Relationships of mathematics achievement with self-determined motivation and mathematics anxiety among senior two students in Northern Rwanda

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Research article

Relationships of mathematics achievement with self-determined motivation and mathematics anxiety among senior two students in Northern Rwanda

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A R T I C L E I N F O

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A B S T R A C T

The most important factors affecting students' mathematics achievement are affective-motivational factors. Grounded on self-determination theory, expectancy-value theory, and control-value theory, we examined the relationship between self-determined motivation (i.e., intrinsic motivation and career motivation) and mathematics anxiety (cognitive and affective components) with mathematics achievement. The authors examined the proposed relations using cross-sectional data of senior two (grade eight) students in Northern Rwanda. Exploratory and confirmatory factor analyses of the subscales adapted from the Science Motivation Questionnaire (SMQ and SMQ-II) confirmed a two-factor structure for mathematics anxiety and a two-factor structure for self-determined motivation. The adapted subscales showed good internal consistency, convergent validity, and discriminant validity. Furthermore, the findings suggest that the adapted subscales can be used to assess intrinsic motivation, career motivation, and mathematics anxiety among Rwandan students in senior two. Based on the findings, mathematics anxiety is a two-dimensional construct comprising both cognitive and affective components, and these components differ in their relationship with mathematics achievement. Cognitive mathematics anxiety was negatively related to mathematics achievement more than affective mathematics anxiety; intrinsic motivation and career motivation were positively related to mathematics achievement. These findings suggest that teachers should promote more self-determined motivation among senior two students to improve their mathematics achievement. Additional longitudinal research is needed to determine whether the observed differential relationship patterns between mathematics anxiety components and mathematics achievement persist over time.

1. Introduction

Affective-motivational factors are the most critical aspects of students' behavior that affect mathematics achievement [1–15]. There is evidence that motivation increases students' mathematics achievement [4], whereas mathematics anxiety diminishes mathematics achievement [7,10,12,14]. Although mathematics anxiety negatively affects students' mathematics achievement, results

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are less consistent when studied as a two-dimensional construct (cognitive and affective mathematics anxiety) [7,14–17]. According to Henschel and Roick [13] and Liebert and Morris [17], mathematics anxiety includes both cognitive and affective components. A cognitive component consists of negative expectations and self-deprecating thoughts about one's performance. An affective component consists of feelings of nervousness, tension, and unpleasant physiological reactions to testing situations. Wigfield and Meece [7] found that affective mathematics anxiety negatively correlated with mathematics achievement, whereas cognitive mathematics anxiety did not. On the other hand, in the study conducted by Henschel and Roick [14], Liebert and Morris [17], and Morris [16], mathematics achievement showed a stronger negative association with cognitive mathematics anxiety than affective mathematics anxiety. As very little research has been conducted, and the results have been conflicting, more research is needed to assess the differential associations between mathematics achievement and components of mathematics anxiety.

Besides mathematics anxiety, studies on students' motivation to learn mathematics and mathematics achievement have reported inconsistent or sometimes contradicting results. Based on these studies, this relation depends on how motivation is defined and measured. Several studies defined motivation as a two-dimensional construct (intrinsic and extrinsic motivation); intrinsic motivation is related to mathematics achievement [3,8,9], but less consistent results have been found regarding extrinsic motivation. Despite studies finding a negative relationship between extrinsic motivation and mathematics achievement [3,8,9], others suggest that extrinsic motivation may positively relate to mathematics achievement. Based on his definition of extrinsic motivation as "perceptions of mathematics usefulness in daily life," Güvendir [11] found that students who consider mathematics useful have better mathematics achievement than those who do not. Self-determination theory (SDT: Ryan and Deci [18]) describes the perceived value of mathematics in daily life or future careers ("identified regulation") as a form of extrinsic motivation that is more self-determined and closer to intrinsic motivation [19,20]. Despite empirical research suggesting that self-determined motivation (i.e., "intrinsic and identified motivation") is positively associated with academic achievement [21–24], these forms of motivation rapidly decrease as students enter adolescence [25]. However, as those studies were conducted in high-income countries' educational contexts, studies in low-income countries' educational contexts like Rwanda are needed.

A competency-based curriculum (CBC) has been implemented in Rwanda, as well as in Tanzania, Mozambique, Zambia, and Zimbabwe, to produce competent students capable of applying new knowledge and becoming experts in solving everyday problems [26–28]. However, students' mathematics achievement in many Sub-Saharan African countries, including Rwanda, is disappointing. Unless the problem is adequately addressed, students in Sub-Saharan African countries will take several years to attain levels comparable to those of their counterparts in high-income economies in East Asia [29]. One of the determining factors of mathematics achievement is the affective-motivational variables of students toward mathematics [22,30]. Hence, variables such as perceived usefulness of mathematics (career motivation), intrinsic motivation, and anxiety toward mathematics play a key role in mathematics learning and achievement [1,4,10,14,31]. Despite the importance of those affective-motivational variables, in Sub-Saharan Africa, only a few studies (if none) have examined how they affect mathematics achievement. In addition, there are no validated research instruments to assess those affective-motivational variables in Sub-Saharan Africa, particularly in mathematics. Therefore, a psychometrically sound instrument is needed to assess affective-motivational variables and to examine their relation to mathematics achievement. This instrument will help teachers to monitor and evaluate their students' motivation and mathematics anxiety. Thus, the present study was guided by the following objectives:

1. To adapt and validate the science motivation questionnaire for Rwandan students in senior two in mathematics.
2. To examine the relationship between mathematics achievement and self-determined motivation and its differential relationship with cognitive and affective mathematics anxiety.

2. Theoretical framework

Theoretical frameworks for measuring students' motivation have been developed, each proposing different yet closely related constructs [32]. While these theories do not explain motivation the same way, most have described motivation as either intrinsic or extrinsic. These theories suggest that extrinsically motivated behaviors are governed by external mechanisms (e.g., rewards and punishments), whereas intrinsically motivated behaviors are governed by personal interests [33]. Some students may engage in mathematics activities not because they find them interesting (intrinsic motivation) but because they recognize how important mathematics will be to their future [34]. According to self-determination theory (SDT: Ryan and Deci [18]), this sense of mathematics being important to future careers is also a type of motivation that may promote academic achievement. In SDT, different types of extrinsic motivation are distinguished by the degree of self-determination (i.e., the degree to which the self determines behavior): "external regulation", "introjected regulation", "identified regulation", and "integrated regulation". Along a self-determination continuum [35], external regulation and introjected regulation are forms of extrinsic motivation that indicate low self-determination because they are mainly influenced by external pressure and are hence controlled forms of motivation (e.g., students seeking grades or avoiding punishment). A form of extrinsic motivation that is more self-determined and, to some extent, similar to intrinsic motivation (e.g., students engaging in an activity they enjoy the most [19,20]) is identified regulation (e.g., "students who learn mathematics because they believe that it will benefit their future careers"). Consequently, some researchers have combined identified regulation with intrinsic motivation to form an autonomous motivation, contrasting with controlled motivation (external and introjected regulation).

According to the expectancy-value theory [36,37], students' motivation depends on their expectations and the value they place on a task. Within this framework, the value component consists of intrinsic, attainment, and utility value. Intrinsic value refers to the enjoyment a person gets from doing a task, and it is similar in some ways to intrinsic motivation [18,35]. The utility value component refers to engaging in a particular task because it fits into the individual's plans, such as studying mathematics to get a mathematics-related job (career motivation). In this sense, the utility value is similar to extrinsic motivation, specifically to the SDT construct of identified regulation, the most autonomous form of extrinsic motivation [18,35]. In addition to influencing students' choice of activities to pursue, expectancy and value also influence their academic achievement [36,38], and these relationships strengthen as students grow [39].

Based on the expectancy-value theory (CVT), Pekrun [40] developed the control-value theory to examine achievement emotions' antecedents and effects. In contrast to expectancy-value theory, control-value-theory focuses on students' perceptions of control over outcomes rather than their expectancies for success. According to CVT, achievement emotions (both positive and negative emotions) depend on control appraisals (such as succeeding in mathematics activities or tests) and value appraisals (such as recognizing the relevance of mathematics for present or future goals). It follows that students' achievement emotions are closely related to their academic achievement, where positive emotions, such as the usefulness of activity, can promote academic achievement, while negative emotions, such as anxiety, can hinder it [14,41,42]. Within CVT, control-related appraisals include self-perceived competence, outcome expectations, and causal attributions. Value-related appraisals include valuing a task or outcome for its own sake ("intrinsic value") and valuing a task or outcome because of its usefulness for achieving a specific goal ("extrinsic value"). Extrinsic value in CVT refers to the expectancy-value theory's utility value and attainment value. As part of the present study, we examined emotions related to mathematics learning (intrinsic motivation and career motivation) and mathematics tests (mathematics anxiety).

The present study examined mathematics anxiety which is a demotivator and detrimental to academic achievement, particularly in mathematics [1,10,12,14,43,44]. Mathematics anxiety is defined as worry or fear that people experience when they are involved in mathematics [12]. According to Wigfield and Meece [7] and Henschel and Roick [13,14], mathematics anxiety consists of two components: negative affective reactions (fear, nervousness, and discomfort) and cognitive reactions (worries about not doing well in mathematics). According to these studies, both components are empirically distinct, despite their correlations.

2.1. Motivation and mathematics achievement

According to previous studies (e.g., Refs. [1,30,38]), motivational factors are more predictive of mathematics achievement than intellectual abilities. However, the relationship between motivation and mathematics achievement is mixed, with some researchers finding positive associations [22,30]. Others have found negative associations between extrinsic motivation and academic achievement [9,45]. Areepattamannil [9] found that intrinsic motivation positively predicted academic achievement among both Indian immigrants and Indian adolescents. On the other hand, extrinsic motivation negatively predicted academic achievement for Indian immigrant adolescents but not for Indian adolescents. Some studies suggested that extrinsic motivation may relate to academic achievement positively. For example, although intrinsic motivation (e.g., "I enjoy learning mathematics", and "I like mathematics") was more significant than extrinsic motivation (e.g., "I think I will use mathematics in my daily life", and "In order to have a job I need to have a sufficient knowledge of mathematics"), Güvendir [11] found that mathematics achievement was positively related to both. García [30] found that high achievers reported significantly higher levels of extrinsic motivation (e.g., "I think mathematics will be useful in the future"), intrinsic motivation, and enjoyment (e.g., "I enjoy studying mathematics) relative to low achieving counterparts. Similarly, Lim and Chapman [22] and Tran and Nguyen [46] found that extrinsic motivation (integrated and identified regulation) and intrinsic motivation positively correlated with mathematics achievement. Manganelli [45] suggested that students driven by intrinsic motivation and autonomous extrinsic motivation (i.e., identified regulation) do better academically by using critical thinking, while students driven by controlled extrinsic motivation (i.e., external and introjected regulation) tend to do poorly.

The above findings [11,22,30,45,46] suggest that extrinsic motivation was positively related to mathematics achievement when conceptualized as mathematics usefulness or mathematics utility. These findings are not surprising because research has shown that sometimes students value the importance of mathematics more than its learning enjoyment. According to Zhu and Leung [34], for instance, students from East Asia and Western cultures value the usefulness of mathematics more than their enjoyment of its learning. Zhu and Leung [34] found that students' perceptions about the usefulness of mathematics (extrinsic motivation) correlated positively with intrinsic motivation. Thus, when students see mathematics as valuable, such motivation as an external stimulator could boost their overall motivation, hence improving mathematics achievement. In developing countries like Rwanda, there has hardly been any research to confirm this.

The literature supports that more self-determined motivation (intrinsic motivation and identified regulation) positively correlates with good mathematics achievement [22,23,46]. In contrast, low self-determined motivation (amotivation, external and introjected regulation) negatively correlates with mathematics achievement. Thus, teachers may improve mathematics achievement via the affective domain by focusing on just a few motivational constructs that correlate most strongly with good mathematics achievement. Hence, the present study examined the relationship between intrinsic motivation and career motivation ("identified regulation") with mathematics achievement.

2.2. Mathematics anxiety and mathematics achievement

Besides motivation, mathematics anxiety is another critical aspect of students' behavior that has long been studied. Mathematics anxiety negatively correlates with student achievement in mathematics [10,12,43]. However, research suggests that mathematics achievement is related differently to cognitive and affective dimensions of mathematics anxiety. Across the U.S., China, and Taiwan samples, affective mathematics anxiety was consistently negatively related to mathematics achievement, but cognitive mathematics anxiety was inconsistent [15]. This negative association of affective mathematics anxiety with mathematics achievement was consistent with Wigfield and Meece's [7] findings. However, the relation differs from the one reported by Henschel and Roick [14], Liebert and Morris [17], and Morris [16]. According to their research, mathematics achievement showed a stronger negative association with cognitive mathematics anxiety than affective mathematics anxiety. These conflicting findings could be because the worry scales used in those studies capture different cognitive aspects. Henschel and Roick [14], Liebert and Morris [17], and Morris [16] used items that address worry about not doing well in mathematics, while Wigfield and Meece [7] used items that address worry about doing well in mathematics. Students who express concern about success are motivated to invest more effort to succeed, which may affect their achievement over the long term. Very few studies have examined the relationship between mathematics achievement and the two components of mathematics anxiety, especially by focusing on concerns about failure in mathematics tests. Additionally, most of those studies were conducted in Western and Asian countries' elementary schools.

2.3. Measuring students' motivation and anxiety

Although measuring students' motivation and anxiety might be complex since those constructs and their components are latent variables [47], they are measured using observed variables (items). It is, however, essential to ensure that those items are valid theoretically and practically before using them as empirical indicators of students' motivation and anxiety. A popular, well-validated, and up-to-date questionnaire to measure students' motivation and anxiety is the science motivation questionnaire (SMQ), mainly developed to identify unmotivated college students so that their special needs can be addressed [48]. The construct validity of SMQ has been tested in several studies [49,50], but the results of an exploratory factor analysis suggest that it should be revised to assess better the latent motivational variables it targets. In 2011, the SMQ was revised, and the exploratory and confirmatory factor analyses of the revised science motivation questionnaire (SMQ-II) confirmed its construct validity. The SMQ and SMQ-II were developed and used initially with college students within the U.S. context, but numerous researchers have adapted and validated them for various study contexts, languages, populations, and specific subject domains [51–58]. To the best of our knowledge, only one study by Fiorella [54] in the U.S. has adopted and validated the SMQ in Mathematics. There is uncertainty about whether the findings can be generalized to Rwandan students in senior two (eighth grade) with different cultural, linguistic, and educational backgrounds. The purpose of this study is to fill in this gap in the literature.

3. Methods

3.1. Participants and procedures

The study involved seven hundred thirty (730) senior two students (grade 8) from six public schools in Musanze, Northern Rwanda. These schools were chosen because they had a high failure rate on national mathematics exams. The principal researcher obtained ethical approval from the University of Rwanda, College of Education, Research Ethics Committee, and authorization for data collection from the District Education Officials (DEO) of Musanze District in Rwanda. A non-random convenience sampling technique was used, in which participants were chosen for their willingness to participate and for belonging to the intact senior two classes at selected schools. The students in senior two were selected because they are critical for mathematics learning and achievement, and they need to be prepared for lower secondary national exams when they reach senior three (grade 9). Participants (40% males and 60% females) signed consent forms to participate in the study. On average, students spent 20 min completing the questionnaire using a paper-and-pencil approach. Students were on average 14.8 years old, with a standard deviation of 1.1.

3.2. Research tools

3.2.1. The science motivation questionnaire (SMQ/SMQ-II)

In this study, we only adapted 10 items from the Science Motivation Questionnaire II (SMQ-II; Glynn [59]) that measure intrinsic motivation (IM) and career motivation (CM), as well as 5 items from the Science Motivation Questionnaire (SMQ; Glynn and Koballa [60]) that measure mathematics anxiety (MA) by adapting science-oriented items to mathematics orientation. Students rated their motivation to learn mathematics, concerns/worries about their mathematics performance, and negative reactions to mathematics tests on a Likert scale with 1 = "Strongly Disagree", 2 = "Disagree", 3 = "Neutral", 4 = "Agree", and 5 = "Strongly Agree". After piloting the adapted questionnaire to hundred (n = 100) senior two students, the final questionnaire was improved based on their suggestions. Students were encouraged to respond to every item on the questionnaire, and incomplete questionnaires were not considered; we, therefore, had no missing data in our dataset.

3.2.2. Mathematics performance

The students' scores on a mathematics test measured their mathematics performance. Based on Rwanda's Lower Secondary Mathematics Curriculum, senior two mathematics teachers and a principal researcher developed a mathematics test that consists of 15 multiple-choice items. A week after completing the motivation survey, students took the test and were graded based on their detailed work and the correct answers. Test scores could range from 0 to 45. The mathematics test items had a Cronbach's alpha of 0.82.

3.3. Data analysis

We utilized two-step structural equation modeling to analyze two conceptually distinct constructs models: measurement and structural [47]. The measurement model assesses both convergent and discriminant validity, while the structural model assesses predictive validity [61]. To use cross-validation, we randomly divided the data into two samples of 365 students each. We used these two samples for exploratory and confirmatory factor analyses, respectively. We first conducted an exploratory factor analysis (EFA) of the adapted SMQ/SMQ-II to compare our findings with those of Glynn [59] and Glynn and Koballa [60]. We performed a series of confirmatory factor analyses (CFAs) to assess the validity of measurement models derived from EFA. We initially conducted a CFA when mathematics anxiety was assumed to measure a single factor. We then conducted CFA when cognitive and affective components of mathematics anxiety were separated, but each component underpinning its items. Testing the predictive validity of mathematics anxiety (i.e., affective and cognitive) and self-determined motivational (i.e., intrinsic and career motivation) dimensions on mathematics achievement was done using the structural model. For model evaluation, the Chi-square, root-mean-square error of approximation (RMSEA $\leq$0.06), comparative fit index (CFI $\geq$0.90), Tucker-Lewis index (TLI $\geq$0.90), and standardized root mean square residual (SRMR $\leq$0.08) fit indices were used [62]. The reliability of the scales was examined using Cronbach's coefficients. To determine whether self-determined motivation, cognitive and affective mathematics anxiety and mathematics achievement were related, we conducted a correlational analysis.

4. Results

4.1. Exploratory factor analysis

Because 15 items were adapted from two different existing questionnaires (SMQ/SMQ-II) that initially were used with a different culture and population (college students), we performed an exploratory factor analysis using principal component analysis to understand Rwandan senior two students' responses to the adapted questionnaire. We used an oblique rotation since motivational constructs are likely to be related [35]. The initial data screening indicated that our dataset had sufficient sampling adequacy for factor analysis (Kaiser-Meyer-Olkin = 0.92; Bartlett's test of sphericity, $\chi^2 = 1698.62, df = 273, p \leq 0.001$), confirming that our correlation matrix of items was of adequate quality.

Based on eigenvalues greater than 1, EFA yielded a three-factor structure explaining 58.6% of the total variance. Using mathematics anxiety as a two-dimension construct composed of cognitive and affective dimensions, we repeated the EFA after removing items with factor loadings less than 0.5. For example, we removed SMQ-II 23 due to its high correlation with SMQ-II 25 and factor loading below 0.5; we also removed SMQ 18 "I hate taking the mathematics tests" since any student may feel this way regardless of mathematics anxiety. The remained 13 items out of 15 loaded significantly onto one of the four factors, indicating each item's unique contribution to the factor (see Table 1). Sixty-nine percent of the total variance was explained by the factors, while the percentage explained by each factor was intrinsic motivation (35.0%), career motivation (12.0%), and mathematics anxiety (cognitive: 12.0% and affective: 10.0%).

4.2. Confirmatory factor analysis

We validated the measurement models by performing a confirmatory factor analysis on a separate sample of 365 students. To confirm the factor structure of mathematics anxiety, we conducted a series of CFAs with a four-factor model (which distinguishes between affective and cognitive mathematics anxiety) and a three-factor model (which considers mathematics anxiety as a

Table 1
Exploratory factor analysis (n = 365).

	Before the exclusion of SMQ-II23 and SMQ 18 and when mathematics anxiety was unidimensional			After the exclusion of SMQ-II23 and SMQ 18 and when mathematics anxiety was multidimensional		
Factors and Items	IM	CA	MA	IM	CA	MA
IM						
SMQ-II 01	0.80			0.81		
SMQ-II 12	0.80			0.82		
SMQ-II 19	0.78			0.80		
SMQ-II 17	0.76			0.78		
SMQ-II 03	0.85			0.86		
CM						
SMQ-II 23		0.68			–	
SMQ-II 10		0.79			0.81	
SMQ-II 25		0.78			0.80	
SMQ-II 07		0.79			0.80	
SMQ-II 13		0.76			0.78	
MA						
SMQ 04			0.82			0.82
SMQ 06			0.78			0.79
SMQ 13			0.79			0.81
SMQ 14			0.70			0.72
SMQ 18			0.48			–

Note: Details on the items and abbreviations used are in Appendix.

unidimensional factor). As both models were nested and had acceptable goodness-of-fit indices (see Table 2), we computed a chi-square difference test to test our hypothesis that the four-factor model would fit the data best. Based on the chi-square difference test, the four-factor model was selected as the preferred model, thus, supporting that the two mathematics anxiety components are distinct. Despite the high latent correlation between cognitive and affective mathematics anxiety, model test comparisons demonstrated that the two components of mathematics anxiety are distinct.

4.3. Reliability and validity of the adapted questionnaire

Based on Cronbach's coefficients of the constructs of the adapted SMQ/SMQ-II (Table 3), the internal consistency reliability for participants' responses is acceptable. According to Table 1, all the factor loadings were statistically significant and greater than 0.40. Cronbach's coefficient of each construct was above the recommended threshold of 0.70 and ranged from 0.78 to 0.84, with an overall coefficient of 0.89. Table 3 shows that the composite reliability (CR) values for all latent constructs exceeded 0.70, ranging from 0.72 to 0.80, indicating high levels of reliability. Moreover, the average variance extracted (AVE) values ranged from 0.55 to 0.59, indicating convergent validity. The square roots of the AVE exceeded its correlation, confirming discriminant validity.

4.4. Correlational analysis

Table 4 presents the correlation coefficients between each of the study constructs. All study constructs showed significant correlation coefficients ranging from −0.69 to 0.78, implying no multicollinearity between constructs. As expected, there was a strong correlation between cognitive and affective mathematics anxiety ($r = 0.76$) which was considerably stronger than previous reports [7,14,15]. Compared to affective mathematics anxiety, cognitive mathematics anxiety had a stronger negative correlation with mathematics achievement. Moreover, cognitive mathematics anxiety and affective mathematics anxiety correlated more strongly with career motivation than intrinsic motivation. However, the cognitive component correlated more strongly with career motivation and intrinsic motivation compared to the affective component. Intrinsic motivation correlated positively with career motivation and significantly and positively correlated with mathematics achievement.

4.5. Relationship between self-determined motivation and mathematics achievement

After validating the measurement model using confirmatory factor analysis, we developed a structural model (CFI = 0.97, TLI = 0.97, SRMR = 0.03, RMSEA = 0.03) to examine the relationship between the student's intrinsic motivation, career motivation, affective and cognitive mathematics anxiety, and mathematics achievement. According to this model, students' intrinsic motivation and career motivation predicted their mathematics achievement positively and significantly. However, compared to career motivation and mathematics anxiety, intrinsic motivation contributed significantly more to students' mathematics achievement, as indicated by the standardized path coefficients (see Fig. 1).

4.6. Relationship between components of mathematics anxiety with mathematics achievement

The present study sought to examine whether affective and cognitive aspects of mathematics anxiety had differential associations with students' mathematics achievement. According to the standardized path coefficients (Fig. 1), both cognitive and affective components of mathematics anxiety negatively predicted mathematics achievement. Cognitive mathematics anxiety was differentially stronger and negatively associated with mathematics achievement than affective mathematics anxiety. These results indicate differential predictive validity for both components of mathematics anxiety.

5. Discussion

Research has shown that students who have high levels of self-determination (" autonomous motivation") perform well academically [21,63,64] and experience enjoyment [65], indicating that self-determined motivation plays a crucial role in academic success. Self-determination theory (SDT), expectancy-value theory (EVT), and control-value theory (CVT) have been widely used for understanding and predicting motivation and academic success. According to SDT studies, intrinsic motivation and identified regulation (e.g., career motivation) refer to "autonomous motivation" while external regulation and introjected regulation refer to "controlled motivation" [35,66]. According to EVT and CVT studies, intrinsic value and utility value (e.g., "the usefulness of mathematics in future plans") are related to academic achievement [36–39]. The present study intended to adapt and validate the science motivation questionnaire and determine the relationship between self-determined motivation (intrinsic motivation and career motivation) and mathematics achievement as well as the differential effect of mathematics anxiety components on mathematics

Table 2
Confirmatory factor analysis.

Model	χ^2	df	CFI	TLI	RMSEA	SRMR	Chi-Square test
Three-factor model	989.62	592	0.93	0.94	0.06	0.04	$\Delta\chi^2 = 90.87, df = 1, p < 0.01$
Four-factor model	898.75	591	0.97	0.96	0.03	0.03	

Table 3
Analysis of the reliability and validity of the adapted SMQ/SMQ-II (n = 730).

Factor	CR	AVE	Alpha
1. Intrinsic motivation	0.75	0.55	0.84
2. Career motivation	0.72	0.56	0.78
3. Cognitive mathematics anxiety	0.80	0.59	0.79
4. Affective mathematics anxiety	0.79	0.58	0.78

Table 4
Means and correlation coefficients between study constructs.

Factor	Mean	1	2	3	4	5
1. Intrinsic motivation	4.2	1.00				
2. Career motivation	4.0	0.78[a]	1.00			
3. Affective mathematics anxiety	3.1	−0.42[a]	−0.48[a]	1.00		
4. Cognitive mathematics anxiety	3.2	−0.45[a]	−0.52[a]	0.76[a]	1.00	
5. Mathematics achievement	24.8	0.55[a]	0.45[a]	−0.53[a]	−0.69[a]	1.00

[a] $p < 0.05$.

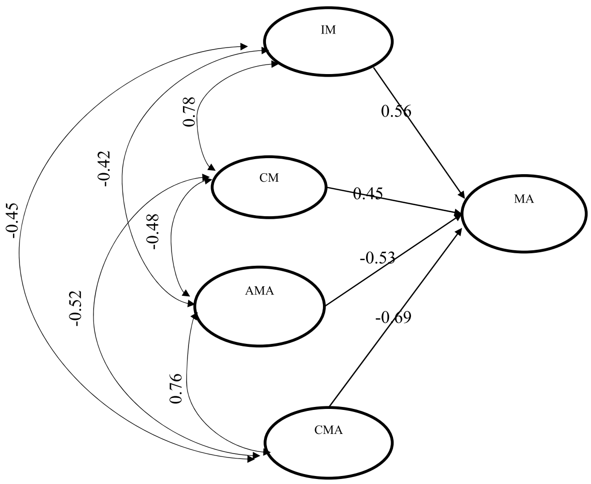

Fig. 1. Correlations between mathematics anxiety and motivational constructs, and their structural relationships with mathematics achievement. CMA, cognitive mathematics anxiety; IM, intrinsic motivation; CM, career motivation; AMA, affective mathematics anxiety; MA, mathematics achievement.

achievement.

5.1. *Adaptation and validation of the SMQ and SMQ-II to assess mathematics motivation and mathematics anxiety*

The intrinsic and career motivation subscales of SMQ-II and the mathematics anxiety subscale of SMQ were adapted and validated using EFA and CFA, and our findings indicated construct validity and reliability. As in previous studies [51–53,55–57,59], there were strong internal consistency patterns across all adapted subscales. Compared to previous studies, the present study showed better model fit indices. However, the previous studies entirely adapted the SMQ-II, while the present study only used self-determined motivation subscales from the original SMQ-II and the mathematics anxiety subscale from SMQ. Additionally, previous studies that adapted the SMQ conceptualized mathematics anxiety as a unidimensional construct [51–57,59], whereas the present study conceptualized it as a multidimensional construct with affective and cognitive components, as proposed by Henschel and Roick [13,14]. The two mathematics anxiety items loaded significantly onto the cognitive component, while the other three loaded onto the affective component. By emphasizing the multidimensional nature of mathematics anxiety, the present study provides implications for future interventions, such as those designed to reduce anxiety in mathematics subjects.

Based on the confirmatory factor analyses, Rwandan senior two students' data fit the proposed four-factor structure measurement model. Like previous studies [7,13–15], the confirmatory and structural analyses indicated that a model which differentiated cognitive from affective mathematics anxiety provided the best fit for the empirical data. According to this finding, there is a distinction between the two components of mathematics anxiety. It is important to note that although the cognitive scale in the present study reflected concerns about failure, two components of mathematics anxiety had stronger correlations than in previous studies that addressed concerns about either success [7,15] or failure [13,14,16,17].

5.2. Differential relationship between mathematics achievement and mathematics anxiety components

In this study, one of the objectives was to examine the differential relationship between components of mathematics anxiety and mathematics achievement. As expected, we found that mathematics achievement related differently to affective and cognitive mathematics anxiety. Specifically, consistent with Henschel and Roick [14], we found that cognitive mathematics anxiety related more negatively to mathematics achievement than affective mathematics anxiety. This result contradicts previous research [7,15] that examined affective and cognitive mathematics anxiety components separately and found a positive or missing relationship between mathematics achievement and cognitive mathematics anxiety. Our cognitive scale addressed concerns about failure, whereas those studies addressed concerns about success, which may have influenced the results.

5.3. Relationship between mathematics achievement and self-determined motivation

In line with self-determination theory [21], students' mathematics achievement was positively related to both intrinsic and career motivation but was more strongly related to intrinsic motivation. The positive relationship between career motivation and mathematics achievement was consistent with the previous studies which conceptualized extrinsic motivation as students' perceptions about the value or usefulness of mathematics [1,11,30]. This is probably due to the items of our career motivation subscale reflecting how mathematics will contribute to students' future careers. Consistent with our findings, Güvendir [11], Lim and Chapman [22], and Tran and Nguyen [46] also found a positive relationship between identified motivation (how students think mathematics will help them in their future jobs) and mathematics achievement. Despite the different conceptualizations of career motivation (e.g., extrinsic motivation, utility value, "identified regulation"), the findings were convergent and consistent for the studies that used items that reflect the usefulness of mathematics. Abín [1] found that students who perceived mathematics as useful and had higher intrinsic motivation tended to perform better on mathematics tasks. According to expectancy-value theory and control-value theory studies, students are motivated to do tasks that fit into their plans, such as studying mathematics to get a good job, and this predicts their academic success [36–39,67].

In congruence with the self-determination continuum [21] and other previous studies [23,46,68], the most self-determined motivation (intrinsic motivation and career motivation ("identified regulation")) positively associated with mathematics achievement. The findings of this study revealed that externally oriented motivation (e.g., career motivation or "identified regulation") might promote students' success in mathematics. In other words, students who perceive mathematics to be important to their future are more likely to learn it, and thus this could enhance their mathematics achievement. Even though intrinsic motivation is well documented to promote students' mathematics achievement strongly, this study suggests that both intrinsic and extrinsic motivation may lead to greater achievement, so promoting both is essential.

6. Limitations

While considering the findings of this study, it is noteworthy that motivation was measured within the framework of self-determination theory [35], expectancy-value theory [37], and control-value theory [40]. This study focused exclusively on intrinsic motivation ("intrinsic value") and one of the "autonomous forms of extrinsic motivation" (utility value or usefulness), namely career motivation, where a person recognizes and perceives the value of mathematics and thus is inclined to learn it [35]. As a result, of the five motivation components of the SMQ II [59], the present study examined only intrinsic motivation and career motivation. Other forms of motivation (e.g., grade motivation, academic goals) and their relation to mathematics achievement need to be studied. It is also important to note that data was collected from senior two students in Musanze district, one of thirty districts in Rwanda; therefore its findings cannot be generalizable to students throughout the country.

Furthermore, the present study used cross-sectional data and cannot be used to draw causal conclusions; we need longitudinal studies to do so. Also, data used in this study came from self-report questionnaires, subject to response bias [69], where participants respond in such a way that others will view them favorably. For example, students may overrate positive feelings (e.g., intrinsic motivation) and underrate bad feelings (e.g., cognitive and affective mathematics anxiety), which may affect the study's validity and reliability. Due to the lack of standardized tests, we measured mathematics achievement using a researcher-made mathematics test. Though the test was validated and had good internal consistency, comparing our results with those of other studies is challenging.

7. Conclusion

Despite the limitations discussed above, this study provides the first evidence that the motivation and mathematics anxiety questionnaire adapted from the SMQ/SMQ-II is valid and reliable for Rwandan senior two students. The adapted questionnaire is, therefore, helpful in measuring students' intrinsic motivation, career motivation, and mathematics anxiety. From the perspective of self-determination theory, expectancy-value theory, and control-value theory, we found that intrinsic motivation and career motivation are essential factors in predicting better mathematics achievement. This study also found that mathematics anxiety can be distinguished into cognitive and affective components, which differ in their relationship to mathematics achievement. To enhance mathematics achievement, educators must arouse their students' self-determined motivation. Moreover, any intervention program aiming to improve mathematics achievement should address both cognitive and affective aspects of mathematics anxiety.

Author contribution statement

Emmanuel Iyamuremye: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Irénée Ndayambaje; Charles Magoba Muwonge: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data.

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Data availability statement

Data will be made available on request.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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APPENDIX. STUDENTS' QUESTIONNAIRE

Gender: M F.

Dear student.

Thank you for accepting to participate in this study that aims to understand your motivation to learn Mathematics. You will provide your answers by rating each of the proposed statements by ticking one of the five scales that most suits your judgment (Strongly Agree, Agree, Neutral, Disagree, or Strongly Disagree). We request you be as honest as you can because your answers will be treated with the utmost confidentiality and will be solely used for research purposes only. Please also note that there is no right or wrong answer here.

Item		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Intrinsic motivation						
SMQ-II 01	The mathematics I learn is relevant to my life.					
SMQ-II 12	Learning mathematics makes my life more meaningful.					
SMQ-II 19	I enjoy learning mathematics.					
SMQ-II 17	I am curious about discoveries in mathematics.					
SMQ-II 03	Learning Mathematics is interesting.					
Career motivation						
SMQ-II 23	My career will involve mathematics.					
SMQ-II 10	Knowing Mathematics will give me a job advantage.					
SMQ-II 25	I will use mathematics problem-solving skills in my career.					
SMQ-II 07	Learning mathematics will help me get a good job.					
SMQ-II 13	Understanding mathematics will benefit me in my career.					
Mathematics anxiety						
SMQ 04	I am nervous about how I will do on the mathematics tests.					
SMQ 06	I become anxious when it is time to take a mathematics test.					
SMQ 13	I worry about failing the mathematics tests.					
SMQ 14	I am concerned that the other students are better at mathematics.					
SMQ 18	I hate taking mathematics tests.					

Note: Cognitive component of anxiety: SMQ 13 and SMQ 14. Affective components of anxiety: SMQ 04, SMQ 06, and SMQ 18. Both items focus on negative affective reactions to doing math tests and on students' concerns/worries about their performance in mathematics.

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