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RESEARCH ARTICLE

An Analysis of the Non-linear Relationship between Test Anxiety and Academic Achievement of Secondary School Students

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Abstract

Background and objectives: Studies on the relationship between test anxiety and academic achievement have yielded mixed findings. While low levels of anxiety are often linked to higher achievement, students may also become complacent, leading to reduced efforts. Conversely, high levels of test anxiety can sometimes motivate students to achieve higher. These divergent findings highlight the complex nature of the relationship, predominantly studied through a linear lens, while overlooking non-linear patterns. This study investigates the nature of this relationship between anxiety and achievement, focusing on polynomial regression (linear, quadratic, cubic, and quartic trends).

Methods: A correlational research design was adopted to examine the non-linear relationship between test anxiety and academic achievement. A sample of 337 students was randomly selected from a population of 2696. Physics Achievement Test (PAT), and Physics Test Anxiety Scale (PTAS) were used for data collection, with reliability estimates of 0.76 and 0.73, respectively. Polynomial regression analysis was conducted using R software to evaluate the linear, quadratic, cubic, and quartic trends.

Results: Findings showed significant linear, quadratic, and quartic relationships between test anxiety and academic achievement, while the cubic component was not significant.

Conclusions: There is a complex and multifaceted relationship between test anxiety and academic achievement.

Keywords

Test, Test anxiety, Academic achievement, Non-linear relationship, Polynomial regression, Students

Abbreviations

PTAS: Physics Test Anxiety Scale; PAT: Physics Achievement Test; TA: Test Anxiety; AA: Academic Achievement; SSS: Senior Secondary School

Introduction

Test is an important instrument or tool used to assess students' cognitive, affective, and psychomotor development. Tests help to ascertain the level of a student's academic progress and understanding of the subject matter or course content. It measures how much information, traits, attributes, or characteristics a learner have [1]. Outcomes of tests and other assessment tools are used to inform policies and make decisions about students' progress and achievement, including promotion, selection, certification, and many more [2,3]. The numerous benefits of tests have made it attract a lot of attention, and premium values, hence, making it a necessity for all students to be on their toes during test-taking situations.

The pressure to thrive well during a test, and maintain good grades as well as excel academically often results in psychological conditions for students,

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characterized by worry, fear, apprehension, discomfort, and restlessness [4,5]. Ocheni, et al. [6] described test anxiety as an anticipatory or examination-related condition that students experience in examination situations. This condition, which may be termed test anxiety or examination-induced anxiety is seen as a multifaceted phenomenon involving cognitive, emotional, and physiological responses that students or test-takers experience before, during, or after a test. Rooted in the fear of failure or judgment, test anxiety manifests through symptoms such as difficulty in concentrating, worry, physical discomfort, negative self-talk, forgetfulness, and fear, which may hinder one from achieving a set academic goal or potential [7,8].

Test anxiety which has been categorized as low, moderate, and high [9,10], is usually triggered by fear of failure, lack of preparation, poor previous test experience [4], and can have a corresponding consequence on students' academic achievement. According to Okeke, et al. [8], test anxiety tends to either increase or decrease students' academic achievement. Benjamin and Mohammed [11] reported that test anxiety significantly predicts students' achievement. Theobald, et al. [12] reported that test anxiety has no relationship with students' academic achievement. According to Alam [13], a negative relationship exists between test anxiety and academic achievement. These findings show discrepancies in the reports of various scholars on the relationship between test anxiety and academic achievement, thereby, making it difficult for us to fully understand the nature of the relationship between test anxiety and achievement. This could lead to the implementation of ineffective interventions that could support students learning and coping with test anxiety.

To overcome these setbacks, understanding test anxiety is crucial to developing strategies that support students' mental health and academic success. Thus, it is necessary to look beyond exploring the linear relationship between test anxiety and achievement as previous studies have, since there could be a likelihood that a non-linear relationship may exist between test anxiety and academic achievement. Research suggests that while low levels of test anxiety may lead to increased achievement, they can also lead to complacency, reduced efforts, and achievement [14,15], whereas, extreme (high) levels of anxiety may, in some cases, motivate students to study harder, resulting in higher achievement [16,17]. These reports imply that if we fail to investigate this non-linear dynamic, we may potentially fail to address the challenges of test anxiety. Adopting the non-linear approach entails employing a polynomial regression (non-linear) that can assess the linear, quadratic, cubic, and quartic trends in the relationship between test anxiety and academic achievement [18]. Thus, this study seeks to explore the non-linear relationship between test anxiety and academic achievement of secondary school students.

Research Objectives

1. What is the nature of the relationship between test anxiety and academic achievement among secondary school students?

Hypotheses

$H0_1$: There is no significant linear relationship between test anxiety and academic achievement of secondary school students.

$H0_2$: There is no significant quadratic relationship between test anxiety and academic achievement of secondary school students.

$H0_3$: There is no significant cubic relationship between test anxiety and the academic achievement of secondary school students.

$H0_4$: There is no significant quartic relationship between test anxiety and academic achievement of secondary school students.

Research Methods

This study adopted the procedure of correlational research design. The study comprised 2696 senior secondary school II (SSS II) physics students, in Benue State, Nigeria, from which a sample of 337 students was drawn through a simple random sampling technique. Two instruments; Physics Achievement Test (PAT), and Physics Test Anxiety Scale (PTAS) were used for data collection. The PAT instrument comprised 20 multiple-choice test items with options A-D; one correct answer (key) and three incorrect options (distractors). Each key is assigned a score of 4, while an incorrect response is assigned a score of zero (0). A total of 80 scores are obtainable for all correct responses. The PTAS contains 20 items on a 4-point scale to measure the test anxiety level of students in Physics. The instruments were face and content-validated by three methodologists. The internal consistency reliability indices of PAT and PTAS were estimated to be .76 and .73 using KR-20, and Cronbach alpha methods, respectively.

The data was collected through a face-to-face method to ensure a maximum return rate. The study adopted the polynomial regression (non-linear) to test linear, quadratic, cubic, and quartic trends in the data. This is because, researchers have relied on using multiple regression to assess the relationship between test anxiety and achievement, overlooking the non-linear analysis of data. This study modeled the non-linear data as multiple regression could lead to poor fitting estimates when the regression model or equation does not model the data correctly. The use of non-linear regression analysis enabled the researcher to plot the data and visually inspect the nature of the relationship between test anxiety and academic achievement. The hypotheses were tested at 0.05 level of significance.

Table 1: Polynomial regression of the relationship between test anxiety and achievement.

Coefficients:	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	27.982	0.524	53.400	< 0.0000000000002***
poly(Anxiety, degree = 4)1	-52.705	9.620	-5.479	0.0000000847***
poly(Anxiety, degree = 4)2	-20.139	9.620	-2.094	0.0371*
poly(Anxiety, degree = 4)3	8.223	9.620	0.855	0.3933
poly(Anxiety, degree = 4)4	20.798	9.620	2.162	0.0313*
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				
Residual standard error: 9.62 on 332 degrees of freedom				
Multiple R-squared: 0.1071, Adjusted R-squared: 0.0963				
F-statistic: 9.952 on 4 and 332 DF, p-value: 0.0000001288				

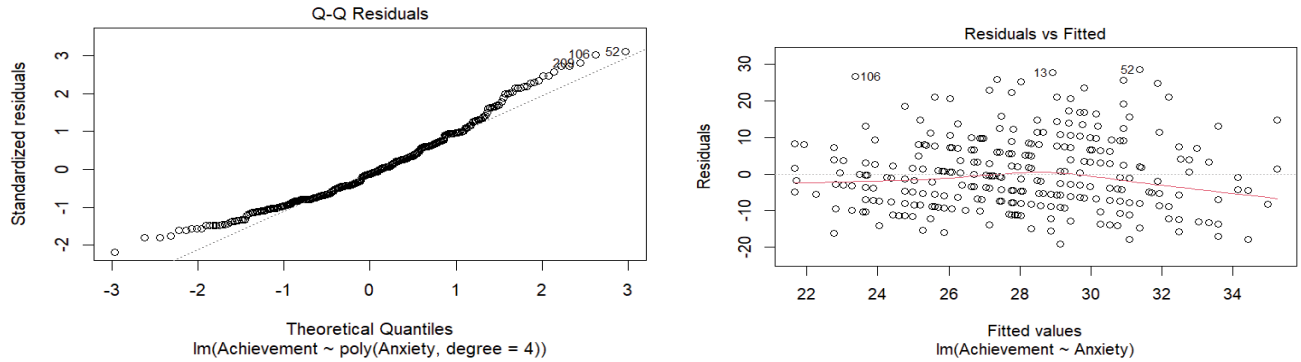

Figure 1: Assumption check.

Ethical considerations

The study involved human subjects, so informed consents were obtained from participants, and approval was granted by the research and ethics committee, University of Nigeria, Nsukka. The researchers adhered to all ethical guidelines during the conduct of this study.

Assumption check

The Q-Q plots and the residual vs. fitted plot in Figure 1 show that the assumption of normality and homoscedasticity (constant variance) were not violated, implying that the regression analysis could be performed.

Results

What is the nature of the relationship between test anxiety and academic achievement among secondary school students?

To examine the nature of the relationship between test anxiety and academic achievement of secondary school students in Physics, a polynomial regression analysis with 4-degree term (1 = linear, 2 = quadratic, 3 = cubic, and 4 = quartic) was conducted. The model included the linear, quadratic, cubic, and quartic terms for test anxiety as predictors of academic achievement.

Model summary

The overall polynomial regression model in Table 1 showed statistically significant results, [$F(4, 332) = 9.952$, $p < 0.001$], indicating that test anxiety explains a significant proportion of the variance in academic achievement. The proportion of test anxiety (coefficient of determination) expressed as R^2 with a value of 0.1071 (*adjust* $R^2 = 0.0963$), suggests that approximately 10.7% of the variance in academic achievement of students is accounted for or explained by the polynomial terms of test anxiety. The results also show that the *intercept* ($\beta = 27.982$, $p < 0.001$), represents the estimated academic achievement of students when test anxiety is at its mean level.

The residuals showed a standard deviation (*SD* = 9.62), with no apparent extreme values, suggesting that the model fit is reasonably well-behaved. The rage (-20.816 - 29.667) for the residuals indicates that the predictions of academic achievement by test anxiety are relatively close to the observed values for most of the students. Based on these results, the polynomial function between test anxiety and academic achievement can be expressed as:

$$\mathbf{AA} = 27.982 - 52.705*\mathbf{TA} - 20.1392*\mathbf{TA}^2 + 20.798*\mathbf{TA}^4,$$

where AA = Academic achievement, and TA = Test anxiety.

There is no significant linear relationship between test anxiety and academic achievement of secondary school students

The result in Table 1 shows that there is a significant

linear and negative relationship between test anxiety and the academic achievement of students with a linear term, β_1 = -52.705, [t = -2.094, p = 0.0371]. This result disputes the null hypothesis but supports the alternate hypothesis that higher levels of test anxiety are associated with lower academic achievement. This relationship can further be visualized in Figure 2. The data points are represented by the dots while the green line represents the regression line or fit. This graph suggests that as test anxiety levels increase, students' academic achievement decreases.

There is no significant quadratic relationship between test anxiety and academic achievement of secondary school students

Table 1 shows a statistically significant quadratic relationship between test anxiety and academic achievement of secondary school students in Physics with a quadratic term, β_2 = -20.139, [t = -2.094, p = 0.0371]. This suggests a curvilinear relationship between test anxiety and academic achievement, implying that the relationship between test anxiety and academic achievement may change direction at different levels of test anxiety. This curvilinear relationship can be visualized in Figure 3 as the regression line of fit seems to form a parabolic shape.

There is no significant cubic relationship between test anxiety and the academic achievement of secondary school students

The result of the analysis in Table 1 shows that the relationship between test anxiety and academic achievement does not show a cubic pattern because the cubic term, β_3 = 8.223, is not statistically significant [t = 0.855, p = 0.3933]. This indicates that the cubic relationship does not significantly improve the model fit. This means that fitting the data of test anxiety and academic achievement onto the polynomial function with a cubic term makes it difficult to understand the relationship between test anxiety and the academic achievement of students.

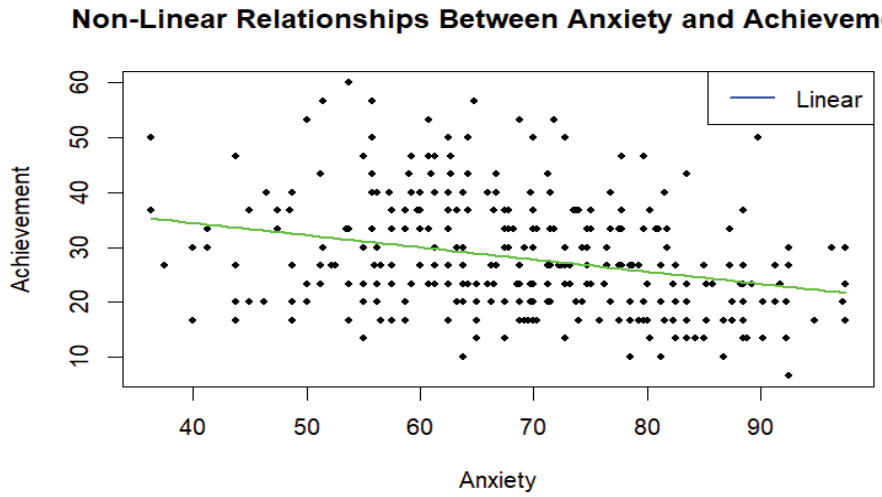

Figure 2: Linear graph of the relationship between test anxiety and academic achievement.

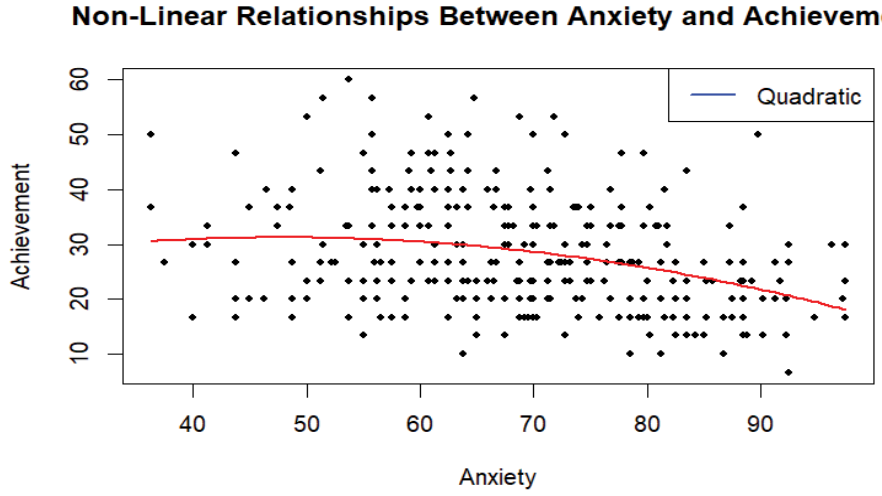

Figure 3: Graph of quadratic relationship between test anxiety and academic achievement.

There is no significant quartic relationship between test anxiety and academic achievement of secondary school students

The result in Table 1 shows that there is a quartic relationship between test anxiety and academic achievement of students with a quartic term, β_4 = 20.798, [t = -2.094, p = 0.0313]. This result suggests a more complex relationship between test anxiety and academic achievement, with multiple inflection points in the relationship. Figure 4 presents clear visual information of this relationship.

Discussion

The results of this study reveal that there is a significant linear, quadratic, and quartic component of the relationship between test anxiety and academic achievement, suggesting a complex relationship. This result could indicate that on a linear term, higher test anxiety leads to lower achievement, but in terms of quadratic and quartic terms, the relationship is not strictly linear, as there are potential points where the slope of the relationship changes, indicating varying effects of test anxiety on academic achievement across different levels. These findings are also supported by Figure 2, Figure 3 and Figure 4. These results are plausible because, lower levels of test anxiety could make students less worried, making them to concentrate, prepare and more focus on their studies, whereas, higher levels of test anxiety could make them stressed, worried, fearful and less motivated, which could impact on their studies and consequently, their achievement. In a similar way, low level of test anxiety could give rise to complacency and reduced efforts which could negatively impact on students' achievement, whereas, extreme or high level of test anxiety could motivate students, making them to take their studies seriously as a result of fear of failure, leading to increased academic achievement. The findings of this study agree with the findings of Zahrakar [14], that while a low level of test anxiety leads to improved achievement, it could also result to unseriousness which may impact achievement negatively. The result also aligns with the findings of [16,17] that high levels of test anxiety, in some cases, may lead to improved academic achievement. Moreover, the findings of Okeke, et al. [8] reported that test anxiety can either increase or decrease students' academic achievement. These reports substantiate the fact that the relationship between anxiety and academic achievement is not only linear but quadratic and quartic.

Limitations of the Study

The data for the study were self-reported responses, given the nature of the survey, the responses could have been subjective, and this could have influenced the result of this study. Future researchers are encouraged to devise more objective means of data collection.

Conclusion

The study explored the nature of the relationship between test anxiety and academic achievement of secondary school students using polynomial (non-linear) regression. The findings from the study indicated a complex relationship between test anxiety and academic achievement, with significant linear, quadratic, and quartic components. The result suggests that in linear terms, higher levels of test anxiety lead to lower academic achievement, whereas, in quadratic and quartic terms, the relationship is non-linear, with varying effects at different test anxiety levels. The study also concludes that a cubic relationship does not exist between test anxiety and academic achievement of students. These results underscore the multifaceted nature of test anxiety and its influence on students' academic achievement.

Recommendations

The following recommendations were highlighted based on the findings of this study:

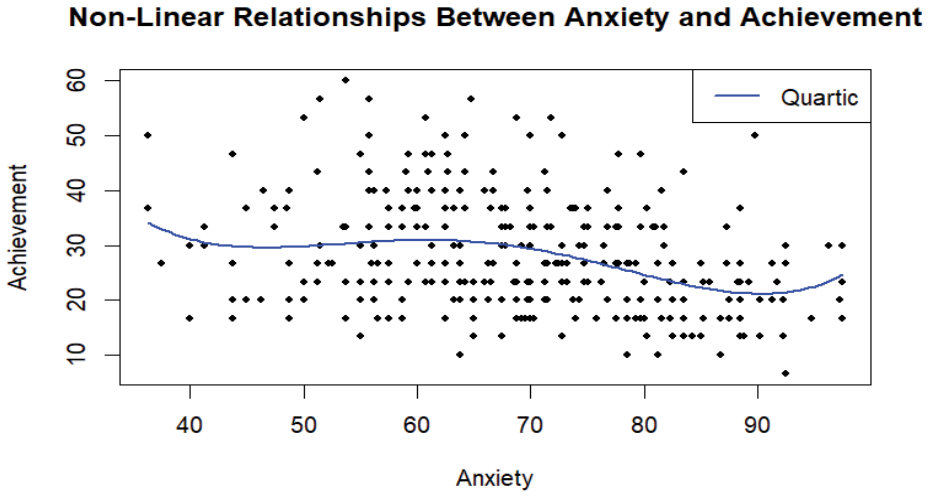

Figure 4: Graph of the quartic relationship between test anxiety and academic achievement.

1. Schools, educators, and other stakeholders should design and implement tiered support and intervention systems that would address varying levels of test anxiety among students.
2. Schools and other learning institutions should incorporate an awareness program on test anxiety into teacher training and curriculum design to enable teachers to manage students' test anxiety levels effectively in order to help them improve in their academic achievement.
3. Therapists and counselors should understand that test anxiety has a multifaceted nature, and could impact students differently, thus, there is a need to design interventions tailored to meet the needs of every student.
4. Students should understand that varying levels of test anxiety have different implications for their academic achievement, hence, they must learn to regulate their anxiety level so that they can be productive academically.

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Data Availability

The data that support the findings of this study are openly available in Havard Dataverse at https://doi.org/10.7910/DVN/KBPF38

Disclosure Statement

The authors report that there is no competing interest to declare.

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Author Contribution Statement

All the authors contributed to this study. The introduction, methods, data analysis, result presentation, and discussions were done by Ocheni, Christopher Adah, while the literature review and data collection were done by Ekwulugo, Adashona Obiamaka. The manuscript was put together by Ocheni, Christopher Adah while the reviewing and editing of the manuscript was done by Ekwulugo Adashona Obiamaka. All the authors read and approved the final manuscript.

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