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Development of Mathematics Motivation Scale: A Preliminary Exploratory Study With a Focus on Secondary School Students

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Abstract

The motivation for learning mathematics is an essential factor in predicting the performance of secondary school students. Students who are intrinsically or extrinsically motivated to learn mathematics generally demonstrate higher performance than others who are not motivated. However, a properly designed instrument for the measurement of this construct has been sparsely reported in the literature. The present study is carried out to develop an instrument of high psychometric properties for measuring the construct. The study involved 439 students randomly selected across secondary schools using a survey research design. An exploratory factor analysis (EFA) was conducted to determine the factor structure and distribution of items in each of the mathematics motivation subscales. The factors are extracted using principal component analysis, and the extracted factors are rotated using varimax. The analysis results in a final 24-item mathematics motivation scale, which contained five subscales with around half of the total variance explained of 48.99% explained variance. A high-reliability coefficient was found for the whole instrument with some empirical evidence of construct validity. The concise instrument is recommended for assessing the motivation of secondary school students, and further studies are recommended for its confirmation of factor structures in independent samples.

Keywords: Development of Instrument; Exploratory Factor Analysis; Mathematics; Motivation; Secondary Schools.

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INTRODUCTION

The teaching and learning of mathematics, especially at the secondary school levels, have been bewildered with a host of challenges in which poor students' performance is at the top of the list. Several attempts have been made globally to alleviate these problems. Among the many factors that have been shown empirically to predict students' performance in mathematics is their motivation to learn the subject. Students who are intrinsically or extrinsically motivated to learn mathematics generally demonstrate higher performance than others who are not motivated (Murayama, Pekrun, Lichtenfeld, & Vom Hofe, 2013). Motivation has been described as an ability of an individual to foster instigations and sustainment of behaviours that are goal-directed (Pintrich & Maehr, 2002). In the realm of mathematics learning, students with high motivation are generally assumed to outperform others with less motivation (Singh, Granville, & Dika, 2002). Therefore, students' motivation affects their learning processes and outcomes (Abdurrahman & Garba, 2014; Barattucci, Pagliaro, Cafagna, & Bosetto, 2017; Sartawi, Alsawaie, Dodeen, Tibi, & Alghazo, 2012). Everyone is naturally different. As such, individuals with an equal amount of affective, cognitive, and psycho-motor characteristics may not exit (Ersoy & Oksuz, 2015). Thus, it can be argued from this perspective that secondary school students' learning is led by motivation and that motivation also enables them in acknowledging the relevance of mathematics to their lives after secondary school education.

Schunk and Mullen (2013) conceptualised motivation as a process at which individuals begin and sustain their goal-directed activities. In the realm of educational settings, many researchers put achievement motivation at a spotlight. For instance, Elliot and Church (1997) in their empirical study, argued that achievement motivation is a pervasive feature of an individual that manifests through strivings for competence on goal-oriented activities. A similar construct to achievement motivation is "motivation to learn" which entails deliberate engagements in academic activities such that new skills and knowledge are eventually acquired (Denzine & Brown, 2015). Students that are filled with learning enjoyment are more probable to be interested in the learning activity, value it, and demonstrate a commitment to such activity in a way that their persistence is enhanced coupled with increased performance (Adao, Bueno, Persia, & Landicho, 2015). On the other hand, students that do not enjoy learning mathematics are less probable to be interested in the learning activity. They have less value for such activity and demonstrate less commitment in a way that their persistence is reduced coupled with decreased performance (Denzine & Brown, 2015). Hence, motivation and its various types are important factors in students' academic performance.

The relationship between motivation and academic performance of students cannot be underestimated. Singh et al. (2002), in an empirical study, argued that motivation has a significant contribution to the academic performance of students. Motivation contributes significantly not only to learning outcomes of secondary school students but also across childhood learning through adolescence (Tella, 2007). Multiple shreds of evidence in diverse fields of studies including mathematics have been documented on the strong relationships between motivation, persistence on learning in the face obstacles, learning curiosity, learning outcomes, approaches to learning, and performance of students (Barattucci et al., 2017; Denzine & Brown, 2015; Zakariya, 2019).Despite the influence of motivation to learn on students' achievement in mathematics, a well-developed measure of the construct with a focus on Nigerian secondary school students is lacking in the literature. Considering the fact Nigerian secondary school students are highly prone to performance attrition in mathematics (Zakariya, Ibrahim, & Adisa, 2016) coupled with cultural sensitivity of personal factors such as motivation, one may argue that the motivation scales developed elsewhere could lack validity and reliability in the Nigerian context. As such, with a reliance on self-determination theory (Deci & Ryan, 1985a, 1985b) and on relevant literature (e.g., Keller, 1987; Pintrich, Smith, Duncan, & Mckeachie, 1991), the present study is aimed at developing a measure that exposes motivation to learning mathematics with a focus on secondary school students in Nigeria.

A potential of the present lies in its ability to indigenise the measure of motivation to learn, such that, a high prediction of students' performance in mathematics may be achieved. Further, secondary school teachers, curriculum planners, policymakers and other education stakeholders will benefit from the findings of the present as proxies toward the improvement of students' performance in mathematics. It is important to remark that the present article reports only preliminary findings of an ongoing project on students' motivation and its relationship with other personal factors. Therefore, the results of initial exploratory factor analyses and reliability of the instrument are reported.

Conceptual framework

Academic motivation in self-determination theory

Self-determination theory (Deci & Ryan, 1985a, 1985b) provides a theoretical framework for motivation by providing a combination of both empirical and conceptual explanations to motives behind individuals' behaviours. Self-determination theory (SDT) postulated that the basis of individuals' motivation is their psychological needs. In more specific terms, psychological needs as competence, autonomy, and relatedness are crucial needs that enhance individuals' motivation. Empirical evidence has been reported to back these claims. For instance, Deci and Ryan (1985a) reported that students' competence, their perceived autonomy, and relatedness have direct effects on motivation to learn. Several other educational researchers have demonstrated applications of SDT as a theoretical structure to motivation in diverse areas such as curriculum instruction (Ryan, 1995), school learning (Deci & Ryan, 1985), physical exercise, and health care (Vallerand, Fortier, & Guay, 1997).

The self-determination theory postulates three types of achievement motivation. These are intrinsic motivation, extrinsic motivation, and amotivation. Intrinsic motivation describes a situation whereby an individual involves in an activity for the sake of the activity itself, the pleasure derived from it, and satisfaction brought about in participating in such activity (Deci & Ryan, 1985b). Achievement intrinsic motivation facilitates learning, fosters competence and stems from an individual's psychological needs and determination (Deci & Ryan, 1985a). On the other hand, extrinsic motivation has been described as something that "pertains to a wide variety of behaviors where the goals of action extend beyond those inherent in the activity itself" (Vallerand & Bissonnette, 1992, p. 600). The third type of motivation, amotivation, involves a situation whereby a person is neither motivated intrinsically nor motivated extrinsically. As it relates to academic settings, students that are amotivated feel incompetent on learnings tasks, show lack of self-control, and ascribe their failures to something beyond their capability (Ayub, 2010).

The relationship between motivation and academic performance have been studied extensively over the years. As such, empirical evidence has substantially established a positive correlation between motivation and students' academic performance (Kusurkar, Ten, Vos, Westers, & Croiset, 2013; Lemos & Veríssimo, 2014; Sartawi et al., 2012; Singh et al., 2002). In a study involving 375 junior secondary schools, Abdurrahman and Garba (2014) investigated the impact of motivation on students' academic achievement in mathematics. One of the important findings of their study was a significant difference that was found in the academic achievement of high motivated ($M=48.23$, $SD = 23.11$) and low motivated ($M= 28.05$, $SD = 17.00$) students in mathematics ($t(373) = 12.36$, $p < .05$). It was also revealed that there was a significant gender difference on effect motivation on academic performance between males ($M = 55.10$, $SD = 19.51$) and female ($M = 32.01$, $SD = 13.79$) students ($t(373) = 15.80$, $p < .05$). These findings are also corroborated in a more recent study on the effect of motivation on academic performance was reported by Mercader, Presentación, Siegenthaler, and Molinero (2017). The longitudinal research examined the predictive power of some dimensions of achievement motivation on mathematics academic performance of school children. Thus, academic motivation may be argued to not only influence students' performance in mathematics but also varies across gender among secondary students.

Measures of achievement motivation

Scale developments for measuring achievement motivation have attracted global attention, and studies with this intention are well documented for more than thirty years. In an attempt to ensure ways of establishing major determinants of students' motivation to learn coupled with finding systematic procedures of knowing these determinants, Keller (1987) developed the ARCS motivation model. Keller identified four different constituents of the motivation of students. These constituents are confidence, attention, relevance, and satisfaction. The ARCS model was utilised in developing Keller's instructional material motivational scale. This survey instrument is a 36-item Likert scale type with four factors: Confidence, attention, relevance, and satisfaction for promoting and sustaining motivation (Keller, 1987). However, this instrument was explicitly developed for instructional design purposes which to some extent limits its applicability to mathematics education research.

Another omnibus instrument designed to expose motivation is the motivated strategies for learning questionnaire (MSLQ). This instrument was developed by Pintrich et al. (1991) and has been adapted and validated by researchers in different countries. Some of the countries are Turkey (e.g., Karadeniz, Büyüköztürk, Akgün, Çakmak, & Demirel, 2008), Hong Kong (e.g., Lee, Yin, & Zhang, 2010), Czech Republic (e.g., Jakešová & Hrbáčková, 2014), and Pakistan (e.g., Nausheen, 2016). MSLQ is made up of two subscales: motivation and learning strategies. Both the motivation and the learning strategies subscales have several sub-components with evidence of construct validity and internal consistency of its items (Pintrich et al., 1991).

Moreover, another crucial achievement motivation instrument is the Échelle de Motivation enÉducation (EME) that was formerly available in French (Vallerand, Blais, Brière, & Pelletier, 1989) and later translated to English language and renamed academic motivation scale (AMS) by (Vallerand et al., 1992). The AMS was developed based on the self-regulated theory and consisted of 28 items. These items that are further divided into seven subscales hypothesised to access three distinct types of intrinsic motivation (intrinsic motivation to accomplish things, intrinsic motivation to know, and intrinsic motivation to experience stimulation), three distinct types of extrinsic motivation (introjected, external, and identified regulation), and amotivation. The sample for the study involved 745 undergraduate students from the province of Ontario, with a mean age of 21 years. The AMS has a satisfactory level of item internal consistency (Cronbach alpha value = .81) and short-term stability over a period of one month using the test-retest method (correlation coefficient = .79). This instrument was embraced by mathematics educators worldwide, and a psychometric investigation of it can be found, elsewhere (Cokley & Helm, 2001).

A cross-examination of the literature on mathematics-related motivation scales reveals that very few direct mathematics motivation scales are available. Most of the available mathematics motivation scales are adaptations from omnibus scales on motivation. Typical examples of these adapted motivational scales into mathematics can be found in the literature (Liu & Lin, 2010; Yavuz, Ozyildirim, & Dogan, 2012). After an extensive and to some extent exhaustive search of the literature, it is observed that the only well-documented direct mathematics motivation scale is the primary school mathematics motivation scale (PSMMS) reported by (Ersoy & Oksuz, 2015). As such, to the best of the researchers' knowledge, there is no scale specifically developed to measure secondary school students' achievement motivation in mathematics. This lack of direct measuring instrument for achievement motivation in mathematics with a focus on secondary school students calls for the development of a new scale. Further, we embark on developing a new scale because of its scarcity and we opine that a complete adaptation of an existing scale might not be fruitful due to context and cultural specificity of motivation.

The present research

Item Development

To develop Item development for mathematics motivation scale in the present study was based on adaptations from the literature reviewed in the measures of academic motivation section. These adaptations require changing of some item wordings and inclusion of mathematics in some items to reflect the specificity of the subject. The initial MMS contains 26 items with the first two items about student's age and sex and the remaining 24 items capture statements on mathematics motivation of the students. Likert scale format was utilised with five points subcategories. Such that students need to rate their agreement or otherwise using one of the following codes: *strongly disagree* (SD), *disagree* (D), *neither agree nor disagree* (N), *agree* (A), and *strongly agree* (SA). The 24 items are subjected to exploratory factor analysis to determine its dimensions. Some mathematics education professors are engaged to examine the face and content validity of MMS before data collection. Their recommendations, suggestions, and comments are implemented to improve the validity of the instrument. Sample items on the MMS are presented in the result section.

Research design

The research design adopted in the current study is a survey type. This entails a one-time survey instrument administration to foster statistical analyses of the collected data (Jansen, 2010). The construct (mathematics motivation of secondary school students) was studied in its natural form without any manipulation of the construct by the researchers. The researchers simply collect the data using the MMS, and the collected data are analysed to give an objective description of the construct.

Data collection and analysis

The MMS was initially administered to 460 senior secondary school students who volunteered to take part in the study by given their individual consents. An adequate sample composed of 224 (51%) males and 207 (42.7%) females and eight students did not indicate their gender types to give a total of 439. The age range of the student is between 12 to 25 years, with a mean of 17.12 years. The survey instrument was administered with the assistant of five teachers in training distributed in various schools. Appropriate permissions are sought and granted in line with the data protection regulations in the country. The students are appropriately informed of the complete anonymous nature of the instrument, and they voluntarily completed the MMS prior to their first lecture of the day. This survey administration took only 10 minutes such that their lessons are not affected. Twenty-nine out of a total of 460 copies of the instrument are excepted from the analysis because of incomplete and inappropriate responses received from some students. The effective 439-sample was analysed using statistical package for social sciences (SPSS) version 25.0.

RESULTS

Exploratory factor analysis

The analysis proceeded by conducting exploratory factor analysis (EFA) to explore the factor structure and to investigate the number of factors to retain in the MMS subcategories. However, before conducting the EFA, the sample adequacy, as well as multicollinearity of the data, are investigated by running Bartlett's sphericity test (BST) and looking into the Kaiser-Meyer-Olkin (KMO) index coupled with the input correlation matrix determinant. The BST test was found to be significant ($p < .01$) with the KMO index of .92 and the correlation matrix determinant of 0.002 was found which is greater than the recommended value (0.00001) for ensuring an adequate EFA sample (Field, 2018).

Thus, the sample is adequate to conduct EFA. Further, it was found that the data do not contain any multicollinearity with a significant approximate BTS chi-square (χ^2 = 2387.87, df = 276, p < 0.01).

Exploratory factor analysis was applied to the 24 items that are conceptualised to expose the mathematics motivation with a principal component analysis for factors extraction. A total of five factors are extracted with items loaded on separate factors without any substantial cross-loading, accounting for a total of 48.99% variance. The variance explained was such that factor 1 explained 29.11%, factor 2 explained 6.32%, factor 3 explained 4.81%, factor 4 explained 4.48%, and factor 5 explained 4.27% of the total variance. In an attempt to enhance the interpretability of the factors extracted varimax with Kaiser normalisation was used to rotate the extracted factors. The varimax rotation converged after 13 iterations whose results are presented in Table 1. The communalities of each item after the extraction are as well also presented in Table 1.

Table 1 Rotated component matrix and item communalities

	Component					Communality
	1	2	3	4	5	
Item 1				.724		.601
Item 2		.569				.455
Item 3				.612		.475
Item 4		.588				.517
Item 5	.445					.589
Item 6		.647				.473
Item 7	.454					.286
Item 8	.612					.492
Item 9					.385	.508
Item 10			.648			.614
Item 11	.543					.512
Item 12					.599	.432
Item 13	.508					.429
Item 14	.596					.483
Item 15					.655	.631
Item 16		.540				.501
Item 17	.427					.493
Item 18					.393	.425
Item 19			.656			.618
Item 20	521					.471
Item 21				.496		.382
Item 22	.411					.385
Item 23	.500					.490
Item 24			.661			.498

Factor 1 is made up of ten items. These include items 5, 7, 8, 11, 13, 14, 17, 20, 22 and 23. The statements of these items describe students' self-efficacy for learning and performance. Hence, this factor was named self-efficacy for learning and performance motivation (SLPM). Factor 2 was made up of four items; items 2, 4, 6 and 16. The statements of these items describe students' intrinsically motivated goals. Hence, this factor was named intrinsic motivation (IM). Factor 3 was made up of three items; items 10, 19 and 24. The statements of these items describe students' perceived utility of mathematics. Hence, this factor was named the utility of mathematics motivation (UMM). Factor 4 was made up of three items; items 1, 3 and 21. The statements of these items describe students' perceived importance of mathematics. Hence, this factor was named as the importance of mathematics motivation (IMM). Factor 5 was made up of four items; items 9, 12, 15 and 18. The statements of these items describe students' extrinsically motivated goals. Hence, this factor was named extrinsic motivation (EM). It is important to remark that the naming of each of the emerged factors of the MMS is an offshoot from the item statements. The authors use their discretions coupled with some insights from the theory and previous literature to come about these names. As such, the names are descriptive of the items that form each factor and are subject to future modifications. More so, the factors as well as the respective items capture only intrinsic and extrinsic motivation as explicated under the conceptual framework section. Table 2 presents some sample items in each respective MMS subscale.

Table 2 Sample items in each MMS subscale

Subscale	Sample item
Self-efficacy for learning and performance motivation	Item 5: I am confident I can understand the basic concepts taught in mathematics Item 8: I'm confident I can understand the most complex concepts presented by the mathematics teacher
Intrinsic motivation	Item 4: When I have the opportunity, I choose mathematics past questions and solve on my own Item 16: Understanding the topics of mathematics is very important to me
Utility of mathematics motivation	Item 19: I think that learning mathematics is important because it stimulates my thinking Item 24: I want to know mathematics so that I can teach my friends and younger ones
Importance of mathematics motivation	Item 1: In a mathematics class, I prefer topics that really challenge me so I can learn new things Item 21: I study hard in mathematics because I want to represent my school in mathematics competition
Extrinsic motivation	Item 9: I want to do well in mathematics because it is important to show my ability to my family, friends, employer, or others Item 12: I can do well in mathematics if my parent and teachers can give some gifts

Reliability of MMS

As evidence of reliability and internal consistency of the MMS and its five subcategories, we computed Cronbach's alpha coefficients. The ensuing results from this analysis are presented in Table 4. None of the values is less than .50, and the reliability coefficient of the 24 items MMS is .89, which showed high internal consistency of the items (Field, 2018).

Table 1 Cronbach's alpha coefficients of Items in each MMS subcategory

Factor	Mean	Variance	Std. Deviation	N of Items	α
MMS	98.02	203.32	14.26	24	.89
SLPM	39.84	46.68	6.83	10	.80
UMM	12.42	6.27	2.50	3	.66
EM	16.70	9.48	3.08	4	.64
IM	16.42	8.49	2.91	4	.61
IMM	12.47	5.50	2.35	3	.53

CONCLUSION

Motivation is a central issue in the field of education, leading students to better study approaches to learning and learning outcomes (Barattucci, 2019; Barattucci & Bocciolesi, 2018; Zakariya, Bjørkestøl, Nilsen, Goodchild, & Lorås, 2020). However, despite the diverse applications and importance of acts based on student's motivation in mathematics, there are few instruments developed to expose this construct with a focus on mathematics learning. The purpose of the present is to develop a short-item scale that captures mathematics achievement motivation among secondary school students. The sophistication of both theoretical and statistical procedures used in developing the instrument is conjectured to foster generalisation. The study covers a total sample of 439 students in their second year of secondary school education. Analyses of the psychometric properties of the instrument provide promising results and confirmed its five-factor structure (self-efficacy for learning and performance motivation, intrinsic motivation, the utility of mathematics motivation, the importance of mathematics motivation, and extrinsic motivation).

Results showed that MMS could be improved, and a future confirmatory factor analysis should follow. The reliability coefficient of the instrument was .89, even if some sub-scales (e.g., the importance of mathematics motivation) showed not completely acceptable reliability value. The established reliability coefficient of MMS is higher than that of some similar instruments reported in the literature (e.g., Vallerand et al., 1992). The study contributes to the literature on the topic by confirming the importance of multiple factors in motivation, and in particular, those supported by the some of the reviewed literature like the utility of mathematics, and intrinsic motivation (e.g., Liu & Lin, 2010; Yavuz et al., 2012).

However, some of the various limitations of this research need to be mentioned. The study sample was of convenience. We did not collect any other important socio-demographical information to look for relations between variables, and we did not measure any other learning outcome or learning variables to look for discriminant validity or convergent validity. Further research is recommended to confirm the factorial structure of the MMS using confirmatory factor analysis.

The instrument for measuring students' mathematics motivation with 24 items and five subcategories can be profitably used in different contexts. The instrument would be useful to education stakeholders who are directly involved in teaching and coordinating affairs related to secondary school mathematics such as mathematics classroom teachers, educators, psychologists, etc. Even though the data utilised for the current study are collected from northern Nigeria, its ensuing findings are presumed to have high generalisation as a result of the level of sophistication in statistical tests applied. This instrument is therefore recommended to measure students' mathematics motivation at the secondary school levels. The current study underlines the importance of investing more on monitoring students' motivation in learning mathematics, in order to manage teaching context factors (teaching methods, course organisation, laboratories, activities, etc.), approaches to learning, attitudes toward mathematics, and improve achievement (Zakariya, 2017; Zakariya, Goodchild, Bjørkestøl, & Nilsen, 2019). The final 24 – item mathematics motivation scale will be available whenever requested from the corresponding author of this article.

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