



Mediating effect of academic grit in the relationship between mathematics engagement and achievement: A PLS-SEM analysis



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ABSTRACT

First-year university students often struggle with the cognitive and motivational demands of university-level mathematics, yet how engagement and perseverance jointly influence achievement remains underexplored. This study examined the mediating role of academic grit in the relationship between mathematics engagement and achievement among 309 first-year students at a Philippine state university. Using Partial Least Squares Structural Equation Modeling (PLS-SEM) with a split-sample validation design, the dataset was randomly divided into exploratory and confirmatory subsamples to reduce the risk of overfitting. Across both analyses, cognitive engagement consistently emerged as the strongest direct predictor of mathematics achievement, with a moderate effect, while emotional engagement made a statistically significant contribution with a small effect. Together, the two constructs accounted for 37.9% of the variance in mathematics achievement. Behavioral engagement, social engagement, and academic grit did not independently predict achievement once these two constructs were included in the model. Because the paths from engagement to grit were weak and non-significant, the structural precondition for mediation was not met, indicating that grit could not function as a mediator. These findings suggest that mathematics instruction should prioritize higher-order, metacognitively demanding tasks that promote deep cognitive processing, while treating emotional engagement as a supportive complement rather than an independent intervention target. Fostering cognitive engagement, rather than simply encouraging perseverance, may therefore provide a more productive pathway to improving mathematics achievement in university settings.

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1. Introduction

Many first-year university students encounter substantial challenges adapting to the abstract, rigorous, and conceptually demanding nature of university-level mathematics. This transitional phase often exposes gaps in foundational knowledge, problem-solving skills, and metacognitive regulation developed in high school (Rach and Heinze, 2017). Success in higher mathematics extends beyond cognitive competence; it requires persistence, active engagement, and sustained motivation to meet the higher intellectual demands. Consequently, growing scholarly attention has turned toward understanding

how non-cognitive factors, particularly academic grit and mathematics engagement, shape students' ability to manage these demands. Examining how these psychological constructs interact offers deeper insight into the mechanisms that facilitate successful adjustment and academic performance in advanced mathematics learning.

Fredricks et al. (2004) conceptualized engagement as encompassing behavioral, emotional, and cognitive dimensions, each capturing the quality of students' involvement in learning. Students who are engaged tend to show enthusiasm, concentration, and resilience when confronted with challenging mathematical tasks (Jansen et al., 2023). Among these dimensions, cognitive engagement, defined by strategic thinking, reflective processing, and self-regulation, has been consistently linked to stronger achievement, as it directly influences how students internalize concepts and solve problems (Li and Lajoie, 2022). Behavioral engagement, characterized by diligence, effort, and participation, has also been shown to support learning by helping

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students remain attentive and consistently involved (Li and Xue, 2023). Emotional engagement, including interest, enjoyment, and positive attitudes toward mathematics, may sustain motivation and persistence among students who might otherwise disengage. Emerging evidence further suggests that emotional engagement may directly contribute to academic outcomes by sustaining the motivational states necessary for deep cognitive processing (Fung et al., 2018; Xia et al., 2022). Still, engagement alone may not necessarily translate into achievement unless it is supported by perseverance and long-term goal commitment. This is where academic grit becomes particularly relevant, as it may help students transform momentary engagement into enduring academic progress.

Grit, as defined by Duckworth et al. (2007), involves sustained perseverance and passion for long-term goals. It is marked by consistent effort and interest over time, even in the presence of setbacks or frustration. In mathematics, where mastery often requires repeated attempts and long periods of conceptual struggle, grit becomes especially consequential (Demir, 2023). It not only reflects determination but also signifies a more profound commitment to one's aspirations, distinguishing it from short-lived persistence (DiNapoli, 2023). Students who demonstrate higher levels of grit generally show greater stamina, resilience, and willingness to confront complex concepts, all of which are essential for navigating the complexities of university mathematics (Tang et al., 2019). Such qualities are particularly valuable in subjects where progress can be slow and requires perseverance until understanding is fully achieved.

Existing studies have established engagement and grit as important predictors of academic performance, yet their interplay remains insufficiently examined. Engagement has been consistently linked to improved academic outcomes (Lee, 2014), while grit has been shown to contribute to achievement beyond cognitive ability (Duckworth and Quinn, 2009). Students with higher grit tend to maintain focus, overcome academic barriers, and persist toward long-term goals (Polirstok, 2017). Recent scholarship suggests that engagement may cultivate grit by reinforcing motivation, disciplined effort, and persistence. In turn, grit may serve as a mediating mechanism through which engagement leads to higher achievement. Despite these conceptual linkages, empirical studies testing this mediational relationship remain scarce. Most prior investigations have also been situated in Western contexts, where cultural orientations toward perseverance and motivation differ markedly from those in Asian educational settings. This highlights a need to explore how these constructs operate within collectivist societies such as the Philippines, where students' academic experiences are intertwined with sociocultural expectations and resource constraints.

Methodologically, earlier research often relies on traditional correlational or regression-based approaches, which may overlook the complex,

multidimensional interactions among engagement, grit, and achievement. To address these limitations, the present study uses Partial Least Squares Structural Equation Modeling (PLS-SEM). This powerful technique assesses both measurement and structural components within a single analytic framework (Hair et al., 2021). PLS-SEM is particularly effective for predictive modeling and mediation testing, making it well-suited for evaluating how engagement and grit collectively shape mathematics achievement.

In response to these theoretical, empirical, and methodological gaps, the present study aims to examine the pathway to mathematics success by assessing the mediating role of academic grit in the relationship between mathematics engagement and achievement using PLS-SEM. More specifically, it seeks to describe the levels of mathematics achievement, academic grit, and engagement among first-year students; determine the relationships among these variables; and investigate whether grit serves as a mediator between engagement and achievement. The study further aims to produce an explanatory structural model that provides a more comprehensive understanding of mathematics achievement.

The significance of this research rests in its potential contributions to both theory and educational practice. Theoretically, it advances the discourse on non-cognitive factors by empirically evaluating a mediational framework integrating engagement and grit, thereby contributing to a more nuanced understanding of motivational dynamics in mathematics learning. Practically, the study offers evidence-based guidance for educators and policymakers seeking to design interventions that promote deeper engagement and sustained perseverance in mathematics. By understanding the conditions under which grit mediates the effects of engagement, schools can develop targeted programs that cultivate resilience, strategic learning habits, and intrinsic motivation, traits essential for success in mathematics and broader academic pursuits.

Drawing from these foundations, Fig. 1 presents the proposed conceptual model illustrating the hypothesized relationships among mathematics engagement, academic grit, and mathematics achievement. The study advances the following hypotheses: (1) mathematics engagement is positively associated with mathematics achievement; (2) mathematics engagement is positively associated with academic grit; (3) academic grit is positively associated with mathematics achievement; (4) academic grit mediates the relationship between mathematics engagement and achievement; and (5) the proposed PLS-SEM model demonstrates acceptable fit and moderate explanatory adequacy. Through this investigation, the study aims to clarify the mechanisms that sustain students' motivation and effort in mathematics learning, ultimately advancing both theoretical understanding and practical approaches to supporting mathematics success.

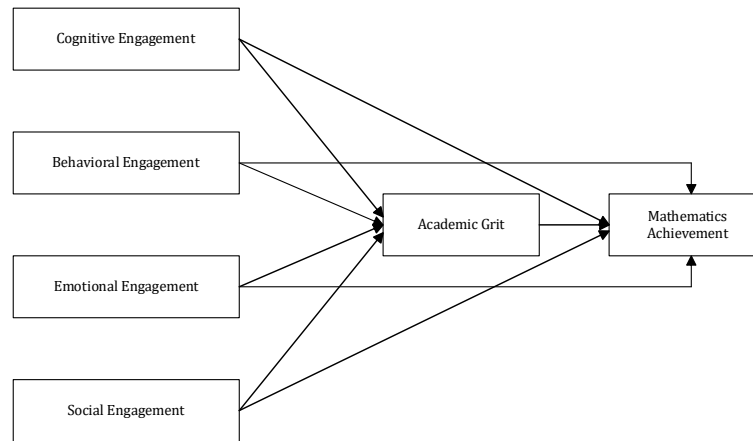


Fig. 1: Hypothesized model of the mediating effect of academic grit between mathematics engagement and mathematics achievement

2. Literature review

2.1. Mathematics engagement and academic achievement

Research in mathematics education identifies mathematics engagement as a key factor in explaining academic achievement. Large-scale and cross-cultural studies indicate that learners with stronger engagement in mathematics tend to record higher achievement across different educational contexts and age levels (Dotterer and Lowe, 2011). Recent evidence also frames this link as reciprocal: engagement supports achievement, while successful academic performance may strengthen later engagement and students' well-being (Putwain and Wood, 2023). Engagement further functions as a mediating pathway through which academic self-concept, motivation, and trauma-related symptoms affect mathematics performance. Students with more positive academic self-concept, for example, are more likely to demonstrate engaged learning behaviors that contribute to achievement gains (Tomás et al., 2020). Contextual conditions likewise matter. Teacher practices, supportive classroom climates, and innovative pedagogical approaches, including gamification, can foster engagement and improve academic outcomes (Zhang et al., 2022). Interventions centered on mastery-oriented goals, self-regulated learning, and favorable attitudes toward mathematics similarly promote both engagement and achievement. Importantly, engagement is multidimensional rather than unitary, as students may show different patterns of behavioral, cognitive, and affective engagement, each with distinct performance implications (Schnitzler et al., 2021). Cognitive engagement is especially relevant because it involves deep processing and self-regulation, whereas emotional engagement supports sustained effort and persistence in mathematics learning (Xia et al., 2022).

2.2. Grit and academic achievement

The link between grit and academic achievement is often explained in terms of related psychological

processes, particularly self-efficacy and achievement goal orientations. Grit may influence performance directly, but it also works indirectly by strengthening students' confidence and encouraging mastery-oriented goals, both of which support better achievement. Studies increasingly show that self-efficacy may partly or fully mediate the association between grit and academic outcomes, suggesting that students' belief in their capabilities can intensify the academic benefits of sustained effort (Alhadabi and Karpinski, 2020).

Self-regulated learning strategies provide another mechanism, as perseverance of effort may improve achievement by promoting more strategic and adaptive learning behaviors (Wolters and Hussain, 2015). However, grit does not operate uniformly across educational settings. Meta-analytic evidence indicates that grade level moderates this relationship, with perseverance of effort showing stronger effects at particular schooling stages (Lam and Zhou, 2022). Teacher support may also amplify the positive association between grit and achievement (Clark et al., 2020). Grit appears especially beneficial for students with moderate cognitive abilities, potentially narrowing achievement gaps in demanding fields such as STEM (Segal and Kalfon-Hakhmigari, 2025). Nevertheless, its predictive power may decline when prior achievement, self-efficacy, and other motivational variables are included, suggesting a limited unique contribution beyond stronger predictors (Tang et al., 2019). Hence, grit remains positively relevant, although its effects are generally modest and conceptually overlapping.

2.3. Engagement and grit

Research across educational settings shows that grit is closely associated with stronger academic engagement. Within this construct, perseverance of effort appears to be the stronger predictor, suggesting that sustained effort is essential for continued participation in learning (Obeng et al., 2025).

Evidence indicates that grit influences engagement directly and indirectly through

academic motivation, self-regulated learning, self-efficacy, and sense of negotiable fate. Students with higher grit tend to report stronger motivation and more adaptive self-regulatory practices, which support deeper involvement in academic work (Zhang et al., 2022). Engagement also mediates the relationship between grit and academic productivity, implying that grit produces positive academic outcomes largely through students' sustained and active participation in learning tasks (Hodge et al., 2018).

Contextual factors further shape this association. Responsive parenting, teacher encouragement, and positive classroom climates may strengthen grit, thereby promoting engagement (Sadoughi and Hejazi, 2023; Wang and Xiao, 2025). Longitudinal and cross-sectional findings also suggest a reciprocal pattern: grit predicts later engagement, while continued engagement may reinforce perseverance over time (Huo, 2022; Tang et al., 2019). Moreover, the effect of grit on engagement becomes stronger when teacher-student and peer relationships are supportive (Lee and Ha, 2023; Liu et al., 2025). Collectively, these findings show that grit and engagement operate as mutually reinforcing academic resources.

3. Methodology

3.1. Research design

This study employed a quantitative research method, utilizing a descriptive-correlational design to address the stated objectives. Descriptive research aims to provide an accurate portrayal of a phenomenon's current condition, while correlational research seeks to examine relationships among variables and to predict potential outcomes based on existing patterns.

This design is deemed appropriate for the present investigation as it not only describes the levels of mathematics achievement, engagement, and grit among the respondents but also explores the associational and mediating relationships among these variables.

3.2. Participants

The study involved 309 first-year university students enrolled in the College of Education at Nueva Ecija University of Science and Technology during the 2024–2025 academic year. Consistent with Kline's (2023) recommendation that samples exceeding 200 are adequate for structural equation modeling, the final sample size was deemed sufficient for analysis. To strengthen the validity of the measurement model, a split-sample validation approach was employed.

The dataset was randomly divided into two independent subsamples: 60% of the respondents ($n = 185$) were used for exploratory model development, whereas the remaining 40% ($n = 124$)

were reserved for confirmatory model validation. A proportionate stratified random technique was used to ensure representation across the ten specializations in the College of Education. The strata included Elementary (8.18%), Special Needs (12.62%), English (11.21%), Filipino (7.71%), Mathematics (13.55%), Science (12.85%), Social Science (8.18%), Physical Education (8.88%), Home Economics (8.18%), and Industrial Arts (8.64%). Of the 428 students, 309 completed the survey, yielding a response rate of 72.19%. This rate is considered acceptable in educational research and adequate for subsequent statistical analyses.

3.3. Measurement

3.3.1. Mathematics engagement scale

The Mathematics Engagement Scale by Wang et al. (2016) measures four dimensions (behavioral, emotional, cognitive, and social engagement) reflecting students' active participation, emotional connection, learning strategies, and interaction with peers. It consists of 32 items rated on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Sample items include "I think about different ways to solve a problem," and "I keep trying even if something is hard." Higher scores indicate greater levels of engagement. Cronbach's alpha for the overall scale was high (0.93) and demonstrated strong predictive validity of mathematics achievement.

3.3.2. Academic grit scale

The Academic Grit Scale was developed by Clark and Malecki (2019) and contains 10 items that assess two core dimensions: perseverance of effort and consistency of interest. Responses are rated on a five-point Likert scale from 1 (not at all like me) to 5 (very much like me). Sample items include "I work toward my academic goals no matter how long they take to reach," and "Even if I am struggling in school, I keep trying my best."

Higher mean scores reflect stronger levels of academic grit. The scale demonstrated high internal consistency reliability ($\alpha = 0.92$) and construct validity.

3.3.3. Mathematics achievement

Mathematics achievement was determined from students' final-semester mathematics grades, obtained from official university records. These grades served as an objective indicator of academic performance and were used to examine their association with engagement and grit.

3.4. Procedures

Data collection followed established ethical and institutional protocols. Prior approval was secured

from the dean and area chair to ensure compliance with research standards. Coordination with subject instructors facilitated the smooth administration of the survey during scheduled class hours. Before data gathering, participants were briefed on the study's purpose, their right to voluntary participation, and the confidentiality of their responses. The standardized instruments were distributed and completed in a supervised classroom setting, requiring approximately 10–15 minutes to finish. This procedure ensured consistency, minimized disruption to regular instruction, and upheld the ethical principles of transparency and informed consent.

3.5. Data analysis

The study employed both descriptive and inferential statistical techniques to comprehensively address the research objectives. Frequency counts and percentages were utilized to describe the distribution of students' mathematics achievement, providing a clear overview of performance levels. To assess the levels of academic grit and mathematics engagement, means and standard deviations were computed, offering insights into the central tendency and variability of students' responses. The Pearson's product-moment correlation coefficient (r) was then employed to determine the strength and direction of the associations among mathematics achievement, academic grit, and mathematics engagement. To further examine the mediating role of academic grit in the relationship between mathematics engagement and mathematics achievement, mediation analysis using Partial Least Squares Structural Equation Modeling (PLS-SEM) was conducted.

Finally, PLS-SEM was also employed to test the overall structural model, evaluating both direct and indirect relationships among variables.

4. Results

4.1. Levels of mathematics achievement of the students

Table 1 presents the distribution of students' mathematics achievement by final grade. The findings indicate that the majority of respondents (45.95%) obtained grades between 2.75 and 2.50, corresponding to a "Poor" level of achievement. This is followed by 33.01% of students who achieved grades ranging from 2.25 to 2.00, described as "Good." Meanwhile, 13.27% of the respondents attained grades between 1.75 and 1.50, interpreted as "Very Good." Only a small proportion (0.97%) achieved "Excellent" performance, with grades between 1.25 and 1.00, while 5.50% and 1.29% fell into the "Very Poor" and "Failed" categories, respectively.

Overall, these results suggest that most students performed below satisfactory levels in mathematics,

with fewer students reaching high levels of achievement.

Table 1: Levels of mathematics achievement of the students

Grades	Equivalent	f	%	Verbal description
1.25 – 1.00	94 – 100	3	0.97	Excellent
1.75 – 1.50	88 – 93	41	13.27	Very good
2.25 – 2.00	82 – 87	102	33.01	Good
2.75 – 2.50	76 – 81	142	45.95	Poor
3	75	17	5.50	Very poor
5	Below 75	4	1.29	Failed
Total		309	100.00	

4.2. Levels of academic grit and mathematics engagement of the students

Table 2 presents the levels of academic grit and mathematics engagement among first-year students. The results show that students demonstrated a very high level of academic grit ($M = 4.42$, $SD = 0.48$), indicating consistent perseverance and sustained effort toward their academic goals. In terms of mathematics engagement, all four dimensions, cognitive ($M = 3.41$, $SD = 0.50$), behavioral ($M = 3.94$, $SD = 0.51$), emotional ($M = 3.73$, $SD = 0.67$), and social ($M = 3.84$, $SD = 0.42$), were rated high, resulting in an overall mean of 3.73 ($SD = 0.42$). These findings suggest that students generally engage positively in mathematics learning across multiple domains.

Table 2: Levels of academic grit and mathematics engagement of the students

Variables	Mean	SD	Verbal description
Academic grit	4.42	0.48	Very high
Cognitive engagement	3.41	0.50	High
Behavioral engagement	3.94	0.51	High
Emotional engagement	3.73	0.67	High
Social engagement	3.84	0.42	High
Overall mathematics engagement	3.73	0.42	High
4.21 – 5.00 (very high), 3.41 – 4.20 (high), 2.60 – 3.40 (moderate), 1.81 – 2.60 (low), 1.00 – 1.80 (very low)			

4.3. Relationship of mathematics achievement, academic grit, and mathematics engagement

The correlation analysis in Table 3 presents significant positive associations among mathematics achievement, academic grit, and the different dimensions of mathematics engagement. Mathematics achievement demonstrated a moderate positive correlation with cognitive engagement ($r = 0.650$, $p < 0.01$), indicating that students who exert greater mental effort and engage in strategic learning tend to perform better in mathematics. Low positive correlations were also observed between mathematics achievement and behavioral ($r = 0.302$, $p < 0.01$), emotional ($r = 0.337$, $p < 0.01$), and social engagement ($r = 0.211$, $p < 0.01$). Furthermore, academic grit was moderately positively correlated with all engagement dimensions, particularly behavioral ($r = 0.450$, $p < 0.01$) and social engagement ($r = 0.417$, $p < 0.01$), suggesting that perseverance is linked to active participation and interaction in learning contexts.

4.4. Mediating effect of academic grit in the relationship between mathematics engagement and achievement

4.4.1. Analysis of reliability and validity

Table 4 presents the measurement properties of all five constructs after item purification on the exploratory subsample (60%, $n = 185$). Twelve items were removed for failing the .60 loading threshold (CE1–CE4, BE5–BE8, EE5, SE5–SE7), and the remaining item sets were frozen for confirmatory estimation without further modification. All retained

constructs met established psychometric thresholds. Factor loadings ranged from 0.644 to 0.899 across engagement constructs and from 0.665 to 0.834 for academic grit. Internal consistency was adequate across all constructs (CA = 0.718–0.913; CR = 0.826–0.928). Convergent validity was confirmed, with all AVE values exceeding the 0.50 threshold: academic grit (0.563), cognitive engagement (0.671), behavioral engagement (.544), emotional engagement (0.511), and social engagement (0.647). No item modifications were made on the confirmatory subsample, ensuring independence between the purification and validation stages.

Table 3: Intercorrelation of mathematics achievement, academic grit, and mathematics engagement

Variables	1	2	3	4	5	6
1. Mathematics achievement	1					
2. Academic grit	0.184**	1				
3. Cognitive engagement	0.650**	0.260**	1			
4. Behavioral engagement	0.302**	0.450**	0.501**	1		
5. Emotional engagement	0.337**	0.294**	0.418**	0.587**	1	
6. Social engagement	0.211**	0.417**	0.323**	0.473**	0.387**	1

** $p < 0.01$

Table 4: Factor loadings, reliability of construct, and AVE

Construct	n	Factor loading	CA	CR	AVE
Academic grit	10	0.665 - 0.834	0.913	0.928	0.563
Cognitive engagement	4	0.784 - 0.824	0.837	0.891	0.671
Behavioral engagement	4	0.644 - 0.792	0.718	0.826	0.544
Emotional engagement	9	0.633 - 0.799	0.881	0.904	0.511
Social engagement	4	0.660 - 0.899	0.818	0.879	0.647

4.4.2. Validity of structural measurements

Table 5 presents the discriminant validity assessment using the Fornell–Larcker criterion. The square roots of the AVE (diagonal values) exceeded all corresponding inter-construct correlations, indicating that each construct shares more variance with its own indicators than with any other construct in the model. Specifically, the $\sqrt{\text{AVE}}$ values were 0.750 (academic grit), 0.819 (cognitive

engagement), 0.738 (behavioral engagement), 0.715 (emotional engagement), and 0.804 (social engagement). Inter-construct correlations ranged from -0.030 to 0.590 , remaining well below their respective $\sqrt{\text{AVE}}$ values in all cases. These results collectively confirm satisfactory discriminant validity across all five constructs, supporting the conceptual distinctiveness of each latent variable in the structural model.

Table 5: Discriminant validity

Construct	AG	CE	BE	EE	SE
Academic grit	0.750				
Cognitive engagement	0.039	0.819			
Behavioral engagement	0.590	-0.019	0.738		
Emotional engagement	0.441	0.170	0.540	0.715	
Social engagement	0.459	-0.030	0.552	0.401	0.804

4.4.3. Path analysis and structural model

The structural model in Fig. 2 illustrates the mediating role of academic grit in the relationship between the mathematics engagement dimensions and mathematics achievement in the exploratory subsample. The model explained 39.5% of the variance in mathematics achievement ($R^2 = 0.395$) and 39.0% of the variance in academic grit ($R^2 = 0.390$), indicating moderate predictive capacity for both endogenous constructs. Among paths to mathematics achievement, cognitive engagement was the strongest significant predictor ($\beta = 0.516$, $p < 0.001$), followed by emotional engagement ($\beta =$

0.240 , $p < 0.001$). Behavioral engagement ($\beta = -0.049$, $p = 0.556$), social engagement ($\beta = 0.120$, $p = 0.127$), and academic grit ($\beta = 0.034$, $p = 0.651$) were non-significant. Among the paths to academic grit, behavioral engagement ($\beta = 0.420$, $t = 4.715$, $p < 0.001$) and social engagement ($\beta = 0.172$, $p = 0.030$) were significant positive predictors. Cognitive engagement ($\beta = 0.029$, $p = 0.626$) and emotional engagement ($\beta = 0.140$, $p = 0.069$) did not significantly predict grit. All indirect effects through academic grit were non-significant, indicating that grit did not mediate the engagement–achievement relationship.

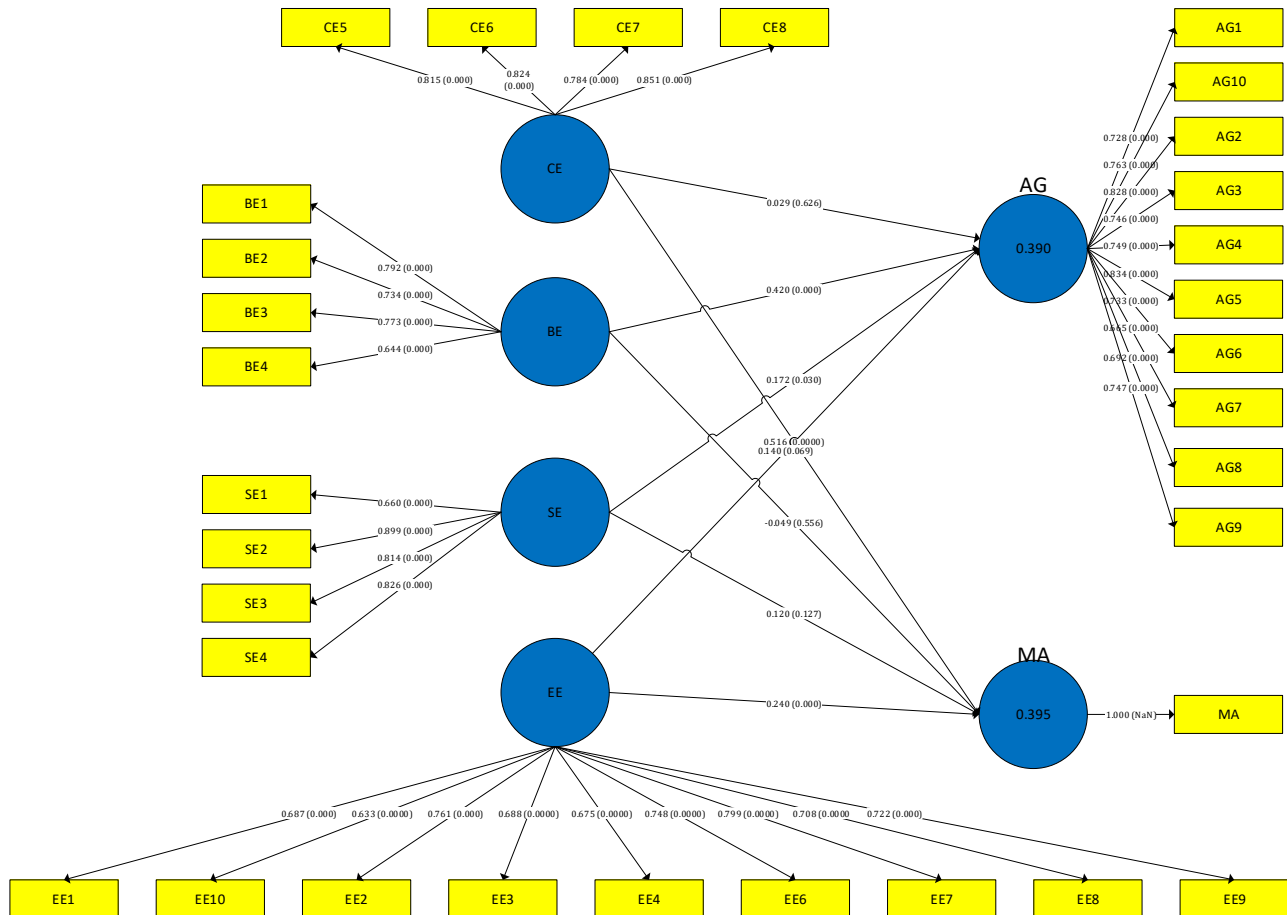


Fig. 2: Structural model illustrating the mediation effect of academic grit between mathematics engagement and achievement

4.5. Refined structural model: Cognitive and emotional engagement as correlates of mathematics achievement

Table 6 presents the measurement properties of the two constructs retained in the refined structural model, estimated on the confirmatory subsample ($n = 124$) without further item modification. Cognitive engagement retained four items (CE5–CE8), with factor loadings ranging from 0.787 to 0.850, $CA = 0.837$, $CR = 0.891$, and $AVE = 0.672$, satisfying all convergent validity and reliability thresholds.

Emotional engagement retained nine items (EE1–EE4, EE6–EE10), with factor loadings ranging from 0.541 to 0.819, $CA = 0.881$, $CR = 0.902$, and $AVE = 0.513$. Although two emotional engagement items (EE1 & EE4) fell marginally below the 0.60 loading threshold, the construct-level indices ($AVE = 0.513$ and $CR = 0.902$) remained above their respective criteria, supporting its retention (Fornell and Larcker, 1981). These results confirm adequate convergent validity and internal consistency for both constructs in the confirmatory model.

Table 6: Factor loadings, reliability of construct, and AVE of the refined structural model

Construct	n	Factor loading	CA	CR	AVE
Cognitive engagement	4	0.787 - 0.850	0.837	0.891	0.672
Emotional engagement	9	0.541 - 0.819	0.881	0.902	0.513

Fig. 3 and Table 7 present the direct path coefficients from the refined structural model, estimated on the confirmatory subsample ($n = 124$). Both cognitive engagement and emotional engagement were significant positive predictors of mathematics achievement. Cognitive engagement demonstrated the stronger effect ($\beta = 0.492$, $t = 9.252$, $p < 0.001$, $f^2 = 0.370$), indicating a large practical significance. Emotional engagement also shows a significant positive association ($\beta = 0.274$, $t = 5.086$, $p < 0.001$, $f^2 = 0.115$), reflecting a small effect. Together, the two constructs accounted for 37.9% of the variance in mathematics achievement ($R^2 = 0.379$), indicating minor-to-substantial

explanatory power. Variance inflation factors for both predictors were 1.100, well below the 3.3 threshold, confirming the absence of multicollinearity. These findings indicate that deep cognitive processing and positive affective orientation toward mathematics each contribute independently to academic achievement.

Table 8 presents the model fit indices for the refined structural model. The SRMR value of 0.077 fell below the recommended threshold of ≤ 0.08 , and the NFI value of 0.907 exceeded the ≥ 0.90 criterion, collectively confirming adequate model fit (Hair et al., 2021). Discriminant validity between cognitive and emotional engagement was further supported

by an HTMT ratio of 0.291, well below the .85 threshold, indicating that the two constructs are empirically distinct. Together, these indices confirm

that the refined structural model adequately represents the observed data and provides a sound basis for interpreting the estimated path coefficients.

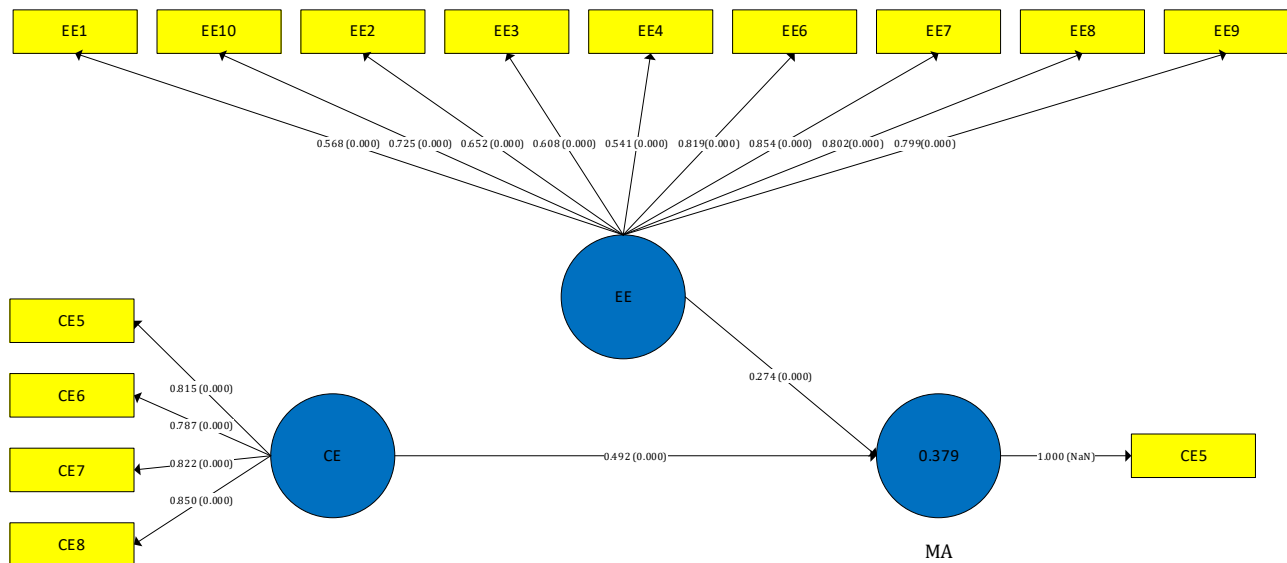


Fig. 3: Refined structural model of predictors of mathematics achievement

Table 7: Structural path coefficients: cognitive and emotional engagement as correlates of mathematics achievement

Path	β	t	p	f^2	VIF	Results
Cognitive engagement $\rightarrow$ mathematics achievement	0.492	9.252	0.000	0.370	1.100	Supported
Emotional engagement $\rightarrow$ mathematics achievement	0.274	5.086	0.000	0.115	1.100	Supported

Table 8: Model fit

Parameters	Fit recommendation	Estimated model
SRMR	≤ 0.08	0.077
NFI	≥ 0.90	0.907

SRMR (standardized root mean square residual); NFI (normed fit index)

5. Discussion

Most first-year students showed poor mathematics achievement: many grasp basic concepts but struggle with the abstraction and higher-order reasoning required in university mathematics. Prior studies attribute this to higher cognitive demands and changes in instructional style that reveal gaps in prior preparation (Johansson et al., 2024). The transition also carries affective costs, frustration, anxiety, and the need to restructure learning strategies, which further hinder performance (Di Martino et al., 2023). Low engagement, limited perseverance, and mathematics anxiety each contribute to underachievement, suggesting that goal-oriented, problem-based instruction could build both persistence and conceptual mastery.

Descriptively, students reported very high grit and uniformly high engagement across four dimensions, but cognitive engagement was the lowest mean. This pattern matches evidence that sustaining higher-order thinking and self-regulation is harder than maintaining behavioral or social participation (Fung et al., 2018). The mismatch between high self-reported grit and modest achievement foregrounds the structural findings below. Consistent with correlations, cognitive engagement was positively associated with

mathematics achievement in both full and refined models. Students who use deep learning strategies and sustain self-regulated mental effort perform better in mathematics (Maamin et al., 2021). Grit correlated positively with engagement dimensions, indicating that perseverance is associated with active and collaborative participation (Datu et al., 2021).

In the exploratory structural model, cognitive engagement is a modest predictor of mathematics achievement, while emotional engagement shows minimal but significant effects. These results indicate that strategic thinking, reflective processing, and sustained mental effort primarily drive mathematics performance, while interest and enjoyment make a secondary contribution (Murayama et al., 2013). Behavioral engagement showed a non-significant negative coefficient, likely a suppression artifact: when cognitive and emotional engagement are included, the remaining variance in behavioral engagement may reflect surface compliance (attendance, task completion) that is decoupled from deep processing. This interpretation aligns with a positive zero-order correlation between behavioral engagement and achievement that becomes negative only after controlling for cognitively richer dimensions. Social engagement was non-significant, suggesting that peer interaction alone does not produce achievement without deeper cognitive involvement. These findings nuance prior meta-analytic work that reports effects across multiple engagement dimensions by positioning cognitive engagement as primary and emotional engagement as modestly supportive (Lei et al., 2018).

Contrary to expectations, academic grit did not mediate. A fundamental requirement for mediation is a significant relationship between the predictor and the proposed mediator. However, the paths from cognitive engagement and emotional engagement to grit were weak and non-significant. Consequently, the conditions necessary for mediation were not met. Moreover, grit was not significantly associated with mathematics achievement. These findings suggest that perseverance alone does not uniquely contribute to achievement when cognitive engagement is taken into account. Cognitive engagement already captures sustained effort directed toward learning and problem solving, thereby accounting for much of the variance that grit might otherwise explain (Rimfeld et al., 2016). Although this finding contrasts with studies reporting positive effects of grit on academic performance (Kaya and Karakoc, 2022), it aligns with Wolters and Hussain (2015), who found that the influence of grit diminished when self-regulated learning was considered, and with Tang et al. (2019), who showed that grit's effects operate primarily through goal commitment and engagement.

The refined model, tested on an independent confirmatory subsample, found that cognitive and emotional engagement were significantly associated with achievement, jointly explaining 37.9% of the variance. Consistently, cognitive engagement showed a moderate effect, whereas emotional engagement a small but meaningful one. Practically, embedding brief, interest-sustaining elements (varied, relevant, success-oriented tasks) within instruction that foregrounds strategic problem-solving addresses both contributors without shifting resources away from cognitive depth. Model fit was adequate, and the HTMT indicated discriminant validity between constructs (Hair et al., 2021). These results reinforce evidence that cognitive engagement and self-regulation robustly predict mathematics achievement (Musso et al., 2019).

Grounded in Self-Determination Theory and Grit Theory, the results imply that mathematics achievement depends on cognitively engaged, affectively positive learning rather than on perseverance alone. Self-regulated, intrinsically motivated students attain deeper understanding and sustained performance (Howard et al., 2021). Instructional implications for first-year university mathematics in the Philippines include: replace passive lectures with structured problem-solving that requires justification, error analysis, and reflection; embed metacognitive prompts in assessments to develop self-monitoring habits; and use brief, efficient affective supports (relevance framing tied to students' future teaching careers) to sustain interest without displacing cognitively demanding tasks. Curricula and assessments should prioritize higher-order thinking rather than procedural recall to reinforce the deep processing shown to drive achievement.

Limitations include the modest confirmatory subsample and the exploratory nature of item

purification conducted on the initial subsample; replication with a larger, independent sample is needed. The AVE for emotional engagement was only marginally above .50, suggesting that item heterogeneity warrants further scale refinement. Finally, all engagement dimensions and academic grit were measured through self-report instruments, which may be influenced by social desirability, leniency, or halo effects.

6. Conclusion

This study examined the mediating role of academic grit in the relationship between mathematics engagement and achievement among first-year university students in the Philippines, using a split-sample PLS-SEM validation design. Across both exploratory and confirmatory analyses, cognitive engagement consistently emerged as a significant, moderate direct predictor of mathematics achievement, with emotional engagement contributing a significant but secondary effect.

Behavioral engagement, social engagement, and academic grit did not independently predict achievement once the two dominant constructs were modeled. Regarding mediation, the engagement-to-grit paths were weak and non-significant, indicating that the structural precondition for mediation was not satisfied. Grit, therefore, could not function as a mediator. This finding possibly refines Grit Theory (Duckworth et al., 2007) by suggesting that perseverance, absent deep cognitive engagement, does not reliably translate into measurable academic outcomes.

This finding also extends the integrative framework of Self-Determination Theory (Ryan and Deci, 2000) by positioning cognitive engagement rather than motivational persistence alone as the primary mechanism linking student effort to mathematics achievement. Instructionally, these results indicate that improving mathematics achievement requires learning environments that foreground higher-order thinking through problem-centered, metacognitively demanding tasks that require students to justify reasoning and monitor their own understanding. While sustaining students' interest and positive affect toward mathematics remains worthwhile, the evidence supports treating emotional engagement as a low-cost complement to cognitive demand rather than an independent intervention target.

Future research should replicate these findings on independent samples, extend the framework across disciplines, and employ longitudinal designs to clarify the developmental pathways through which cognitive engagement shapes long-term mathematics success. Complementing quantitative approaches with qualitative methods such as interviews or classroom observations would further enrich understanding of how students experience and sustain cognitive engagement in university mathematics.

List of abbreviations

AG	Academic grit
AVE	Average variance extracted
BE	Behavioral engagement
CA	Cronbach's alpha
CE	Cognitive engagement
CR	Composite reliability
EE	Emotional engagement
f	Frequency
f ²	Effect size
HTMT	Heterotrait–Monotrait ratio
M	Mean
MA	Mathematics achievement
n	Sample size
NFI	Normed fit index
p	Probability value
PLS-SEM	Partial least squares structural equation modeling
r	Pearson correlation coefficient
R ²	Coefficient of determination
SD	Standard deviation
SE	Social engagement
SRMR	Standardized root mean square residual
STEM	Science, technology, engineering, and mathematics
t	t-statistic
VIF	Variance inflation factor
α	Cronbach's alpha
β	Standardized beta coefficient

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Compliance with ethical standards

Ethical considerations

The study was approved by the NEUST College of Education Institutional Ethics Review Committee (Approval No. 20261377). Participants were informed of the study's purpose, procedures, voluntary nature, and right to withdraw without penalty. Informed consent was obtained. No identifying information was collected, and data were kept confidential, securely stored, and used solely for research purposes.

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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