Initial Development of Mathematical Grit Scale for Senior High School

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ABSTRACT

Purpose of the study: Studies indicate that domain-specific grit scales have higher predictive power, yet no scale has been developed solely for mathematics. This study seeks to develop a reliable instrument for assessing mathematics-related grit of senior high school students.

Methodology: A two-phase mixed-methods approach was employed, starting with in-depth interviews with Grade 12 students to develop the initial 46 items for the scale, which was then used in the quantitative phase through Exploratory Factor Analysis using JASP 0.19.3 Intel software.

Main Findings: From the initial 46 items, the instrument was reduced to 32 items through Exploratory Factor Analysis with four extracted dimensions: Proactive Perseverance, Intrinsic Learning Drive, Perceived Mathematical Importance, and Extrinsic Learning Drive. The scale also showed high overall internal consistency.

Novelty/Originality of this study: This study can be considered novel since the output, the Mathematical Grit Scale, would make a significant contribution to both psychology and education, particularly in the study of grit-related constructs. This would contribute to the ongoing research on the construct of grit in education.

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1. INTRODUCTION

In attaining the K to 12 curriculum goal, mathematics remains one of the pillars of quality education and the production of highly efficient learners. Proficiency in this domain is crucial for academic success, as it serves as a foundational element in entry to and completion of higher education [1]. Given its importance, educational institutions continuously explore various pedagogical strategies to ensure that learners persevere and perform well in mathematics [2], [3]. One of the indicators positively associated with mathematical achievement is grit [4], [5]. Grit is a trait characterized by passion and perseverance toward long-term goals and a predictor of success [6]. Although grit has been extensively studied across various fields, there remains a significant gap in the availability of instruments that specifically measure mathematical grit among Senior High School (SHS) students. Despite the growing recognition of grit's importance, existing grit scales—such as the Grit-O and Grit-S—are general in nature and do not specifically address the challenges and demands of mathematics learning.

This gap is evident when examining large-scale international assessments. Programme for International Student Assessment (PISA) 2022 reported that the Philippines scored 355 in Mathematics, placing second to the last among participating OECD countries [7]. Trends in International Mathematics and Science Study (TIMSS) results likewise showed that the Philippines ranked lowest in mathematics proficiency [8]. Locally, The Philippine Development Plan (PDP) envisions a resilient and prosperous nation through Ambisyon Natin 2040. However, the Science Education Institute (SEI-DOST) reports ongoing academic decline, particularly in STEM, with mathematics showing the lowest proficiency in the National Achievement Test for Senior High School (SY 2018-2019) [9]. The PISA 2018 results also revealed that the Davao Region scored below the national average, reflecting a proficiency level under 1 on the PISA scale [10]. These recurring outcomes highlight mathematics as an area requiring urgent improvement. Among predictors of academic success, grit plays a crucial role [11]. These results also highlight a critical issue: the need for tools that measure grit specific to mathematics to better understand and address the factors contributing to poor performance in this area. Grit equips individuals to persist despite setbacks [12]. Those with high grit also demonstrate greater determination and engagement [4], [13]. However, grit cannot be fully assessed without tools designed for specific domains such as mathematics.

This study is anchored on Grit Theory [14] and Growth Mindset Theory [15]. Grit Theory posits that perseverance and passion toward long-term goals are central to success [16]. Meanwhile, Growth Mindset Theory asserts that students' beliefs about their abilities shape their responses to challenges and academic outcomes [17]. Grit Theory guides the study in identifying indicators of mathematical perseverance, while Growth Mindset Theory explains how students who believe they can improve view challenges as opportunities—an attitude also shown by gritty individuals [18]. Existing grit scales, such as the Grit-O [14] and Grit-S [6], are domain-general. Although these scales have shown stronger predictive validity in academic contexts, they fall short in predicting outcomes specific to mathematics. Furthermore, there is a lack of tools to assess how grit influences students' perseverance and success in this subject. Therefore, there is an urgent need to develop a scale that measures mathematical grit, which could help identify effective strategies for fostering resilience and improving performance in mathematics [19].

This study aimed to develop a Mathematical Grit Scale for Senior High School students. The findings could help design interventions that cultivate grit, enhance motivation, and ultimately improve mathematical performance at the national level. Specifically, this study sought to: (1) determine the dimensions of the Mathematical Grit Scale; and (2) ascertain the reliability of the Mathematical Grit Scale. By achieving these objectives, this study seeks to contribute to improving the quality of education in mathematics in the Philippines and provide a foundation for future interventions aimed at enhancing students' grit and academic success.

2. RESEARCH METHOD

2.1. Participants/Respondents

The study had two phases with separate samples from three senior high schools in Digos City. The qualitative phase involved in-depth interviews with participants in School A who were chosen based on pre-determined criteria: (1) muat be a bona fide senior high school student enrolled in any of the academic strands: STEM, ABM, HUMSS, GAS; and (2) must be willing to participate in the study. This study provided exemption for those senior high school students who were not part of the abovementioned criteria. Purposive sampling was used to select participants based on characteristics relevant to the study [20]. Furthermore, the researchers adhered to data saturation which could be achieved with 5 to 25 interviews [21]. In this study, data saturation was achieved with nine participants, where the researchers began with five participants and added four more until saturation was met.

For the second phase, a quantitative survey was conducted with 350 respondents who were randomly chosen from Schools B and C. Respondents were randomly chosen according to the following criteria: (1) must be a bona fide senior high school student currently enrolled in any of the academic strands; and (2) must be willing to participate in the study. Stratified sampling was used by dividing the population into groups called strata and randomly selecting members from each group [22], [23]. The number of respondents consisted of 350 respondents, as exploratory factor analysis (EFA) requires at least 300 cases [24]. Afterwards, pilot testing was conducted on 50 senior high school students using simple random sampling for reliability testing. Exclusion criteria for the second phase were those senior high school students who were not part of the above-mentioned criteria.

2.2. Research Instrument

In the qualitative stage, semi-structured interview guide questionnaires anchored on previously validated scale on grit that involves passion and perseverance were used [14]. The interview guide was employed for a comprehensive one-on-one interview with senior high school students at School A as the study's participants. Using an inductive approach and from the qualitative content analysis, the researchers formulated items to capture the dimensions of mathematical grit. The items were then consolidated for the survey and presented in a 5-point Likert scale (1=Strongly Disagree, 2=Disagree, 3=Neither Agree nor Disagree, 4=Agree, 5=Strongly Agree), which was treated as interval or ratio type of data to reflect increasing levels of agreement. After that, the survey questionnaire was validated by five experts with masters and PhDs in mathematics education, before proceeding to exploratory factor analysis.

2.3. Design and Procedure

The mixed-method approach was employed in the study. This allows the researcher to gather data by using both qualitative and quantitative approaches [25]. Specifically, this study utilized an exploratory sequential research design, as data were gathered initially through a qualitative method followed by quantitative data collection [26]. The researchers first obtained approval from the DepEd Division Office of Digos City and permission from the schools involved to gather data. The first phase was an in- depth interview, followed by the second phase of data collection through a survey. The data from the interview were analyzed and sorted out to create the items for the survey questionnaires. The survey then underwent face validity by five experts with masters and PhDs in mathematics education. After finalizing the scale, pilot testing was conducted on 60 students in School A through simple random sampling. Its Cronbach's alpha was .930, demonstrating strong internal consistency.
Exploratory factor analysis (EFA) was then employed in the study. It is a research tool that identifies key factors from a large set of factors and is used for further analysis [27]. Factor analysis is also essential in developing a survey questionnaire [28]. These strengthen the appropriateness of factor analysis, as it allowed the researchers to identify the representative indicators of mathematical grit, which were later used in developing the final scale. A reliability test was then done through a pilot test administered to 50 students in School A using simple random sampling to get the Cronbach's Alpha [29].

3. RESULTS AND DISCUSSION

3.1. Dimensions of the Mathematical Grit Scale

This study employed exploratory factor analysis (EFA) to extract key factors from the initial Mathematical Grit Scale, based on the responses of 350 senior high school students from three selected schools in Digos City. Before conducting the EFA, an initial reliability test was carried out yielding a Cronbach's alpha of $\alpha = .930$, showing excellent reliability and supporting the decision to proceed with the EFA.

Table 1. KMO Test and Bartlett's Test of Sphericity

Kaiser-Meyer-Olkin Test for Sampling Adequacy		.957
Bartlett's Test of Sphericity	Chi-Square	10212.858
	df	1035
	Sig.	<.001

To ensure the suitability of the data for EFA, Kaiser-Meyer-Olkin (KMO) and Bartlett's Test of Sphericity were used (Goni et al., 2020). As shown in Table 1, results yielded a KMO value of .957 and a highly significant Bartlett's Test (Chi- Square = 10212.858, $p < .001$), indicating that the data were appropriate for factor analysis. The study proceeded with principal axis factoring (PAF) and direct oblimin rotation—an oblique method that considers possible correlations among factors [30]. With this, items with a factor loading below .50 were removed, strengthening the validity of the factor structure.

The next step was to determine the number of factors using parallel analysis, a reliable EFA method for determining significant components and variable loadings. This method compares the eigenvalues of a data set before rotation to those of a matrix of random values with the same dimensions [31]. Accordingly, four factors were identified suited for the Mathematical Grit Scale. Table 2 presents the four dimensions, along with their eigenvalues, percentage of total variance explained, and the cumulative percentage of the extracted factors, arranged in descending order of variance explained. The results of the rotated sums of squared loadings revealed that Factor 1 explained the highest variance at 17.4%, followed by Factor 2 (16.6%), Factor 3 (10.9%), and Factor 4 (6.6%). Other factors were excluded from the analysis as they did not meet the criteria (Table 6). In total, the four retained factors accounted for 51.4% of the total variance.

Table 2. Total Variance Explained

	Eigenvalues	Unrotated Solution SumSq. Loadings	% of Variance	Cumulative %	Rotated Solution SumSq. Loadings	% of Variance	Cumulative %
Factor 1	18.623	18.155	39.5	39.5	8.008	17.4	17.4
Factor 2	3.328	2.863	6.2	45.7	7.619	16.6	34.0
Factor 3	1.917	1.412	3.1	48.8	5.001	10.9	44.8
Factor 4	1.743	1.233	2.7	51.4	3.035	6.6	51.4

A scree plot was used to evaluate and examine the distribution and number of generated factors. Figure 1 depicts the eigenvalues graph for all factors using the scree plot. The graph reveals a gradual change, with a noticeably flattening around the 4th factor suggests that the Mathematical Grit Scale in the context of senior high school students comprises four distinct factors.

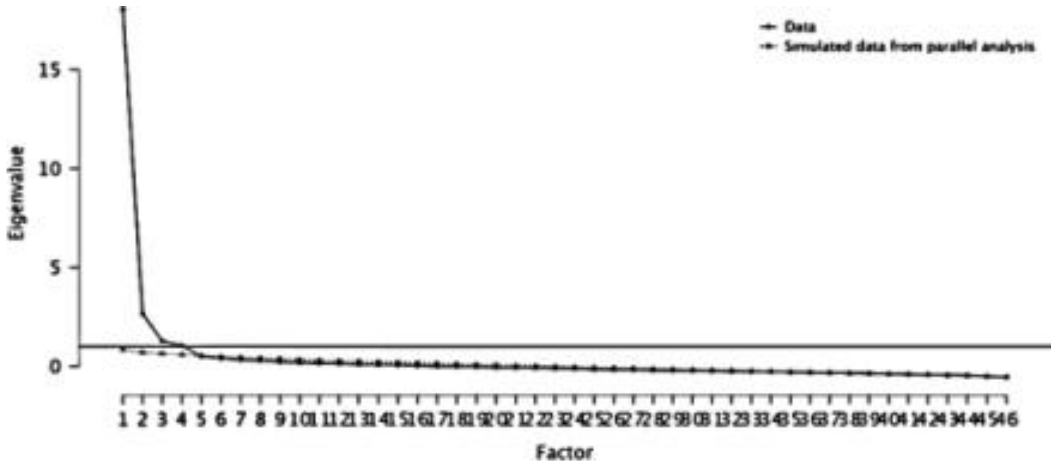

Figure 1. Scree Plot

After completing all the necessary analyses, the researchers removed the factors containing fewer than three measured variables to improve reliability and accuracy. Following this, four factors remained, containing eigenvalues greater than 1, establishing their reliability and suitability [28], [27]. The Cronbach's alpha for these factors was calculated, showing that all components exhibited strong internal consistency, with reliability coefficients ranging from .50 to just under .90 [32].

Data shown in Table 3, resulted in four extracted factors with 32 items remaining. These factors: proactive perseverance, intrinsic learning drive, perceived mathematical importance, and extrinsic learning drive, provide an exploration on students' grit in maintaining passion and perseverance in their mathematical learning despite setbacks and difficulties.

Table 3. Rotated Factor Matrix with Factor Loadings

	Factor 1	Factor 2	Factor 3	Factor 4
Item 3	.717			
Item 5	.701			
Item 7	.673			
Item 9	.669			
Item 1	.620			
Item 4	.597			
Item 10	.573			
Item 16	.571			
Item 2	.554			
Item 8	.550			
Item 12	.544			
Item 13	.519			
Item 19	.503			
Item 38		.801		
Item 39		.763		
Item 41		.713		
Item 37		.700		
Item 44		.665		
Item 40		.631		
Item 35		.574		
Item 29		.574		
Item 28		.545		
Item 36		.541		
Item 46		.506		
Item 34			.659	
Item 21			.600	
Item 11			.593	

Item 20	.526	
Item 30	.514	
Item 33		.620
Item 6		.554
Item 14		.504

The results indicate that the data are suitable for Exploratory Factor Analysis (EFA), with a KMO value of .957 and a significant Bartlett's Test (Chi-Square = 10212.858, p < .001), confirming appropriate data structure for factor extraction. The use of Principal Axis Factoring (PAF) with Direct Oblimin rotation was effective in accounting for correlations among factors. The removal of items with factor loadings below .50 strengthened the validity of the final model by focusing on the most relevant variables. Furthermore, the use of parallel analysis effectively identified four factors, explaining 51.4% of the total variance, supporting the reliability of the scale. The Cronbach's alpha values ranging from .50 to .90 also demonstrate strong internal consistency, with the overall alpha of .926 confirming the scale's reliability. The lower alpha for Extrinsic Learning Drive suggests further refinement is needed for that factor. Overall, the scale provides a reliable and valid measure of mathematical grit, offering significant contributions to educational research and practice.

The identified factors: *Proactive Perseverance*, *Intrinsic Learning Drive*, *Perceived Mathematical Importance*, and *Extrinsic Learning Drive* align with existing research on grit but add a domain-specific focus on mathematics, contributing new insights into how grit influences success in this area. To ascertain this, the literature review is utilized to support how the factors mentioned above contribute to a greater comprehension of the mathematical grit of a student. Furthermore, this strengthens the credibility of the results by grounding them in established findings.

3.1.1. Proactive Perseverance

This factor is identified as "proactive perseverance" after aligning the items with the literature. As presented in table 14, it had a total of 13 items with a Cronbach's alpha of .922, ensuring a strong internal consistency, showing reliability of the items. Proactive perseverance is the ability of a student to pursue a goal with consistent effort while anticipating and overcoming challenges. It combines patience, vision, strategic thinking, and initiative, fostering resilience and persistence. This factor drives the student to make a strategic plan towards their goals in math and implement it autonomously with sustained effort [33]. Additionally, students with this trait persevere, seize growth opportunities, and gain satisfaction from learning, which strengthens their determination and positivity in math [34], [35]. Lastly, proactive perseverance builds stress resistance, explaining how students persist in math despite difficulties [35], which is supported by Duckworth's Grit Theory [36]. Their persistence is a key factor to better performance in math, as it plays a much larger role in mastering math concepts and developing problem-solving skills.

Table 4. Items with Factor Loadings for Proactive Perseverance (factor 1)

	Proactive Perseverance	Factor Loadings
3	I keep learning math with a positive mind.	.717
5	I put consistent effort to improve my math skills.	.701
7	I work hard to learn math concepts to also help others understand it.	.673
9	I keep learning math concepts even though my progress is slow.	.669
1	I keep going in dealing with math problems no matter how hard it is.	.620
4	I spend several hours in studying math.	.597
10	I stay patient in learning math concepts, even when it's hard.	.573
16	I consistently practice and improve my skills in math.	.571
2	I stay focused while solving math problems.	.554
8	I try new methods when I struggle in math.	.550
12	I give myself time to understand and process the math concepts I learned.	.544
13	I handle difficult math problems by analyzing them thoroughly.	.519
19	I keep working on math problems for as long as it takes to get the right answer.	.503

3.1.2. Intrinsic Learning Drive

As shown in table 5, this factor is identified as "intrinsic learning drive" grounded in the correspondence between items and established literature. It consists of 11 items with a reliability score of .922, still showing a strong internal consistency. Intrinsic learning drive compels an individual to engage in learning activities out of genuine interest, intellectual curiosity, and personal relevance, even without external factors [37]. This suggests that students with an internal drive for mathematics gain genuine satisfaction from learning willingly, fostering strong engagement and long-term retention [38]. Additionally, intrinsic drive shapes a person's behavior, learning, and performance because they are more likely to invest time and effort in things that resonate with their passion [39]. Thus, the students manifest a will to learn, which is a crucial aspect in learning math [40]. This drive supports academic performance and fosters autonomy and lifelong learning, as these students are more likely to persevere through challenges and delve into deeper concepts to truly understand mathematical concepts.

Table 5. Items with Factor Loadings for Intrinsic Learning Drive (factor 2)

	Intrinsic Learning Drive	Factor Loadings
38	I have always loved math.	.801
39	I find engaging with math fun.	.763
41	I continue learning math even without my teacher's feedback.	.713
37	I take advantage of opportunities of joining math competitions.	.700
44	I enjoy learning math even when I'm alone.	.665
40	I want people to recognize that I am good at math	.631
35	I stay motivated to learn math even without my teacher's support.	.574
29	I have a good class standing (grades) in math.	.574
28	I feel confident in my skills in math.	.545
36	I use my interest in math to succeed in it.	.541
46	I continue learning math even when I feel discouraged	.506

3.1.3. Perceived Mathematical Importance

This component is referred to as "perceived mathematical importance" following the refinement of items and a review of relevant literature. As depicted in table 6, this factor comprised five items, yielding a Cronbach's alpha of .815, which suggests that the component demonstrated strong internal consistency. Perceived mathematical importance reflects the student's valuation of math and its relevance to their future goals. When students perceive math as meaningful, they are more likely to exert effort, persist, and engage [38]. Perceived mathematical importance also strongly predicts engagement and academic achievement [41]. Similarly, students' motivation and emotional connection to math are significantly enhanced when they see the subject as valuable [42]. It was further emphasized that students' affective engagement, closely tied to how they perceive the importance of math, directly influences their academic outcomes [43]. These findings affirm that fostering students' value of mathematics is critical for encouraging sustained engagement and academic resilience.

Table 6. Items with Factor Loadings for Perceived Mathematical Importance (factor 3)

	Perceived Mathematical Importance	Factor Loadings
34	I feel happy when I solve math problems correctly.	.659
21	I believe math is about understanding, not just memorizing.	.600
11	I know that learning math is necessary.	.593
20	I understand the importance of math for my future career.	.526
30	I understand the essence of learning math.	.514

3.1.4. Extrinsic Learning Drive

This component is called "extrinsic learning drive" after reviewing the items and literature. Presented in table 7 and with three items, this factor demonstrated poor internal consistency, yielding a reliability coefficient of .582. Extrinsic motivation refers to learning due to external factors, such as family, rewards, recognition, social pressure, and avoidance of punishment. A supportive and stimulating extrinsic learning drive increases students' enjoyment of learning which simultaneously improves academic motivation and performance [44]. External assistance, such as encouragement from teachers and classmates, also promotes self-regulation and positive learning attitude, promoting long-term dedication and effort [45]. Thus, this factor strengthens motivation, fosters resilience, and encourages a long-term commitment to academic success.

Table 7. Items with Factor Loadings for Extrinsic Learning Drive (factor 4)

	Extrinsic Learning Drive	Factor Loadings
33	I feel inspired by my family to study in math.	.620
6	I use my family as motivation to keep studying and learning math	.554
14	I struggle with math more than other subjects.	.504

The factors: proactive perseverance, intrinsic learning drive, perceived mathematical importance, and extrinsic learning drive can reliably assess student's mathematical grit. They capture key aspects of academic engagement, with proactive perseverance and intrinsic drive reflecting internal commitment, while perceived importance highlights the relevance of math to future goals. Although extrinsic drive shows weaker consistency, it still provides valuable insight into the impact of external motivations. The strong internal consistency demonstrated by the three factors highlights their reliability in understanding student behavior. Overall, these factors are well-aligned with existing literature, supporting their suitability for inclusion in the scale and their applicability in explaining and predicting student success in mathematics.

3.3. Reliability of the Mathematical Grit Scale

The reliability of the scale was evaluated through pilot testing and Cronbach's alpha coefficients for the four identified factors. Table 8 presents the Cronbach's alpha coefficients for four identified factors of mathematical grit, showing a Cronbach's alpha cut-off score of .70, which reflects a sufficient internal consistency [46].

Cronbach's alpha values exceeded .80 for factor 1 (α = .898), factor 2 (α = .869), and factor 3 (α = .802), confirming that the items were internally consistent and accurately measured their respective dimension. Factor 4, however, has a Cronbach's alpha value below .70, showing poor internal consistency, which may be caused by its smaller number of items. This also suggests that its items may not consistently measure the same construct and may require revision. Nevertheless, with an overall Cronbach's alpha of .926, the scale demonstrates an excellent internal consistency and reliability, showing that the scale consistently assesses the students' grit.

These findings highlight the importance of evaluating each factor's consistency and the potential need for revision in factors with lower reliability [47]. Compared to previous studies, this research not just reinforces the critical role of reliable instruments in educational assessments but also underscores the challenges of capturing extrinsic motivation with a limited number of items.

Table 8. Scale Reliability Test

Factors		Cronbach's α	Interpretation
Factor 1	Proactive Perseverance	.898	Good
Factor 2	Intrinsic Learning Drive	.869	Good
Factor 3	Perceived Mathematical Importance	.802	Good
Factor 4	Extrinsic Learning Drive	.532	Poor
	Overall	.926	Excellent

This study contributes to the existing literature by developing a reliable domain-specific Mathematical Grit Scale, which addresses the limitations of domain-general grit scales. While domain-general scales may lack precision in predicting subject-specific engagement and performance, domain-specific scales offer more accurate insights. Recent studies have shown that domain-specific grit measures are better predictors of academic achievement in contexts like sports and language learning, as they capture nuances tied to particular fields [48], [49]. By focusing on mathematics, this study provides a tailored tool for measuring grit in math learning, offering a more effective way to assess and improve students' perseverance and engagement in this area.

4. CONCLUSION

The study aimed to develop a reliable Mathematical Grit Scale for senior high school students, identifying four key dimensions: proactive perseverance, intrinsic learning drive, perceived mathematical importance, and extrinsic learning drive. Using a mixed-method approach, the scale demonstrated strong internal consistency through Exploratory Factor Analysis (EFA), with only Factor 3 requiring modification, confirming its reliability. The 32-item scale provides an effective tool for assessing grit in mathematics, which can significantly influence students' long-term performance. The study supports the idea that success in mathematics is not solely dependent on cognitive ability but also on mindset, determination, and external factors. While the study provides valuable insights, its limitations include a focus on a single region and reliance on self-reported data. Practical implications for educators include using the scale to assess and cultivate mathematical grit, fostering resilience, perseverance, and a positive attitude in students. Teachers can design interventions based on the scale, and curriculum developers can integrate grit-enhancing factors into learning activities. Future research could further validate the scale using Confirmatory Factor Analysis (CFA), as well as explore its application across diverse educational contexts. The Mathematical Grit Scale offers a data-driven approach to developing motivated and academically resilient students, contributing to sustained success in mathematics education.

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