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Development and validation of mathematics persistence scale for secondary school students

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ABSTRACT

The study focused on development and validation of the mathematics persistence scale (MPS) for measuring secondary school students' persistence in learning mathematics. The study employed a descriptive survey design. Three research questions guided the study. The population of the study comprised 13,516 students distributed in 59 public secondary schools in Nsukka Education Zone, Enugu State, Nigeria. A multi-stage sampling procedure was used in selecting a sample size of 1,378 secondary school mathematics students used for the study. In the development of MPS, 85 items were first constructed and subjected to face validity. After face validation, eight items were deleted in line with the recommendations and suggestions of the validators. The remaining 77 items were further subjected to exploratory factor analysis using statistical package for the social science version 25. 28 factorial pure items, that loaded into four salient factors (persistence in classroom mathematics exercise, persistence in mathematics take home assignments, persistence in a group mathematics tasks, and persistence in mathematics examination) emerged from the analysis. Confirmatory factor analysis of four factors using lavaan and semPlot packages indicated a harmony between four factor model and the data. The internal consistency coefficients of four factors ranges from 0.78 to 0.92.

Keywords: secondary education, development and validation, mathematics, mathematical persistence

INTRODUCTION

Students that enroll in secondary education are referred to as secondary school students. Secondary education is a transitional level of education, and it is found between primary and tertiary education. In other words, secondary education serves as the last educational phase for students who want to pursue a secondary education but not tertiary education. Secondary education can also be seen as a form of education for teenagers (Gallengo, 2007). Historically, secondary education in Nigeria dated back to era of missionaries' evangelism. As a matter of fact, missionaries brought secondary education to Nigeria in the late 1850s as an additional kind of instruction for students who wanted to advance their education beyond primary school (Chika, 2009). Subjects such as mathematics and English language are taught at both primary and secondary school levels. It is at this stage that learning difficulties from primary education are expected to be identified and addressed in order to enable students pursue their desired academic careers. A strong performance in mathematics is one of the indicators of whether a student would be allowed to continue their studies in science related fields after secondary education.

Mathematics is a fundamental discipline that employs numbers, forms, and symbols to solve problems in a way that is both scientific and logical. Understanding mathematics could be an effective strategy for overcoming the technology lag of developing and impoverished countries (Ogbu et. al., 2020). In the majority of countries, mathematics is not only made mandatory for learner in elementary and secondary education, but it is also a prerequisite for elevating students from one class to another. Many countries have recognized the value of mathematics, and numerous policies and programs are being implemented to increase students' understanding of mathematics. For instance, a lot of mathematics competitions with prizes have been held in Nigeria specifically for secondary school students with the intention of enhancing their interest and desire in studying mathematics. This desire is expected to manifest in the students' achievement in mathematics. Unfortunately, students' achievement in mathematics seems not to have reflected the investments towards learning of mathematics. For instance, the West Africa Examinations Council (WAEC) chief examiner's report (WAEC, 2014-2022) regrettably noted that students do poorly in external mathematics examinations. This suggests that the goals of secondary mathematics education in Nigeria are not being fully met. Therefore, the need to find the lasting solution to students' poor achievement in mathematics cannot be overstated. Interestingly students' cognitive, affective, and behavioral attitudes are said to have impacts on how well students succeed in mathematics (Ngeche, 2017). Students' behavioral attitude include their perception that mathematics is a tough discipline, which is meant for

only the bright students. Although, mathematical content may be more challenging than other disciplines, students are still expected to put in the necessary time and effort in order to succeed in learning mathematics. Hence, students are expected to show a high level of persistence, when finding solutions to challenging mathematical tasks, if they are to significantly improve their achievement in mathematics to acceptable standards.

Persistence is an attribute that is needed from any student who wants academic success. Working through challenges in order to achieve specific goals is what persistence requires (Holman et al., 2016). It is a quality that enables students to work hard in pursuit of a goal even in the face of difficulties (Purdie, 2016). Persistence could be manifested by how long students persist in trying difficult exercises until the right answers are found (Tinto, 2017). Another way to think about persistence is as the propensity of people to overcome obstacles and problems in order to accomplish specific objectives. Students' learning has been found to be greatly influenced by their perseverance (Madhlangobe et al., 2014). In order to be persistent, one must keep trying to solve a problem after an initial failure. Therefore, in this study, students' mathematics persistence is defined as the extent to which students work to overcome barriers and difficulties along the learning curve in order to solve difficult mathematical problems or to understand difficult mathematical concepts. It entails attempting the same mathematical problems again until the right answers are found. It seems that the words "persistency" and "motivation" are occasionally used synonymously. It should be highlighted that despite their similarities, persistence and motivation differ in some ways. Persistence requires both motivation and persistence, while the opposite may not necessarily be true. A sustained kind of motivation is persistence. For instance, students could feel enthusiastic to start a work but lose up easily when faced with little obstacles. Nevertheless, since some students believe that Mathematics challenging subject, it calls for the greatest amount of persistence from them.

Many other behavioral acts, such as bring challenging mathematical problems to mathematics teachers or senior colleagues for assistance, are examples of how students' mathematical persistence could be demonstrated. The students' capacity to try to comprehend a particular mathematical concept before it is taught in the classroom, as well as their inability to become discouraged by the length of the solutions to difficult mathematical problems are all evidence of students' mathematics persistence. Furthermore, students could demonstrate mathematics persistence by their capacity to complete mathematics assignments on time, regardless of how challenging they may be. Contrarily, the rise in popularity of quick and shortcut solutions to mathematical tasks among the students are attributes of low mathematics persistence. A student who does not persevere is likely to do poorly in a variety of academic areas, particularly in mathematics, which many people view as being abstract subject. Research on students' perseverance are more frequently conducted with the goal of examining undergraduate or graduate students' perseverance in completing their degree programs (Hsu & Bailey, 2011; Thalib et al., 2018). As a matter of fact, studies on secondary school persistence in learning various secondary school subjects are almost lacking.

Understanding secondary school students' mathematics persistence could provide teachers the chance to mentor students, help to flatten the increasing curve of low achievement in secondary school mathematics, and raise the standard of instruction. It appears that little is known about secondary school students' persistence in learning mathematics, particularly in Nigeria. This may be due to the dearth of trustworthy and efficient tools for assessing and comprehending secondary school students' persistence in mathematics. There, providing empirically validated tools for assessing secondary school students' mathematics persistence would create more opportunities for researchers to further explore the roles of mathematics persistence in students' learning outcomes.

Statement of the Problem

The underachievement of students in mathematics is now a major worry for all parties involved in education, particularly researchers. The hunt for a solution to students' low mathematics performance has consumed a lot of resources, yet the students' bad performance seems to have persisted. Yet, efforts to find a long-term fix go on. The persistence of students to complete their education has been found to be positively correlated with their academic success. Also, it's conceivable that learning persistence and achievement among secondary school students are positively correlated. Furthermore, to overcome poor achievement in mathematics, guiding information for students can be gained by analyzing the roles of persistence on secondary school students' learning outcomes. Of course, It becomes quite challenging to modify available persistence scales to evaluate secondary school students' persistence in learning a particular school subject, such as mathematics because, from literature, the majority of persistence scales are created for tertiary students without focusing on a single subject or course. The study, therefore, set out to create and validate mathematics persistence scale (MPS) for secondary school students, which could be easily adapted to other subject areas so as to address the issue of the inadequate of empirically validated instruments that accurately measure secondary school students' mathematics persistence.

Purpose of the Study

The general purpose of the study was to develop and validate mathematical persistence scale (MPS) for measuring secondary school students' mathematics persistence. Specifically, the study sought to determine:

1. the salient factors that underlie MPS,
2. the reliability of MPS, and
3. the construct validity of MPS

Research Questions

1. How many salient factors underlie MPS?
2. What are the reliabilities of the salient factors that underlie MPS?
3. What is the construct validity of MPS?

MATERIALS & METHODS

The study employed a descriptive survey research design. Descriptive survey research designs describe the attributes or characteristics of individual(s) or event(s) or object(s). The characteristics of MPS is described in this study. The population of the study was 13,516 secondary school students distributed in 59 public secondary schools in Nsukka Education Zone, Enugu State, Nigeria. The sample size was 1,378 students comprising 708 and 608 boys. The sample size was selected using multistage sampling procedure. The first stage was the selection of 40 schools out of the 59 schools using purposive sampling technique. The second stage was the selection on class level from each of the 40 schools selected in first stage using simple random sampling technique by balloting. The last stage was selection one intact class each from the class level selected in stage using simple random sampling technique by balloting. A total of 40 intact classes were selected and a total 1,378 secondary school students were found in the intact classes. The students in the intact classes constituted the sample size for this study. The instrument for data collection was MPS developed by the researchers. MPS was developed by following the following recommendations:

(a) specification of the domain of the construct,

(b) developing the initial items,

(c) purification of the measures,

(d) collection of data, and

(e) assessing the validity and reliability of the proposed measuring scale (Churchhill cited in Liu et al., 2019).

Specification of the Domain of the Construct

Specification of the domain of the construct entails defining the construct, which the instrument is designed to measure. In other words, it means having good knowledge of the construct. It can also be seen as definition of the objective of the scale. Proper specification of the domain of construct is achieved through extensive literature review. In specifying the domain of the construct (mathematics persistence) of this study, students' mathematics persistence is the tendency of students to strive to comprehend or get solutions to difficult or challenging mathematics concept or questions/exercise. Mathematics persistence could manifest when challenges or difficulties associated with mathematics could not discourage students from attempting to comprehend mathematics.

Developing the Initial Items

Developing the initial items entails writing the individual items that are expected to measure the identified construct. In this study, 85 items that were expected to measure secondary school students' mathematics persistence were first written by the researchers. These items were then arranged in a four-point Likert type rating scale. The instrument was scored, as follows: very low extent (VLE)=1, low extent (LE)=2, moderate extent (ME)=3, and very high extent (VHE)=4. The instrument is designed in such a way that higher score on the instrument indicates high mathematics persistence, whereas low score indicates low mathematics persistence.

Purifying the Measure

Purification of the measure entails logical validation of the instrument by experts. The initial 85 items of MPS were subjected to face validation by three experts in the Faculty of Education, University of Nigeria, Nsukka. Two of the experts were in Educational Measurement and Evaluation Unit, Department of Science Education, while one was in Educational Psychology Unit, Department of Educational Foundations These experts were given copies of MPS and were asked to check whether

(a) each of the items is appropriate for measuring students mathematics persistence,

(b) the vocabularies of the items are appropriate for secondary school students, and

(c) the items contains some elements of ambiguity.

These experts were also requested to make suggestions and recommendations that would improve the overall quality of the instrument. Based on the recommendations and suggestions by the experts, some items were recast while eight items were completely deleted, thereby, leaving the initial 85 MPS items with 77 items after validation by experts. Thereafter, copies of MPS with 77 items were administered on 1,378 students, which constitute the sample size for the study, by the researchers with the help of the mathematics teachers in the sampled school. The responses of these students were then collated.

The collated responses of students on the 77 items were further subjected to exploratory factor analysis using the statistical package for the social science (SPSS) version 25. Factor analysis takes a set of variables and reduces them to a smaller number of underlying factor, which accounts for as many variances as possible (Cohen et al., 2007). Eigenvalues and scree plot were used in determining the number of factors that were in MPS. Factors with eigenvalues greater than one are considered acceptable based on Kaiser normalization, a default value in SPSS. Eigenvalues are measures of variance among factors. The criterion for inclusion of an item in a factor is based on factor loading with values greater than or equal to 0.40, which is in line with the recommendation of some experts (Gana & Broc, 2019; Hair et al., 2002). Items with factor loadings less than .40 is said to be factorial impure and were deleted. Items that loaded in more than one factor are said to have cross-loaded and considered as factorial complex; these items were also deleted. Selected items loaded only on one factor and are said to be factorial pure. Factors with at least four items are retained are considered in this study as salient factors, whereas factors with less than four items were deleted. In addition, it has been observed that a cumulative variance in the eigenvalues of 60.047% denotes moderate explanatory power, which most researchers would be satisfied with (Cohen et al., 2007). Hence, research question one was answered using eigenvalues, cumulative variances in the eigenvalues and scree plot. The reliabilities of the salient factor were determined using Cronbach's

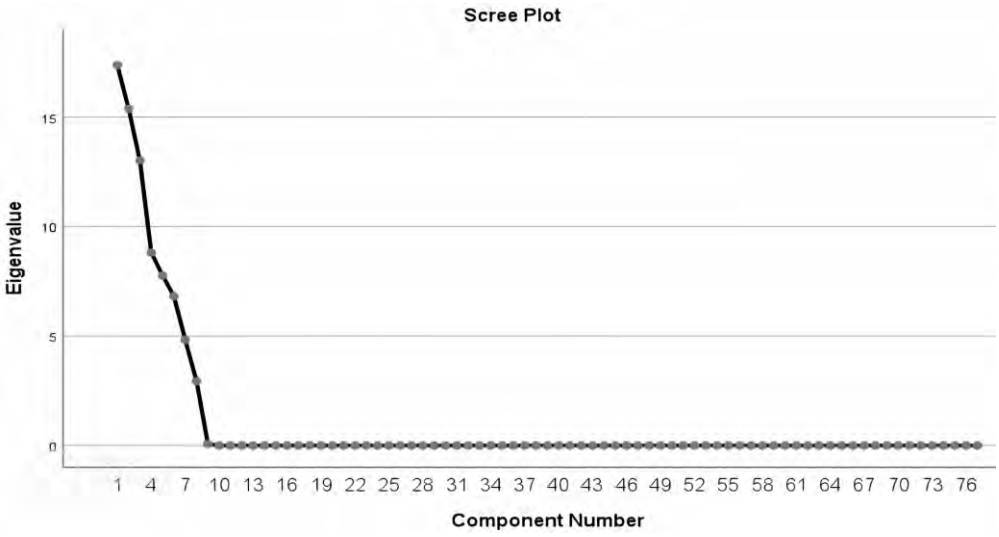

Figure 1. Scree plot for the correlation matrix (Source: Authors' own elaboration)

Table 1. Eigenvalues for rotated factor analysis of MPS

Factors	Initial eigenvalues			Rotation sums of squared loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	17.372	22.561	22.561	14.055	18.253	18.253
2	15.382	19.976	42.537	13.187	17.126	35.379
3	13.013	16.900	59.438	11.940	15.506	50.885
4	8.811	11.443	70.881	10.813	14.043	64.928
5	7.765	10.084	80.965	8.577	11.139	76.066
6	6.817	8.854	89.819	7.545	9.798	85.864
7	4.825	6.267	96.086	5.511	7.157	93.021
8	2.943	3.822	99.907	5.303	6.886	99.907

alpha, which was used in answering research question two. Orban et al. (2017) noted that 0.7 is the minimum reliability index a scale must possess to be considered as reliable. The reliability of salient factors of MPS was equally judged based on the benchmark of 0.7. The construct validity of the selected items was determined using confirmatory factor analysis, specifically, through lavaan (latent variance analysis) an R package for structural equation modelling (Rosseel, 2012). The validity of the instrument was judged based on the comparative fit index (CFI), Tucker-Lewis index (TLI), root-mean square error (RMSEA). Kline (2016) recommends that CFI and TLI values greater than or equal to 0.90 indicates good fit; and RMSEA of .05 or less is an indication of good fit. These indices with the help of path diagram were used in answering the research question three.

RESULTS

The result of this study is presented in line with the research questions that guided the study.

Research Question One: How Many Salient Factors Underlie MPS?

The scree plot in **Figure 1** reveals that eight factors are above the bend in the elbow while the remaining factors are below the bend in the elbow. Catell (1996) and Pallant (2001) suggested that factors that are above the bend in the elbow are worthy to be retained while those below the bend in the bend in elbow should be discarded. Therefore, there are eight factors that underlies MPS. This is further supported by **Table 1**.

Table 1 shows that eight factors, which account for 99.907 variance underlie MPS. Of the 77 items subjected to factor analysis 25 items were factorial complex and were deleted, 16 were factorial impure and were equally deleted. 36 factorial pure items loaded on eight factors. Of these 36 items, only two items loaded on factor 5, three items loaded on factor 6, two items loaded on factor7 while one item loaded on factor 8. Since the number of items in these factors are less than four, they are considered as non-salient factor and were deleted, therefore, four factors are the salient factors that underlie MPS. These factors and their corresponding item loading are shown on **Table 2**.

Table 2 reveals that items 8, 10, 12, 22, 24, 25, 30, 32, 42, 42, 44, 46, 54, and 57 loaded on factor 1 (persistence in classroom mathematics exercise). Items 20, 27, 48, 56, and 62 loaded on factor 2 (persistence in mathematics take home assignments). Items 23, 35, 47, and 59 loaded on factor 3 (persistence in a group mathematics tasks). Items 5, 17, 29, 41, 53, and 71 loaded on factor 4 (persistence in mathematics examination). These are the salient factors that underlie MPS. These extracted 28 items were further re-administered on similar sample of students using the outlined sampling techniques. The response of the students were further subjected to reliability and confirmatory factor analysis.

Table 2. MPS salient factor loadings

S/N	Loaded items	Items	Factor loadings			
			F1	F2	F3	F4
1	Item8	I do not give up solving difficult mathematical questions/exercises.	.477			
2	Item10	I keep taking difficult mathematics questions to my teachers/colleagues for assistance.	.458			
3	Item12	I always take note of difficult mathematics exercises/questions in my textbooks and keep attempting them until I get the answers.	.626			
4	Item22	I am not discouraged by the length of the solutions to mathematical problems.	.549			
5	Item24	There is no limit on number of time I attempt difficult questions in mathematics until I get correct answers.	.614			
6	Item25	The more difficult mathematics problems are the more efforts I put in solving them.	.535			
7	Item30	I wake up in the night to attempt some difficult mathematics topics.	.600			
8	Item32	I know that if do not get the solutions to difficult mathematics questions immediately, I will definitely get that if I keep attempting.	.770			
9	Item42	I solve/study mathematics for a long time without getting tired easily.	.504			
10	Item44	I start attempting difficult mathematics topics/exercises in my textbooks even before they are taught in classrooms.	.412			
11	Item46	No matter the difficult of my mathematics assignments, I always complete them and submit on time.	.556			
12	Item54	I hardly stop attempting difficult mathematics exercises/ questions	.538			
13	Item57	I do not get discouraged for given wrong answers to questions in mathematics lessons, I keep attempting.	.478			
14	Item20	Correct answers to difficult mathematics questions are obtained by students like me that can resolve after initial failed attempts.		.438		
15	Item27	Difficulty mathematics questions/exercises are meant for students like me that do not give up on them easily.		.727		
16	Item48	I always achieve my targeted grades in mathematics no matter the challenges.		.581		
17	Item56	I do not sleep on time, in an attempt to get solutions to difficult mathematics questions/exercises.		.400		
18	Item62	I do not have rest of mind if do not get solutions to difficult mathematics exercise/questions.		.429		
19	Item23	I keep solving difficult mathematics questions even when my colleagues have given up.			.576	
20	Item35	I sacrifice my time and efforts to understand difficult topics in mathematics.			.717	
21	Item47	I keep discussing difficult mathematics exercises/ topics with my classmates.			.468	
22	Item59	Difficulties in learning mathematics cannot make me to change my career choice.			.537	
23	Item5	Every difficult topics or question in mathematics is solvable if given enough attention and efforts.				.496
24	Item17	Every good grade I have made in mathematics is as a result of not given up on difficult questions.				.511
25	Item29	Every good grade I have made in mathematics was as a result of not given up on easily on difficult topics				.424
26	Item41	Whenever my mathematics teachers advise me to study hard, I take it seriously				.470
27	Item53	I am always preoccupied with finding solution to difficult mathematics questions or exercises.				.605
28	Item71	I keep paying serious attention when difficult topics are being taught in my class.				.584

Table 3. Reliability estimates of persistence in classroom mathematics exercise, persistence in mathematics take home assignments, persistence in a group mathematics tasks, & persistence in mathematics examination

S/N	Name of the factor	Cronbach's alpha coefficients
Factor 1	Persistence in classroom mathematics exercise	.85
Factor 2	Persistence in mathematics take home assignment	.78
Factor 3	Persistence in a group mathematics tasks	.89
Factor 4	Persistence in mathematics examination	.92

Research Question Two: What Are the Reliabilities of the Salient Factors That Underlie MPS?

Table 3 shows reliability estimates for the four salient factors that underlie MPS. The names of these factors are persistence in classroom mathematics exercise, persistence in mathematics take home assignments, persistence in a group mathematics tasks, and persistence in mathematics examination. The reliability coefficients ranges from .78 to .92. These results reveal that MPS is reliable as the underlie factors show strong reliability estimates of .78 and above. The implies that MPS is reliable to measure secondary school students' mathematics persistence.

Research Question Three: What Is the Construct Validity of MPS?

Figure 2 shows the path diagram of the four salient Factor that underlies MPS. **Figure 2** was plotted using semPlot an R package for visualization of structural equation modelling (Epskamp, 2015). Going by the statistically significant value of χ^2(344, n=1,378)=26,521.213, p=0.025 associated with the above model, the harmony between the model and the data is not perfect. However, other indices for testing model fit, such as CFI (.955) and TLI (.936) indicate harmony between the model and data. This further supported that MPS is good to measure secondary school students' mathematics persistence.

DISCUSSION

Research question one examines the number of salient factors that underlie secondary school students' MPS. **Table 2** reveals that there are four salient factors (persistence in classroom mathematics exercise, persistence in mathematics take home assignments, persistence in a group mathematics tasks, and persistence in mathematics examination) out of eight factors that

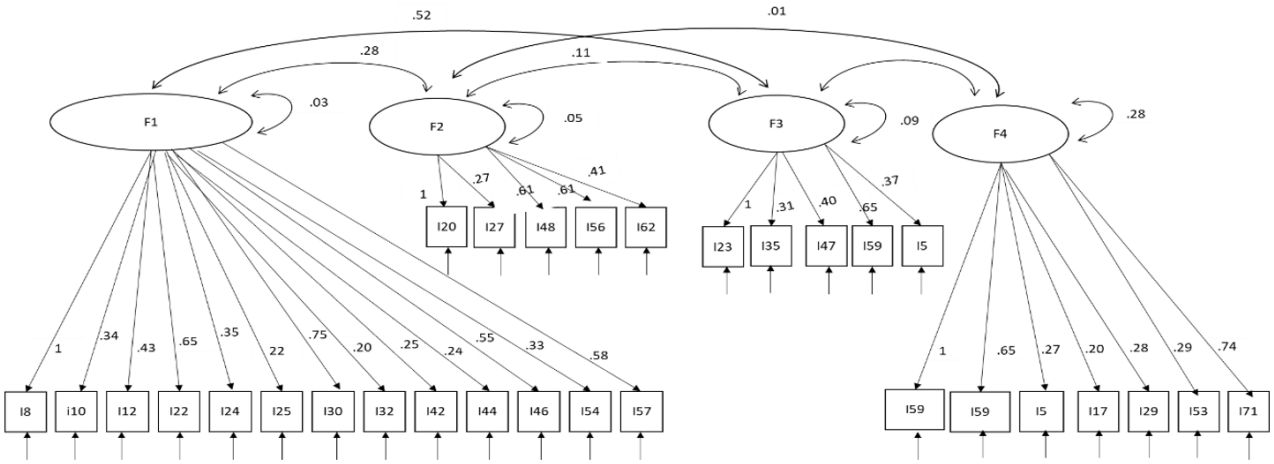

Figure 2. Path diagram of four-factor model (Source: Authors' own elaboration)

underlie secondary school students' MPS. The reason for the four salient factors that underlie the secondary school MPS could arise either from the fact that persistence could be multidimensional in nature, or the complexity associated with mathematics as a subject. The finding is in consonance with Thalib et al. (2018) who discovered that persistence scale that measures undergraduate students' academic persistence to complete their degrees has four factors. More so, **Table 1** revealed that a cumulative of 70.881% variance in eigenvalues is explained by four salient factors that underlie the scale. The 70.881% cumulative eigenvalues variance is above the 60.047% moderate explanatory power researchers would be happy with (Cohen et al., 2007).

The reliability of MPS was revealed in **Table 3**. The reliabilities indices of four factors were all above 0.7. The reason for the high reliability indices for the factors may be attributed to the clarity and the appropriateness of the items. This finding is in line with Orban et al. (2017) who noted a minimum of 0.7 in statistics anxiety instrument for students of tertiary institutions. The confirmatory factor analysis reveals that there is harmony between the data and four factors model that parsimoniously explain students' mathematics persistence.

CONCLUSIONS

The development of MPS followed rigorous processes that involved, specification of the domain of the construct, developing the initial items, purification of the measures, collection of the necessary data, assessing the validity and reliability of the instrument. Based on the findings of the study, it is concluded that, the developed and validated secondary school MPS has reliable and quality psychometric properties.

Recommendations

Based on the findings of the study, the following recommendations were made:

1. Mathematics teachers, school guidance and counsellors should use MPS to measure their students' mathematics persistence and offer appropriate support.
2. Researchers who wish to measure students' mathematic persistence or persistence in other subjects should easily adopt or adapt MPS by simply replacing 'mathematics' with the subject of their choice.
3. Experts should equally consider focusing more of their attentions on secondary and primary school students' persistence at subject level as this would provide more guidance information to students.
4. Government should sponsor a national research on assessment of all secondary school students' mathematics persistence in Nigeria for urgent diagnostic and remediation of any identified cases of low mathematics persistence.

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Ethical statement: The authors stated that, in line with the local legislation and public secondary school requirement, ethical review approval was not required for this study. The researchers informed the students used for this study about the purpose of the research, confidentiality, and their right to withdraw from the study without adverse percussion.

Declaration of interest: No conflict of interest is declared by authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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