THE PREDICTIVE POWER OF A MULTIDIMENSIONAL MATHEMATICS ENGAGEMENT SCALE ON STUDENTS' MATHEMATICS ACHIEVEMENT IN EKITI STATE, NIGERIA

Janet ADEGBUYI[1], Roseline SAMA[2]
[1] University of Ibadan, Institute of Education (Nigeria)
[2] Alex Ekweme Federal University, Ndufu Alike (Nigeria)
adeyemisi1969@gmail.com, roselineanochiwa@gmail.com

Abstract

This study examined the relationships between student engagement and academic achievement using a multi-dimensional student mathematics engagement scale to determine the engagement factors specifically relevant to students' mathematics achievements. A survey design was applied in this study. A multistage sampling procedure was used to select a sample of 1008 Senior Secondary School students from 24 schools in Ekiti State, Nigeria. Robust 6-dimensional student mathematics Engagement scales (SMES) with a reliability index of each of the sub-scales of the SMES ranging from 0.68 to 0.87 were used to predict students' achievement in mathematics. (These dimensions were: Personal Agency Engagement, Positive Affective Engagement, Negative Affective Engagement, Positive Behavioural Engagement, Negative Behavioural Engagement and Cognitive Engagement). Regression analysis of the sub-scales showed that only Negative Behaviour Engagement predicted students' achievement in Mathematics ($\beta = -0.12$, $t = -0.2952$, $p < 0.05$). This implies that students with negative behaviour engagement tend to perform poorly in mathematics. Teachers should use any opportunity to select resources that can arouse students' interest and make them vigorous learners during mathematics lessons for better performance.

Keywords: Student mathematics engagement scale, multi-dimensional, Prediction of Mathematics achievement

1. Introduction

The ultimate goal in all educational endeavours is to realize meaningful achievement and learning outcomes through a series of classroom instructional practices and student engagement. By implication, there is a close link between engagement and achievement. Consequently, an educational system with little or no meaningful student engagement will barely bear positive outcomes.

Adegbuyi (2019) refers to student engagement as a multiple-dimensional concept comprising six discrete dimensions namely; positive affective, negative affective, positive behavioural, negative behavioural, cognitive and agentic or personal agency dimensions. These six dimensions are interrelated. Positive affective engagement refers to students' positive responses to teachers, learning tasks, schools, classmates, and student's genuinely treasured learning. Negative affective engagement denotes students' negative reactions in the classroom. These are the existence of annoyance, dryness, and worry.

Positive behavioural engagement describes the high level of students' involvement in teaching and learning activities in terms of devotion and effort (Salhab and Daher, 2023).

Students display excellent performance during class. It also involves the effort students put into their academics to effect a positive change in learning outcomes. This effort includes participation, task completion, performance and natural skills (Sweet et. al, 2021). Negative behavioural engagement refers to students' level of apathy during class, inability to complete homework and solve academic problems during class, and students' truancy or coming late to class.

Cognitive engagement describes students' level of investment in class activity, appreciation of the worth of learning and readiness to go beyond the least requirements (Capone and Lepore, 2022). It also involves the level of students' persistence in solving academic problems, students' perceptions and beliefs about course materials, and the readiness to put on the energy needed to comprehend difficult concepts. Agentic engagement or personal agency refers to students' deliberate, vigorous, and constructive influence on the drift of teaching they acquire through questioning, articulating of favorites, and students' demand for what they desire from the teacher (Bui, 2023)

Although student engagement has been examined as a multi-dimensional concept (Hastie, et. al 2022) and some studies have drawn attention to the positive relationships that exist between student engagement and achievement, there is limited research directly investigating the relationships between the different dimensions of student engagement and academic achievement in mathematics in Ekiti state. Therefore, the basic purpose of this study was to examine the relationships between student engagement and academic achievement using a multi-dimensional mathematics engagement scale to determine the extent to which student engagement explains or predicts students' mathematics achievement. In addition, the engagement factors specifically relevant to the mathematics achievements of students were also examined.

Research Question

1. How reliable are each sub-scales of the student Mathematics Engagement scale?
2. Is there any relationship among the identified factors of the Student's Mathematics Engagement scale?
3. Which of the student Mathematics engagement scale sub-scales is the best predictor of Mathematics achievement?

Objective of the Study

This study examined the relationships between student engagement and academic achievement using a multi-dimensional student mathematics engagement scale to determine the extent to which student engagement explains or predicts students' mathematics achievement. In addition, the engagement factors specifically relevant to the mathematics achievements of students were also examined to see how learning and achievement in Mathematics can be improved.

2. Literature Review

2.1. Empirical Studies on Mathematics Engagement and Achievement

Yang, and Sanborn (2021) identified that active participation in mathematics classes and consistent homework completion are robust predictors of academic success. Complementing these findings, empirical studies have demonstrated that regular attendance and engagement in mathematics-related activities are correlated with higher academic achievement (Tshering, 2024).

Research by Han and Liou-Mark (2023) has shown that students who exhibit positive emotional responses toward mathematics tend to perform better academically. This is supported by studies, such as those by (Abín et. al, 2020) which confirm that students' interest in and enjoyment of mathematics are significant predictors of their achievement in the subject.

Syaiful, Huda, Mukminin, and Kamid, (2022) emphasized the role of cognitive strategies, such as metacognition and critical thinking, in enhancing mathematics performance. Supporting this, research by Minarni and Napitupulu (2020) indicated that students who utilize higher-order thinking skills and effective study strategies in mathematics tend to achieve superior academic results.

Wu, et al. (2022) found that positive peer relationships and supportive teacher-student interactions significantly contribute to higher academic performance. Alam and Mohanty (2023) highlighted the importance of a supportive social environment in nurturing mathematics achievement among secondary school students.

Fung, Tan and Chen (2018) explored the relationships between student engagement and mathematics achievement using a sample of 295,416, 15-year-old students from 11,767 secondary schools in 34 countries who participated in the Program for International Student Assessment (PISA) 2012. Their research assessed affective, behavioral, and cognitive engagement, revealing that more engaged students achieved higher scores, with cognitive engagement showing the strongest relationship with achievement. Furthermore, students who are highly engaged in at least two dimensions had higher achievement levels than those who engaged in only one dimension.

2.2. Multidimensional Scales and Predictive Power

Maamin, Maat, and Iksan, (2021) examined the relationship between student engagement and mathematical achievement among secondary school students. They found that affective engagement had the strongest predictive power for mathematics achievement, followed by behavioural and cognitive engagement.

Quintero et al. (2022) developed and validated the Mathematics and Science Engagement Scales, which measure engagement across behavioural, emotional, cognitive, and social dimensions. Their work confirmed the multidimensional nature of engagement and its predictive validity for academic performance.

3. Methodology

3.1. Research Design

A survey design of the Instrumentation research type was applied in this study. This type of research authenticates large and small populations by selecting small participants from the population to establish the connection that exists among constructs.

3.2. Sample and Sampling Technique

A multistage sampling procedure was used to select a sample of 1008 Senior Secondary School 3 students. Participants were selected from 24 schools in Ekiti State, Nigeria. First, one Senatorial District was randomly selected from the existing three Senatorial Districts in Ekiti State. From the selected Senatorial District, there are five Local government areas out of which four LGAs were randomly selected. From each of the selected Local government areas, simple random sampling was used to select three public senior secondary schools and three private senior secondary schools. Thus, the number of schools in this work was 12 public senior secondary schools and 12 private senior secondary schools respectively. Finally, 42 SS2 students were randomly selected from each of the 24 schools ($24 \cdot 42 = 1008$ students).

3.3. Instrument: Students Mathematics Engagement Scale

The instrument consists of six sub-scales with 35 items of students' mathematics engagement scale viz: (Personal Agency Engagement, Positive Affective Engagement, Negative Affective Engagement, Positive Behavioural Engagement, Negative Behavioural Engagement and Cognitive Engagement). The scale was first constructed by Adegbuyi and Adegoke (2017) through Exploratory Factor Analysis and Parallel Analysis with 45 items. Thereafter, the scale was validated and standardized by Adegbuyi (2020) with 35 items through confirmatory factor analysis and a graded response model of the IRT framework.

Table 1. Method of Data Analysis

Research Question	**Statistical software package**
1. How reliable are each sub-scales of the students' Mathematics Engagement scale?	Reliability analysis using Ordinal Alpha coefficient analysis
2. Is there any relationship among the identified factors of the Student's Mathematics Engagement scale?	Confirmatory factor analysis, AMOS package
3. Which of the students' Mathematics engagement scale sub-scale is the best predictor of Mathematics achievement?	Inferential statistics using multiple Regressions in AMOS package

4. Results and Discussion

Research Question 1: How reliable are each sub-scales of students' Mathematics Engagement scale?

Table 2. Reliability of all the 6 sub-scale of students Mathematics Engagement scale

Factor	**Name**	**Ordinal Alpha**	**Cronbach's Alpha**	**Cronbach's Alpha Based on Standardized Items**	**No of Items**
Factor 1	Personal Agency Engagement	0.87	.846	.846	11
Factor 2	Positive Affective Engagement	0.69	.716	.726	6
Factor 3	Negative Affective Engagement	0.73	.843	.847	7
Factor 4	Positive Behavioural Engagement	0.68	.676	.687	3
Factor 5	Negative Behavioural Engagement	0.73	.724	.727	4
Factor 6	Cognitive Engagement	0.77	.691	.695	4

Table 2 shows the Ordinal alpha coefficient of each of the sub-scale of students' Mathematics Engagement scale. The value of the ordinal alpha coefficient showed the reliability of each of the sub-scale of students' Mathematics Engagement scale which ranges from 0.68 to 0.87. This shows that all the sub-scales of students' Mathematics Engagement scale are reliable.

Research Question 2: Is there any relationship between the identified factors of students' Mathematics Engagement scale?

Table 3. Sample correlation coefficient between all pairs of factors

Sample Correlation			**Estimate**
PERANG	<-->	POSAFF	.336
PERANG	<-->	NEGAFF	-.116
PERANG	<-->	POSBEH	.377
PERANG	<-->	NEGBEH	-.269
PERANG	<-->	COGNIT	.636
POSAFF	<-->	NEGAFF	-.373
POSAFF	<-->	POSBEH	.372
POSAFF	<-->	NEGBEH	-.229
POSAFF	<-->	COGNIT	.425
NEGAFF	<-->	POSBEH	-.258
NEGAFF	<-->	NEGBEH	.459
NEGAFF	<-->	COGNIT	-.168
POSBEH	<-->	NEGBEH	-.193
POSBEH	<-->	COGNIT	.416
NEGBEH	<-->	COGNIT	-.269

Sample correlation coefficient between all pairs of factors was done to find the pattern of relationships between the factors. The result of table 3 and path diagram in figure1 showed that the sample correlation between the factors ranges between -.373 to 0.636 meaning that the factors correlate well, meaning that there exist connection among the latent variables. In other word the items in the extracted factors are likely to be measuring the same trait.

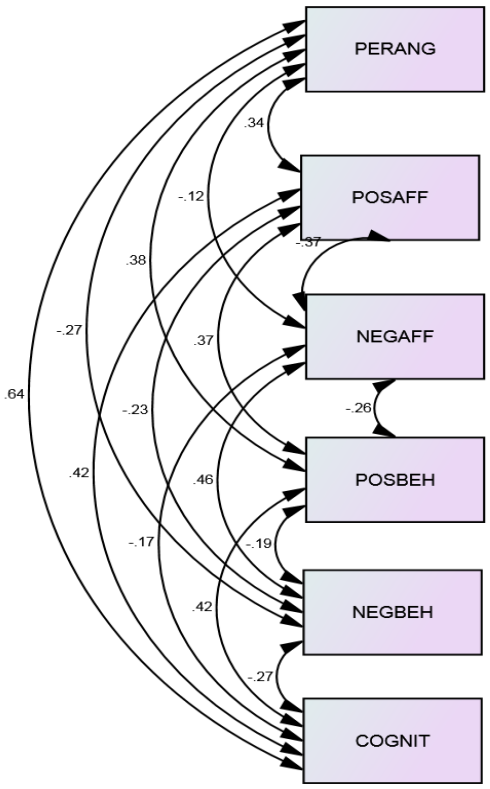

Figure 1. Path diagram of sample correlation between the identified factors of students' Mathematics Engagement scale

Research Question 3: Which of the students' Mathematics Engagement scale sub-scale is the best predictor of Mathematics achievement?

Table 4. Level of prediction of regression model

Model Summary[b]				
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
1	.198[a]	0.39	.034	6.879
Independent variable: Congnit_Eng, Neg_Aff_Eng, Pos_Beh_Eng, Per_Ang_Eng, Pos_Aff_Eng, Neg_Beh_Eng				
b. Dependent Variable: MATHS TEST				

Table 4 provides the R, and R^2, this was used to define the level of fitness at which the regression model predicts the dependent variable. The value of R denotes the value of multiple correlation coefficients. In this case, R represents the measures of quality of the prediction of the Mathematics achievement test. Here, the value of .198 shows the level of prediction ascribed to the Mathematics achievement test. The "R Square" shows the squared multiple correlation coefficients. This refers to the amount of variance in the dependent variable that can be accounted for by the independent variables. From the table, all the latent variables explain 39 % of the variation in the Mathematics achievement tests. This result indicates a good level of prediction which shows the fitness of the regression model.

Table 5. The regression model fits

ANOVA[a]						
Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1	Regression	1936.507	6	322.751	6.821	.000[b]
	Residual	47364.350	1001	47.317		
	Total	49300.857	1007			
a. Dependent Variable: MATHS TEST						
b. Predictors: (Constant), Congnit_Eng, Neg_Aff_Eng, Pos_Beh_Eng, Per_Ang_Eng, Pos_Aff_Eng, Neg_Beh_Eng						

Table 5 shows the F column. The F examined how well the regression model fit the data. The table displays that the measured variables significantly predict the mathematics achievement test, $F(6, 1001) = 6.821$, $p < .05$ (i.e., the regression model has a good data fit model).

Table 6. Statistical significance of sub-scales of students' mathematics engagement

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	22.561	2.057		10.968	**.000**	18.525	26.598
	Per_Ang Eng	-.050	.039	-.048	-1.287	**.198**	-.126	.026
	Pos_Aff_Eng	.130	.090	.056	1.446	**.148**	-.046	.307
	Neg_Aff_Eng	-.113	.073	-.064	-1.541	**.124**	-.257	.031
	Pos_Beh_Eng	.162	.126	.047	1.284	**.200**	-.086	.410
	Neg_Beh_Eng	-.302	.102	**-.115**	-2.952	**.003**	-.502	-.101
	Congnit_Eng	-.082	.096	-.033	-.859	**.390**	-.270	.106
MATHS TEST								

Unstandardized coefficients specify the extent to which Mathematics achievement test varies with the measured variable when all other measured variables are held constant. Table 6 examined whether the value of unstandardized/standardized coefficient is equal to 0 in the distribution. If p is less than .05, this suggested that the coefficients are significantly different from 0. The p-value is found in the "Sig." columns. The result of table 6 shows that Negative behaviour Engagement is statistically significantly different from 0 (zero), which means that it has a unique contribution to the level of students' performance in Mathematics with the value of P = 0.003 < 0.05. Not only that, figure 2 gives the pictorial representation of regression model of students' mathematics achievement and the six dimensions of students' mathematics engagement. However, with the result of table 6 and the graph in figure 2, Negative behaviour Engagement appeared the best predictor out of the six sub-scales of students Mathematics Engagement scale with the value of Beta = -.115.

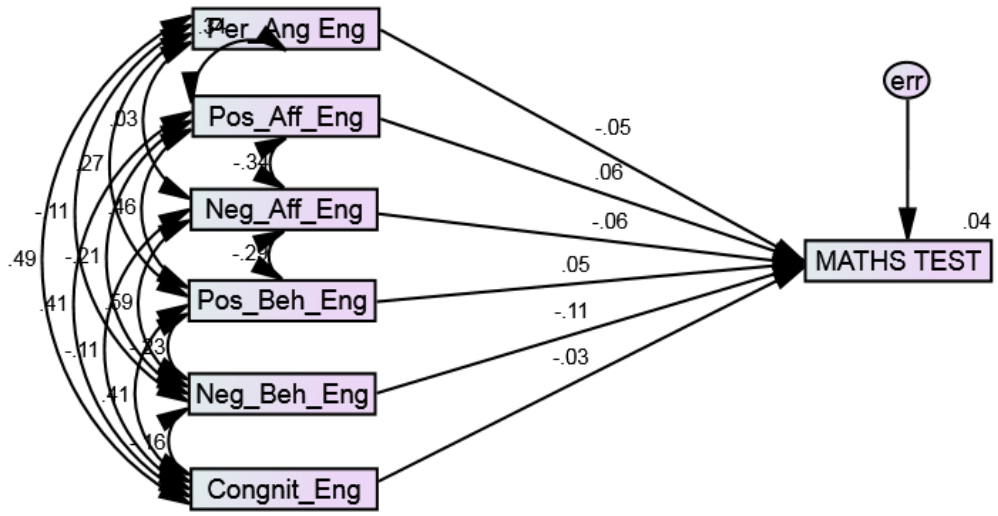

Figure 2. Pictorial representation of students' mathematics achievement and the six dimensions of students' mathematics engagement scale.

5. Conclusion

5.1. Summary of Findings

The key outcomes of this study are as follows:

- The reliability coefficient of each of the sub-scales of students' Mathematics Engagement scale which ranges from 0.68 to 0.87 shows that all the sub-scales of students' Mathematics Engagement scale are highly reliable.
- The correlation indices of all the sub-scales of students' Mathematics Engagement scale range between -.373 to 0.636. The values indicate that the items of the scale were meaningfully related and contributed to the construct being measured. In other word the items in all the sub-scales measure students' mathematics engagement.
- The six sub-scales were utilized to evaluate the level of students' Engagement in Mathematics. The result showed that Negative behaviour had the largest influence on the achievement of students in Mathematics.

5.2. Recommendations

Based on the outcomes of this work, the following recommendations were made:

- Teachers and school administrators need to identify those students with negative dispositions toward mathematics during the teaching and learning processes and try to occupy them in meaningful teaching and learning processes for high-level performance in their classrooms.
- Teachers and educators should use any opportunity available to them to select some resources that can stimulate the interest of students and make them vigorous learners during mathematics lessons for better performance.
- Educationalists and teachers should be close to their students and select the necessary method that will enable them to deliver interesting teaching that can increase the level of students' engagement in mathematics during their lessons.

References

Abín, A., Núñez, J. C., Rodríguez, C., Cueli, M., García, T., & Rosário, P. (2020). Predicting mathematics achievement in secondary education: The role of cognitive, motivational, and emotional variables. *Frontiers in Psychology*, *11*, 523356.

Adegbuyi, J. Y. (2019). Construction and Use of Multidimensional Student Mathematics Engagement Scale In Predicting Mathematics Achievement Among Senior Secondary School Students In Ekiti State, Nigeria [Doctoral Dissertation].

Alam, A., & Mohanty, A. (2023). Cultural beliefs and equity in educational institutions: exploring the social and philosophical notions of ability groupings in teaching and learning of mathematics. *International Journal of Adolescence and Youth*, *28*(1), 2270662.

Bui, H. H. (2023). Directed Motivational Currents Through Group Projects: A Study Of Vietnamese University Students [Doctoral Dissertation, University Of Essex].

Capone, R., & Lepore, M. (2022). From distance learning to integrated digital learning: A fuzzy cognitive analysis focused on engagement, motivation, and participation during COVID-19 pandemic. *Technology, Knowledge and Learning, 27*(4), 1259–1289.

Fung, F., Tan, C. Y., & Chen, G. (2018). Student engagement and mathematics achievement: Unraveling main and interactive effects. *Psychology in the Schools, 55*(7), 815–831. https://doi.org/10.1002/pits.22139

Han, S., & Liou-Mark, J. (2023). Self-efficacy and attitudes towards mathematics of undergraduates: A US and Taiwan comparison. *Journal of Mathematics Education, 8*(1), 1–15.

Hastie, P. A., Stringfellow, A., Johnson, J. L., Dixon, C. E., Hollett, N., & Ward, K. (2022). Examining the concept of engagement in physical education. *Physical Education and Sport Pedagogy, 27*(1), 1–18.

Maamin, M., Maat, S. M., & H. Iksan, Z. (2021). The influence of student engagement on mathematical achievement among secondary school students. *Mathematics, 10*(1), 41.

Minarni, A., & Napitupulu, E. E. (2020). The role of constructivism-based learning in improving mathematical high-order thinking skills of Indonesian students. *Infinity Journal, 9*(1), 111–132.

Quintero, M., Hasty, L., Li, T., Song, S., & Wang, Z. (2022). A multidimensional examination of math anxiety and engagement on math achievement. *British Journal of Educational Psychology, 92*(3), 955–973.

Ryan, R. M., & Deci, E. L. (2020). Intrinsic and extrinsic motivation from a self-determination theory perspective: Definitions, theory, practices, and future directions. *Contemporary educational psychology, 61*, 101860.

Salhab, R., & Daher, W. (2023). University students' engagement in mobile learning. *European Journal of Investigation in Health, Psychology and Education, 13*(1), 202–216.

Sweet, J. J., Heilbronner, R. L., Morgan, J. E., Larrabee, G. J., Rohling, M. L., Boone, K. B., & Conference Participants. (2021). American Academy of Clinical Neuropsychology (AACN) 2021 consensus statement on validity assessment: Update of the 2009 AACN consensus conference statement on neuropsychological assessment of effort, response bias, and malingering. *The Clinical Neuropsychologist, 35*(6), 1053–1106.

Syaiful, Huda, N., Mukminin, A., & Kamid. (2022). Using a metacognitive learning approach to enhance students' critical thinking skills through mathematics education. *SN Social Sciences, 2*(4), 31.

Tshering, G. (2024). Perceptions of Teachers and Students Regarding the 10th Grade Students' Homework in Perspectives: Academic Achievement and Practices. *Asian Journal of Education and Social Studies, 50*(5), 403–412.

Wu, F., Jiang, Y., Liu, D., Konorova, E., & Yang, X. (2022). The role of perceived teacher and peer relationships in adolescent students' academic motivation and educational outcomes. *Educational Psychology, 42*(4), 439–458.

Zhou, S., Zhou, W., & Traynor, A. (2020). Parent and teacher homework involvement and their associations with students' homework disaffection and mathematics achievement. *Learning and Individual Differences, 77*, 101780.