previous studies have focused on isolated variables without considering the complex interplay among multiple student-related factors and emotional variables (Okeke & Nwoye, 2022; Eze *et al*., 2023; Obi & Ezeudu, 2024) [12, 26, 27]. Furthermore, limited attention has been given to the mediating role of test anxiety in shaping students' academic outcomes in Biology among secondary school students in Anambra State. This gap highlights the need for a more integrated approach to understanding academic achievement.

The present study seeks to address this gap by examining the causal pathways linking student-related factors—academic goal orientation, self-regulated learning, academic resilience, and academic motivation—to academic achievement in Biology, with test anxiety serving as a mediating variable. By exploring these relationships within a single framework, the study aims to provide deeper insights into the mechanisms that influence students' performance.

The study is grounded in established theoretical perspectives, including Social Cognitive Theory, which emphasizes the role of self-efficacy and self-regulation in learning (Bandura, 2021) [37]; the Control-Value Theory of Achievement Emotions, which highlights the influence of emotions such as anxiety on academic outcomes (Pekrun & Perry, 2020) [29]; and Self-Determination Theory, which

underscores the importance of motivation in shaping academic behavior (Ryan & Deci, 2020) [34]. Together, these theories provide a comprehensive framework for understanding how cognitive, motivational, and emotional factors interact to influence academic achievement.

From a practical standpoint, the findings of this study are expected to have important implications for teaching and learning. By identifying the key student-related factors that influence academic achievement and understanding the mediating role of test anxiety, educators can develop targeted strategies to support students' learning. For example, interventions aimed at enhancing self-regulation, promoting resilience, and reducing anxiety can significantly improve students' performance in Biology (von der Embse *et al*., 2021; Putwain *et al*., 2022; Howard *et al*., 2021) [1, 32]. School counselors can also play a role in helping students develop coping strategies to manage examination-related stress.

Students' academic achievement in Biology is shaped by a complex interplay of student-related factors and emotional processes. Test anxiety, in particular, serves as a critical mechanism through which these factors influence academic outcomes. By employing a causal path analysis framework, this study contributes to a deeper understanding of these relationships and provides valuable insights for improving Biology education in Anambra State.

Statement of the Problem

Students' academic achievement in Biology at the secondary school level remains a persistent concern in Anambra State, despite the subject's importance for science education and career development. Examination reports from both internal school assessments and external bodies such as WAEC and NECO have continued to show inconsistent and, in many cases, unsatisfactory performance among students. This trend raises critical questions about the underlying factors responsible for students' difficulties in mastering Biology concepts, particularly in an educational environment where success in science subjects is highly valued.

Over the years, efforts to improve students' performance in Biology have largely focused on external factors such as teacher quality, instructional materials, curriculum implementation, and school facilities. While these factors are undoubtedly important, they do not fully explain the variations in students' academic outcomes. Increasingly, attention has shifted toward student-related factors, including academic goal orientation, self-regulated learning, academic resilience, and academic motivation, as key determinants of learning and achievement. However, existing studies have often examined these variables in isolation, making it difficult to understand how they collectively influence students' performance in Biology.

Furthermore, there is growing recognition that emotional factors, particularly test anxiety, play a crucial role in shaping academic outcomes. Many secondary school students experience significant levels of anxiety before and during examinations, which can negatively affect their concentration, memory recall, and overall performance. Despite this, limited research in the context of Anambra State has examined how test anxiety interacts with student-related factors to influence academic achievement in Biology. Specifically, the mediating role of test anxiety in the relationship between student-related characteristics and academic performance has not been adequately explored.

Another major gap lies in the methodological approaches adopted in previous studies. Most research in this area has relied on simple correlation or regression analyses, which are insufficient for capturing the complex, interrelated nature of the variables involved. There is a lack of studies employing causal path analysis to examine both direct and indirect relationships among student-related factors, test anxiety, and academic achievement. Without such comprehensive analysis, it is difficult to identify the mechanisms through which these variables influence students' performance.

Therefore, the problem of this study is the persistent poor and inconsistent academic achievement of secondary school students in Biology in Anambra State, coupled with insufficient empirical evidence explaining how student-related factors interact and how test anxiety mediates their effects on achievement. Addressing this gap is essential for developing effective interventions that can enhance students' learning outcomes and improve performance in Biology.

Research Questions

1. What are the direct effects of student-related factors (academic goal orientation, self-regulated learning, academic resilience, and academic motivation) on students' academic achievement in Biology among secondary school students in Anambra State?
2. To what extent does test anxiety mediate the relationship between student-related factors and academic achievement in Biology among secondary school students in Anambra State?

Research Hypotheses

1. Student-related factors (academic goal orientation, self-regulated learning, academic resilience, and academic motivation) have no significant direct effect on students' academic achievement in Biology among secondary school students in Anambra State.
2. Test anxiety does not significantly mediate the relationship between student-related factors and students' academic achievement in Biology among secondary school students in Anambra State.

Methodology

This study adopted a model-testing correlational design to examine the relationships among student-related factors—academic goal orientation, self-regulated learning, academic resilience, and academic motivation—test anxiety, and academic achievement in Biology. The design was considered appropriate because it enables the simultaneous estimation of direct and indirect effects within a hypothesized causal framework using path analysis (Kline, 2021; Hair *et al*., 2022) [16, 21].

The study was conducted in the Onitsha Education Zone of Anambra State, Nigeria, which comprises Onitsha North, Onitsha South, and Ogbaru Local Government Areas. The population consisted of 2,154 Senior Secondary Two (SS2) Biology students in public secondary schools. From this population, a sample of 630 students was selected using **a** multi-stage sampling procedure involving stratification by location, proportionate selection of schools, and simple random sampling of students. This approach ensured that

the sample was representative of the population (Creswell & Creswell, 2018) [9].

Data were collected using six structured instruments adapted to the Biology context: Biology Test Anxiety Questionnaire (20 items), Biology Academic Goal Orientation Scale (16 items), Biology Self-Regulated Learning Questionnaire (18 items), Biology Academic Resilience Scale (15 items), Biology Emotional Intelligence Questionnaire (20 items), and Biology Academic Motivation Scale (18 items). All instruments were measured on a 4-point Likert scale ranging from *Strongly Disagree (1)* to *Strongly Agree (4)*, with higher scores indicating higher levels of the respective constructs. Students' academic achievement was obtained using a proforma based on their school records.

The instruments were subjected to expert validation to ensure content relevance and clarity, while construct validity was established using Confirmatory Factor Analysis (CFA)**,** with fit indices meeting recommended thresholds (Hu & Bentler, 1999) [19]. Reliability was determined using Cronbach Alpha coefficients, which ranged from 0.72 to 0.91, indicating acceptable to excellent internal consistency (Nunnally & Bernstein, 1994) [25].

Data collection was carried out through direct administration of the instruments with the assistance of trained research assistants, ensuring a high response rate and adherence to ethical standards such as confidentiality and voluntary participation. Data were analyzed using path analysis with Maximum Likelihood Estimation (MLE) in R software. Preliminary analyses confirmed that assumptions of normality, linearity, homoscedasticity, and absence of multicollinearity were satisfied (Field, 2018) [13]. Standardized regression coefficients were used to address the research questions, while hypotheses were tested using bootstrapped confidence intervals to determine the significance of direct and indirect effects (Hayes, 2018) [17]. Statistical significance was set at the 0.05 level.

Results

Research Question One

What are the direct effects of student-related factors (academic goal orientation, self-regulated learning, academic resilience, and academic motivation) on students' academic achievement in Biology among secondary school students in Anambra State?

Table 1: Direct Effects of Student-Related Factors on Academic Achievement in Biology

Predictor Variable	B	SE	t-value	p-value	B
Academic Goal Orientation	0.028	0.004	6.303	< .001	.154
Self-Regulated Learning	0.044	0.005	9.199	< .001	.237
Academic Resilience	0.032	0.004	7.862	< .001	.172
Academic Motivation	0.051	0.005	10.293	< .001	.271

Note. B = unstandardized regression coefficient; SE = standard error; t = t-statistic; β = standardized regression coefficient

The results of the analysis in Table 1 indicate that all the student-related factors examined have significant positive direct effects on students' academic achievement in Biology. Academic goal orientation significantly predicted academic achievement ($B = 0.028$, $\beta = .154$, $p < .001$), suggesting that students who set clear academic goals and remain focused on achieving them tend to perform better in Biology. Self-regulated learning also demonstrated a strong positive effect ($B = 0.044$, $\beta = .237$, $p < .001$), indicating that students who actively plan, monitor, and evaluate their learning processes achieve higher academic outcomes.

Academic resilience was equally found to significantly influence academic achievement ($B = 0.032$, $\beta = .172$, $p < .001$), implying that students who are able to cope with academic challenges and persist despite difficulties are more likely to succeed. Academic motivation recorded the strongest effect ($B = 0.051$, $\beta = .271$, $p < .001$), highlighting the importance of students' interest, effort, and commitment to learning. These findings collectively demonstrate that student-related factors significantly enhance academic achievement in Biology.

Hypothesis One

Student-related factors have no significant direct effect on students' academic achievement in Biology.

Since all the direct paths in Table 1 from student-related factors to academic achievement are statistically significant ($p < .001$), the null hypothesis is rejected. This indicates that student-related factors significantly predict academic achievement in Biology.

Research Question Two

To what extent does test anxiety mediate the relationship between student-related factors and academic achievement in Biology among secondary school students in Anambra State?

Panel A: Effects of Student-Related Factors on Test Anxiety

Table 2: Mediating Role of Test Anxiety in the Relationship between Student-Related Factors and Academic Achievement in Biology

Predictor Variable	B	SE	t-value	p-value	B
Academic Goal Orientation	−0.338	0.027	−12.663	< .001	−.341
Self-Regulated Learning	−0.400	0.027	−14.626	< .001	−.402
Academic Resilience	−0.278	0.027	−10.336	< .001	−.277
Academic Motivation	−0.445	0.026	−17.099	< .001	−.441

Panel B: Effect of Test Anxiety on Academic Achievement

Predictor Variable	B	SE	t-value	p-value	B
Test Anxiety	−0.060	0.005	−11.946	< .001	−.322

Note: B = unstandardized regression coefficient; SE = standard error; t = t-statistic; β = standardized regression coefficient

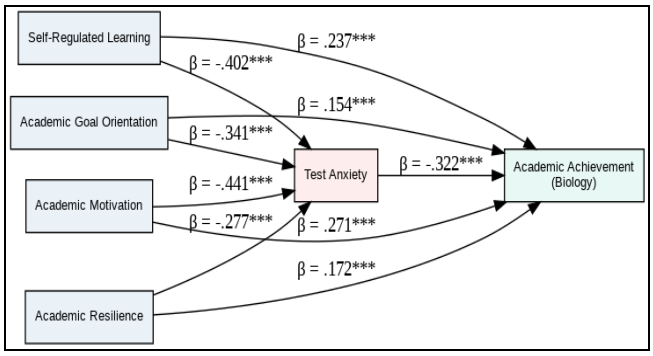
The findings in Table 2 further show that student-related factors significantly predict test anxiety in a negative direction. Academic goal orientation (B = −0.338, β = −.341, p < .001), self-regulated learning (B = −0.400, β = −.402, p < .001), academic resilience (B = −0.278, β = −.277, p < .001), and academic motivation (B = −0.445, β = −.441, p < .001) all significantly reduce test anxiety. This suggests that students with higher levels of these attributes experience lower levels of anxiety during examinations.

In addition, test anxiety significantly predicts academic achievement in Biology in a negative direction (B = −0.060, β = −.322, p < .001), indicating that increased anxiety leads to lower academic performance. Taken together, these results show that test anxiety serves as a significant mediator in the relationship between student-related factors and academic achievement.

Hypothesis Two

Test anxiety does not significantly mediate the relationship between student-related factors and academic achievement in Biology.

Given that student-related factors significantly influence test anxiety and test anxiety significantly influences academic achievement in Table 2, the null hypothesis is rejected. This confirms that test anxiety significantly mediates the relationship between student-related factors and academic achievement in Biology. The causal path model for the study is shown in Fig 1.



The path diagram in Fig 1 presents a comprehensive model illustrating both the direct and mediated relationships between student-related factors and academic achievement in Biology. Four exogenous variables—academic goal orientation, self-regulated learning, academic resilience, and academic motivation—are shown as predictors of academic achievement. Each of these variables has a direct positive path to academic achievement, indicating that improvements in these student characteristics are associated with better performance in Biology. Among the predictors, academic motivation exhibits the strongest direct effect (β = .271), followed by self-regulated learning (β = .237), academic resilience (β = .172), and academic goal orientation (β = .154). These direct paths confirm that students who are motivated, strategic in their learning, resilient in the face of challenges, and goal-oriented tend to achieve higher academic outcomes.

In addition to the direct effects, the diagram incorporates test anxiety as a mediating variable that explains part of the relationship between the student-related factors and academic achievement. All four predictors have significant negative paths to test anxiety, indicating that higher levels of these positive student characteristics are associated with lower levels of anxiety during tests. In turn, test anxiety has a significant negative effect on academic achievement (β = −.322), suggesting that increased anxiety hinders students' performance. This configuration demonstrates a partial mediation model, where student-related factors influence academic achievement both directly and indirectly through their impact on test anxiety. Overall, the diagram highlights the dual mechanism through which enhancing positive student attributes can improve academic outcomes—by directly boosting performance and by reducing debilitating test anxiety.

Discussion of Findings

This study examined how student-related factors—academic goal orientation, self-regulated learning, academic resilience, and academic motivation—shape academic achievement in Biology among secondary school students in Anambra State, and whether test anxiety explains part of these relationships. The discussion interprets the findings in light of prior empirical work, while also acknowledging contrasting evidence in the literature.

Direct Effects of Student-Related Factors on Academic Achievement

The results show that all four student-related factors significantly and positively predict academic achievement in Biology, with academic motivation exerting the strongest influence, followed by self-regulated learning, academic resilience, and academic goal orientation. This pattern suggests that students' internal dispositions are not peripheral but central to how well they perform in a cognitively demanding subject like Biology.

The strong effect of academic motivation is consistent with a substantial body of research indicating that motivated students are more persistent, invest greater effort, and are more willing to engage in deeper learning processes (Ryan & Deci, 2020; Howard *et al*., 2021; Guay, 2022) [15, 18, 34]. Studies in science education contexts have similarly reported that motivation enhances students' engagement with complex content and predicts higher academic outcomes (Froiland & Worrell, 2021; Cerasoli *et al*., 2022) [8, 14]. However, not all studies have found uniformly strong effects. Some scholars argue that motivation alone may not guarantee improved performance if it is not supported by effective learning strategies or enabling learning environments (Richardson *et al*., 2021; Schunk & DiBenedetto, 2020) [33, 35]. This suggests that while motivation is critical, its impact may depend on how it interacts with other factors such as self-regulation and instructional quality.

Self-regulated learning also emerged as a significant predictor of achievement, reinforcing the view that students who can plan, monitor, and evaluate their learning tend to perform better academically. This finding aligns with earlier studies showing that self-regulated learners are more strategic, adaptable, and effective in managing academic tasks (Panadero, 2021; Broadbent & Poon, 2021; Theobald, 2021) [5, 28]. In Biology, where conceptual understanding and application are essential, such skills appear particularly valuable. Nonetheless, some studies have reported weaker or inconsistent effects of self-regulation, especially in contexts where students lack adequate guidance or scaffolding (Dent & Koenka, 2020) [10]. This indicates that the effectiveness of self-regulated learning may vary depending on contextual factors such as teacher support and classroom structure.

Academic resilience was also found to significantly predict achievement, suggesting that students who are able to cope with setbacks and persist despite difficulties tend to achieve better outcomes. This finding supports earlier research highlighting resilience as a protective factor that enables students to sustain performance under challenging conditions (Martin & Marsh, 2021; Cassidy, 2022; Turner *et al*., 2022) [7, 22, 41]. However, some scholars caution that resilience alone may not be sufficient to ensure high achievement if students face persistent structural challenges such as limited resources or ineffective teaching (Agasisti *et al*., 2023) [2]. Thus, resilience should be viewed as one part of a broader system of support rather than a standalone solution.

Although academic goal orientation had the smallest effect among the predictors, it was still significant, indicating that students who approach learning with clear goals tend to perform better. This finding is consistent with research showing that mastery-oriented goals promote deeper learning and greater persistence (Elliot *et al*., 2021; Senko & Dawson, 2021) [11, 36]. However, contrasting evidence suggests that performance-oriented goals may sometimes enhance achievement in competitive academic settings, particularly where assessment systems emphasize grades and rankings (Murayama & Elliot, 2021; Hulleman *et al*., 2022) [11, 20]. This highlights the complexity of goal orientation and suggests that its effects may depend on the broader educational context.

Mediating Role of Test Anxiety

The findings further reveal that test anxiety significantly mediates the relationship between student-related factors and academic achievement. All the student-related variables were found to significantly reduce test anxiety, while test anxiety, in turn, negatively predicted academic achievement. This indicates that one of the ways through which student-related factors influence performance is by shaping students' emotional experiences during examinations.

The negative relationship between test anxiety and academic achievement is well documented in the literature. Previous studies have shown that high levels of anxiety can impair cognitive functioning, reduce working memory capacity, and hinder students' ability to retrieve information during tests (Pekrun & Perry, 2020; von der Embse *et al*., 2021; Putwain *et al*., 2022) [29, 32, 43]. The present findings are consistent with these studies, confirming that anxiety remains a significant barrier to academic success in examination-oriented contexts such as Nigeria.

The mediating role of test anxiety observed in this study is also supported by prior research indicating that psychological resources such as self-efficacy, motivation, and resilience can influence academic performance indirectly by reducing anxiety (Talsma *et al*., 2021; Howard *et al*., 2021; Putwain *et al*., 2022) [18, 32, 37]. Students who are confident, well-prepared, and emotionally stable are less likely to experience debilitating anxiety, which in turn enhances their performance.

However, some studies present a more nuanced perspective by suggesting that not all forms of anxiety are detrimental. Moderate levels of anxiety, often referred to as facilitative anxiety, may actually enhance performance by increasing alertness and motivating students to prepare more thoroughly (Zeidner, 2020; Thomas *et al*., 2022) [39, 44]. In this regard, the relationship between anxiety and achievement may not be strictly linear. Instead, it may follow an inverted U-shaped pattern, where both very low and very high levels of anxiety are associated with poorer performance. This perspective suggests that interventions should aim not necessarily to eliminate anxiety entirely, but to help students manage it effectively.

Conclusion

This study provides evidence that academic achievement in Biology is shaped by a combination of student-related factors and emotional processes. While motivation, self-regulated learning, resilience, and goal orientation directly enhance students' performance, their effects are also transmitted through test anxiety. The findings reinforce the need to consider both cognitive and emotional dimensions of learning, while also acknowledging that the strength and direction of these relationships may vary depending on contextual and individual differences.

Recommendations

Based on the findings of this study, the following recommendations are proposed to enhance students' academic achievement in Biology among secondary school students in Anambra State:

1. Teachers should adopt instructional strategies that stimulate students' interest in Biology, such as inquiry-based learning, practical activities, and real-life applications of biological concepts. When students see the relevance of what they are learning, they are more likely to develop intrinsic motivation and sustain effort in their studies. Schools can also introduce reward systems and recognition programs to reinforce positive academic behaviors.
2. Students should be trained in effective learning strategies, including goal setting, time management, self-monitoring, and reflective learning. Teachers can support this by guiding students on how to plan their study schedules, track their progress, and adjust their learning approaches when necessary. Incorporating study skills training into the school curriculum will help students become more independent and effective learners.
3. Schools should create supportive learning environments that encourage persistence and resilience. Teachers can help students develop resilience by providing constructive feedback, encouraging effort rather than just outcomes, and helping students view challenges as opportunities for growth. Counseling units in schools should also organize programs that teach coping strategies for dealing with academic setbacks.
4. Students should be guided to adopt mastery-oriented goals that focus on understanding and improvement rather than merely achieving high grades. Teachers can promote this by emphasizing learning processes, providing meaningful feedback, and reducing excessive competition in the classroom. This approach will encourage deeper engagement with Biology content.
5. Given the significant mediating role of test anxiety, schools should implement interventions aimed at helping students manage anxiety. This can include relaxation techniques, test-taking strategies, and confidence-building exercises. Teachers should also create less threatening assessment environments by providing adequate preparation, clear instructions, and continuous assessment opportunities.

6. School counselors should play a more active role in supporting students' emotional and psychological well-being. Regular counseling sessions, workshops, and seminars should be organized to help students develop coping skills, manage stress, and build confidence in their academic abilities.
7. Teachers should be trained on how to integrate cognitive, motivational, and emotional support strategies into their teaching practices. Professional development programs should focus on helping teachers understand the role of student-related factors and test anxiety in academic achievement, as well as how to address these factors effectively in the classroom.
8. Educational policymakers should consider incorporating components that address students' emotional well-being and learning strategies into the secondary school curriculum. Policies should also support the provision of adequate resources for counseling services and teacher training programs aimed at improving students' academic outcomes.
9. Parents should be encouraged to provide a supportive home environment that fosters positive study habits and reduces academic pressure. They should also be sensitized to recognize signs of test anxiety and provide appropriate emotional support to their children.

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