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Path Analysis of Grit, Self-Efficacy, Self-Regulation, and Science Academic Performance in Online Learning

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Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

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ABSTRACT

Aims: This study investigates the relationships between grit, self-efficacy, self-regulation, and Science academic performance among junior high school students in an online learning context. While previous research has established the importance of these non-cognitive skills in academic success, their specific interplay during the pandemic remains underexplored. This study tested a model examining the impact of grit, self-regulation, and self-efficacy on students' Science academic performance in an online setting, focusing on the extent of these traits, their relationships with performance, individual contributions, and the mediating role of self-regulation and self-efficacy.
Study Design: The research employed a quantitative design and path analysis.
Place and Duration of Study: The study included 216 junior high school students from a private school in Bacolod City during the 2020-2021 school year selected through random sampling.
Methodology: Data were collected through online surveys, completed via Google Forms over two weeks. The instruments used were the Short Grit Scale, Self-Efficacy Online Learning Questionnaire, and Academic Self-Efficacy Scale for Filipino Junior High School. Descriptive and inferential statistics were used to analyze data, with model relationships tested using path analysis.

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Results: Findings revealed that students exhibited average levels of grit and moderately high levels of self-efficacy and self-regulation. Grit did not directly impact Science academic performance, nor did self-regulation or self-efficacy mediate this relationship. An unexpected finding was that consistency of interest negatively impacted time management, while perseverance of effort positively influenced metacognitive skills, time management, and persistence.
Conclusion: These results highlight the complexity of factors influencing academic performance in online learning environments. While grit, self-efficacy, and self-regulation are essential for student development, their direct impact on academic performance requires further investigation. This study underscores the need for educational strategies that cultivate these non-cognitive skills to improve students' academic performance across diverse learning settings and modalities.

Keywords: Grit; self-efficacy; self-regulation; science academic performance; online learning; path analysis.

1. INTRODUCTION

The COVID-19 pandemic has led to widespread school closures, prompting a global shift to online learning. This abrupt transition from traditional teaching methods to virtual and distance learning has encountered numerous challenges and obstacles [1]. Educational institutions have sought to address these issues by developing online learning curricula using available resources. In the Philippines, the Department of Education's Basic Education Learning Plan has proposed various instructional delivery modes, including face-to-face, online distance learning, modular distance learning, TV/radio-based instruction, blended learning, home-schooling, and other suitable methods [2]. However, the implementation of these modes has highlighted existing limitations, leading to potential gaps in student learning and compromised instructional quality, particularly evident in poor student assessment results in distance learning [3].

The shift from traditional classrooms to online platforms has increased student responsibility in managing their learning. While numerous studies have examined the roles of grit, self-efficacy, and self-regulation in academic performance, few have explored the interplay of these factors in students' Science academic performance within the online learning context during the COVID-19 pandemic. This study aims to investigate the interrelationships and models among grit, self-efficacy, and self-regulation in an online learning setup, and to elucidate their impact on Science academic performance. The findings may offer valuable insights for educators and policymakers, providing guidance on how to support students' needs in online learning environments during and beyond the pandemic.

The present study sought to test a model that investigates the role of grit, self-regulation, and self-efficacy in students' Science academic performance. It also sought to (a) Determine the extent of grit in terms of consistency of interest and perseverance of effort; self-regulation in terms of metacognitive skills, time management, environmental structuring, persistence, and help-seeking; self-efficacy in terms of perceived control, competence, and persistence; as well as the level of Science academic performance of students in an online learning setup, (b) Investigate the significant relationships among grit in terms of consistency of interest and perseverance of effort, self-regulation in terms of metacognitive skills, time management, environmental structuring, persistence, and help-seeking, self-efficacy in terms of perceived control, competence, and persistence, and Science academic performance of students in an online learning setup, (c) Examine whether each of the variables and constructs—namely, grit in terms of consistency of interest and perseverance of effort, self-regulation in terms of metacognitive skills, time management, environmental structuring, persistence, and help-seeking, and self-efficacy in terms of perceived control, competence, and persistence—makes an independent contribution to the Science academic performance of students in an online learning setup when all other variables are part of the path analysis model, and (d) Determine whether self-efficacy in terms of perceived control, competence, and persistence and self-regulation in terms of metacognitive skills, time management, environmental structuring, persistence, and help-seeking play a mediational role in the Science academic performance of students in an online learning setup.

2. REVIEW OF RELATED LITERATURE

2.1 Grit and Science Academic Performance

Grit defined as perseverance and passion for long-term goals [4], has been widely studied in the context of academic performance. Several studies have demonstrated the positive relationship between grit and academic success particularly in challenging environments. It was found that students with higher levels of grit were more likely to achieve higher GPAs even in the face of intellectual challenges [4]. In the context of Science education, studies observed that grittier students tend to outperform their peers in college-level Science courses [5]. This suggests that grit is essential for persistence and resilience in demanding subjects like Science [6]. During the COVID-19 pandemic, online learning became the primary mode of education presenting unique challenges that required grit to overcome. It is emphasized that grit plays a crucial role in helping students adapt to the online learning environment, where self-motivation and persistence are needed to succeed without the structure of a traditional classroom [7]. The ability to stay focused and complete tasks in this new learning modality is critical for academic success during this period of disruption.

2.2 Self-Efficacy and Science Academic Performance

Self-efficacy described by Bandura (1989) as an individual's belief in their ability to succeed, is a significant predictor of academic achievement [8]. In academic contexts, students with higher self-efficacy tend to set more challenging goals, apply greater effort, and persist through difficulties [9]. In Science education, Honicke and Broadbent (2016) found a moderate positive correlation between self-efficacy and academic performance, with students who believe in their Science-related abilities performing better [10]. Self-efficacy has become even more critical in online learning environments during the COVID-19 pandemic. According to Bahçekapılı and Karaman (2020), students' belief in their ability to learn independently has been a key factor in their ability to succeed in online courses [11]. The absence of face-to-face interaction and immediate support requires learners to trust in their capacity to manage their learning processes. Additionally, Alhadabi and Karpinski (2020) suggest that self-efficacy mediates the relationship between grit and academic performance highlighting its role in sustaining motivation for Science learning, especially in remote learning settings [6].

2.3 Self-Regulation and Science Academic Performance

Self-regulation involves a learner's ability to control their learning processes, from setting goals to monitoring progress and adjusting strategies as needed [9]. This skill is particularly essential in Science education, where problem-solving and critical thinking are required. Wolters and Hussain (2015) demonstrated that self-regulation is positively associated with academic achievement, as students who manage their learning strategies effectively tend to perform better in Science [12]. In online learning during the pandemic, self-regulation became a critical factor in determining students' success. Students who were able to regulate their learning in the absence of direct oversight from teachers were better able to stay on track. Buzzetto-Hollywood and Quinn (2019) noted that online learners who practiced self-regulation were more likely to succeed, as the online environment demands a higher level of independence and proactive engagement in learning [7]. Self-regulation complements grit, as students who manage their learning processes effectively are better able to persist and overcome academic challenges.

2.4 Online Learning During the COVID-19 Pandemic

The COVID-19 pandemic forced a rapid shift to online learning, which posed significant challenges for both students and educators. Many students struggled with the lack of face-to-face interaction, technical issues, and the need for increased self-discipline and motivation [1]. According to Baticulon et al. (2021), medical students in the Philippines cited internet connectivity, a lack of physical learning resources, and the absence of peer collaboration as significant barriers to learning during the pandemic [3]. These barriers have highlighted the importance of grit, self-efficacy, and self-regulation in adapting to the online learning environment. In a study by Rice et al. (2019), students with higher levels of self-efficacy were better equipped to handle the demands of online learning, demonstrating greater resilience and academic achievement [13]. Furthermore, Liaw and Huang (2013) argued that online learning environments that encourage self-regulated learning help improve students' motivation and

academic outcomes [14]. As schools continue to rely on online learning due to the pandemic, it is essential to further explore how these non-cognitive factors influence students' ability to succeed in Science and other academic areas. With the extensive research and findings explained in this section, there is an increasing need to study grit, self-efficacy, and self-regulation on how they influence the learners' academic performance in an online learning environment.

3. METHODOLOGY

This study employs a quantitative research design using path analysis to explore the relationships among grit, self-efficacy, self-regulation, and science academic performance. Path analysis is suitable for examining complex relationships among multiple variables and testing hypothesized models. The study sample consists of 216 junior high school students from a private school in Bacolod City, selected through random sampling to ensure that every student had an equal chance of being selected, reducing selection bias and increasing the generalizability of the results. The participants were chosen based on their enrollment in an online learning setup during the school year 2020-2021. Hoe (2008) cited a proposed critical sample size of 200 when using Structural Equation Modeling [15]. As a rule, any number above 200 is sufficient statistical power for data analysis. Data were collected using the following instruments. These instruments were chosen for their validity and reliability in measuring the constructs of grit, self-efficacy, and self-regulation among students.

GRIT-S (Short Grit Scale). The research instrument for grit is the Short Grit Scale (Grit-S), standardized by Duckworth [4]. The test has two dimensions – (1) Perseverance of effort and (2) Consistency of interest. The instrument has a 5-Likert scale.

SOL-Q (Self-Efficacy Online Learning Questionnaire). The research instrument for self-regulated learning is the Self-Regulated Online Learning Questionnaire (SOL-Q). The questionnaire is a 36-item test with a 7-Likert scale. It has indicators, Metacognitive skills, Time Management, Environmental Structuring, Persistence, and Help-seeking.

ASES-FJHS (Academic Self-Efficacy Scale for Filipino Junior High School). The research instrument for self-efficacy is the Academic Self-Efficacy Scale for Filipino Junior High School Students by Dullas [16]. The instrument is a 62-item test with a 4-Likert scale. It also has three components, Perceived control items, Competence items, and Persistence items.

Data were collected through online surveys using Google Forms due to pandemic-related restrictions. The surveys were distributed via email and completed by the students over a two-week period. Path analysis was conducted using AMOS software to determine the direct and indirect effects of grit, self-efficacy, and self-regulation on science academic performance. Descriptive statistics were used to summarize the extents of grit, self-efficacy, and self-regulation among the students. Pearson correlation coefficients were calculated to examine the relationships among the variables.

4. RESULTS AND DISCUSSION

4.1 The Extent of Grit, Self-Regulation, Self-Efficacy, and Level of Science Academic Performance of Students in an Online Learning Setup

Based on the gathered data, Junior High School students taking online classes reported an “Average” extent of grit in terms of consistency of interest and perseverance of effort, a “Moderately High” extent of self-regulation (including metacognitive skills, time management, environmental structuring, persistence, and help-seeking), and a “Moderately High” extent of self-efficacy (including perceived control, competence, and persistence). These findings suggest that students maintain grit and perseverance in learning despite the transition to online classes during the pandemic (see Table 1). Even without prior training in online learning tools, students displayed moderately high levels of self-regulation and self-efficacy. Their self-efficacy reflects their perceived competence and control over tasks, despite the reduced learning objectives and the need to adjust to new learning styles. Students demonstrated adequate persistence, indicating their ability to work efficiently despite challenges.

Indicators of self-regulated learning showed moderately high levels. Students exhibited good metacognition and moderate time management, indicating their ability to consider time in their work. They also showed acceptable evaluation of

their learning environment, suggesting that they ensure their surroundings are conducive to learning. Additionally, students used help-seeking strategies, asking for assistance with content, emotional, or technical issues. The findings align with previous studies, indicating that students who perceive themselves as persistent and interested are more likely to have high self-efficacy [6]. Grit in online classes helps students survive struggles, learn from mistakes, and demonstrate passion and self-regulation [7]. The average extent of grit indicates that students remain persistent and diligent in pursuing long-term goals despite pandemic-related obstacles [5]. Self-regulation in online learning does not occur naturally, making it challenging for students to manage their learning process [17]. Studies show that students with high self-regulation and self-efficacy are active participants in online classes [18]. This consistency with Wolters and Hussain (2015) suggests that high self-efficacy students use self-regulated learning strategies [12]. Despite the challenges of online learning, students have shown the ability to regulate their learning and exhibit self-efficacy [3].

The academic performance level of students in Science is equivalent to proficient, as defined by the Department of Education Order #31 series of 2012, as shown in Table 2. Surprisingly, the data revealed that students maintained a proficiency level in Science over the first three quarters in an online class, which differs from the expected result.

This suggests that students may have adapted and become familiar with the structure of their learning process in Science. Additionally, the availability of free learning materials and resources on the internet, which are often objective-based, could have contributed to their proficiency in Science. According to Paul and Jefferson (2019), there was no significant difference in Science academic performance between face-to-face and online classes [19]. This implies that students who performed well in face-to-face classes also excelled in the online class setup despite the limitations and challenges.

4.2 Relationship of Grit, Self-Regulation, Self-Efficacy, and Science Academic Performance of Students in Online Learning Setup

The results indicated that consistency of interest has moderate significant relationships with perseverance of effort and competence, but weak relationships with metacognitive skills, time management, environmental structuring, self-regulation persistence, perceived control, self-efficacy persistence, and Science academic performance. No significant relationship was found between consistency of interest and help-seeking. This suggests that students' firm interest and passion in an online class significantly relate to their effort and perseverance, allowing them to work consistently on tasks and use effective learning strategies [4,20]. Interestingly, students with strong and fixed interests tend not to seek help, believing their focus will enable them to carry out tasks independently [4]. While perseverance of effort has a stronger impact on academic achievement than consistency of interest, both are linked to better performance [20]. Students in an online class showed that their enduring effort is linked to academic performance, suggesting that maintaining effort can lead to better outcomes. Both aspects of grit have significant relationships with Science academic performance [12].

Metacognitive skills demonstrated significant moderate relationships with environmental structuring, self-regulation persistence, help-seeking, perceived control, competence, self-efficacy persistence, and Science academic performance, but no significant relationship with time management. This implies that students who exhibit metacognitive skills know when and where to learn and can manage their learning environment and persistence [21]. Time management did not show significant relationships with environmental structuring, help-seeking, perceived control, competence, self-efficacy persistence, or Science academic performance, but had a weak relationship with self-regulation persistence. This suggests that while time management enhances skills, it does not necessarily correlate with better performance [21].

Environmental structuring showed moderate significant relationships with self-regulation persistence, self-efficacy persistence, and Science academic performance, and weak relationships with help-seeking, perceived control, and competence. This indicates that a conducive learning environment supports persistence and academic achievement. Self-regulation persistence had moderate significant relationships with help-seeking, perceived control, self-efficacy persistence, and weak relationships with competence and Science

academic performance. This suggests that students' regulated persistence influences their task management and efficiency, contributing to better academic outcomes [22].

Help-seeking showed moderate significant relationships with perceived control and self-efficacy persistence, and weak relationships with competence and Science academic performance. This implies that asking for assistance can influence students' control and persistence in learning [23]. Perceived control revealed strong significant relationships with competence, moderate relationships with self-efficacy persistence, and Science academic performance. This indicates that students who believe their actions have consequences are better able to manage their learning and achieve academic success [24]. Competence had strong significant relationships with self-efficacy persistence and moderate relationships with Science academic performance, while self-efficacy persistence showed a moderately significant relationship with Science academic performance. This highlights the importance of self-efficacy in academic success [11].

Overall, the indicators and subscales of grit, self-efficacy, and self-regulation generally have significant relationships with Science academic performance, except for time management. Grit, self-regulated learning skills, and self-efficacy are all linked to academic success in an online learning environment [17,12]. Interestingly, time management did not significantly impact students' academic performance in an online class. While effective time management is often associated with greater academic achievement, students may not always follow through on their plans. This suggests that students are more driven by goal setting than by time management techniques, relying on persistence, focus, and motivation to achieve better performance [25].

Table 1. Mean and Standard Deviation of Grit in terms of Consistency of Interest and Perseverance of Effort; Self-regulation in terms of Metacognitive Skills, Time Management, Environmental Structuring, Persistence, Help-seeking; and Self-efficacy in terms of Perceived Control, Competence, and Persistence

	Mean	Standard Deviation	Extent
[a]Grit			
Consistency of Interest	2.76	.83	Average
Perseverance of Effort	3.33	.73	Average
[b]Self-regulation			
Metacognitive Skills	5.09	.72	Moderately High
Time Management	5.10	.83	Moderately High
Environmental Structuring	5.19	1.13	Moderately High
Persistence	4.66	1.13	Moderately High
Help-seeking	5.01	1.08	Moderately High
[c]Self-efficacy			
Perceived Control	3.10	.40	Moderately High
Competence	2.71	.43	Moderately High
Persistence	3.10	.45	Moderately High

Note: [a]Grit 4.50 – 5.00 – High; 3.50 – 4.49 – Moderately High; 2.50 – 3.49 – Average; 1.50 – 2.49 – Moderately Low; 1.00 – 1.49 – Low. [b]Self-Regulation 6.50 – 7.00 – Very High; 5.50 – 6.49 – High; 4.50 – 5.49 – Moderately High; 3.50 – 4.49 – Average; 2.50 – 3.49 – Moderately Low; 1.50 – 2.49 – Low; 1.00 – 1.49 – Very Low. [c]Self-Efficacy 3.50 – 4.00 – High; 2.50 – 3.49 – Moderately High; 1.50 – 2.49 – Moderately Low; 1.00 – 1.49 – Low.

Table 2. Level of Science Academic Performance of Students in Online Class

	Mean	Standard Deviation	Interpretation
*Science Academic Performance	89	4.98	Proficient

**Note: 90 – Above – Advanced; 85 – 89 – Proficient; 80 – 84 – Approaching Proficiency; 75 – 79 Developing; 74 –Below – Beginning.*

Table 3. Cross-tabulation of Pearson's r Coefficient of Grit in terms of Consistency of Interest and Perseverance of Effort, Self-regulation in terms of Metacognitive Skills, Time Management, Environmental Structuring, Persistence, Help-seeking, Self-efficacy in terms of Perceived Control, Competence, Persistence, and Science Academic Performance

	CI	PE	MS	TM	ES	SRP	HS	PC	CO	SEP	SAP
Consistency of Interest		.388**	.197**	-.264**	.223**	.252**	.004	.250**	.304**	.294**	.217**
Perseverance of Effort	.388**		.476**	.052	.331**	.435**	.198**	.523**	.578**	.591**	.376**
Metacognitive Skills	.197**	.476**		.128	.502**	.544**	.447**	.475**	.471**	.579**	.411**
Time Management	-.264**	.052	.128		.016	.169*	.061	.026	.026	.132	.088
Environmental Structuring	.223**	.331**	.502**	.016		.398**	.288**	.291**	.257**	.422**	.276**
Self-Regulation Persistence	.252**	.435**	.544**	.169*	.398**		.322**	.333**	.269**	.479**	.223**
Help-seeking	.004	.198**	.447**	.061	.288**	.322**		.302**	.210**	.353**	.238**
Perceived Control	.250**	.523**	.475**	.026	.291**	.333**	.302**		.741**	.656**	.419**
Competence	.304**	.578**	.471**	.026	.257**	.269**	.210**	.741**		.714**	.401**
Self-Efficacy Persistence	.294**	.591**	.579**	.132	.422**	.479**	.353**	.656**	.714**		.470**
Science Academic Performance	.217**	.376**	.411**	.088	.276**	.223**	.238**	.419**	.401**	.470**	

*Note: CI – Consistency of Interest, PE – Perseverance of Effort, MS – Metacognitive Skills, TM – TimeManagement, ES – Environmental Structuring, SRP – Self-Regulation Persistence, HS – Help-seeking, PC – Perceived Control, CO – Competence, SEP – Self-Efficacy Persistence, SAP – Science Academic Performance, **. Correlation is significant at the 0.01 level (2-tailed), *. Correlation is significant at the 0.05 level (2-tailed)*

4.3 Models of Grit, Self-Efficacy, Self-Regulation, and Science Academic Performance of Students in an Online Learning Setup

The hypothesized model is tested for goodness of fit. Every path presented in Fig. 1 was found to be significant. These are the possible paths and patterns of causal relationships present in an online learning setup. The path diagram includes standardized beta coefficients. Table 4 summarizes the Root Mean Square Error Approximation (RMSEA), the Goodness of Fit Index (GFI), the Adjusted Goodness of Fit Index (AGFI), the Comparative Fit Index (CFI), the Tucker-Lewis Index (TFI), the Normed Fit Index (NFI), and other fit indices.

Table 4 presents the statistical values related to fitting the hypothesized path model, as shown in Fig. 1.

The AMOS program presents various indices to confirm the fitness of the model. The chi-square value, X2, is the universal measure used to verify the goodness of fit of a model. Aside from it, Marquier (2019), which suggests the different indices that measure good fit [28]. CFI, NFI, TLI, GFI/AGFI values of .90 or above indicate a good fit. The fit index values showed no fit in any of the indices; thus, it needs to be reevaluated and restructured. Suppose the fit indices do not reach the accepted value. In that case, the researcher must review the hypothesized model and do revisions and adjustments until it reached the accepted value. Table 5 presents the index category and the level of acceptance for every index.

Overall, the relationships specified in the hypothesized model did not account for all the data as suggested by the Chi-square value (X2 = 423.880, p = .000). Other goodness of fit indices X2/df = 15.139; RMSEA=.256; GFI=.685; AGFI = .258; CFI=.556; TLI = .128; NFI = .552 also indicated that the model fitted the data poorly. Modification is necessary in order to attain a better fitting and more parsimonious model.

4.4 The Revised Model

Since the hypothesized path model was found to be poorly fit on its data, the decision to revise the path model was made. It was based on theoretical understanding and empirical findings. Fig. 2 presents the revised model.

The revised model included five additional paths between different self-efficacy and self-regulation subscales. Paths from self-efficacy perceived control to self-efficacy competence, from self-efficacy competence to self-efficacy persistence, from self-efficacy persistence to self-regulation metacognitive skills, from self-regulation metacognitive skills to self-regulation environmental structuring, and from self-regulation metacognitive skills to self-regulation help-seeking were added.

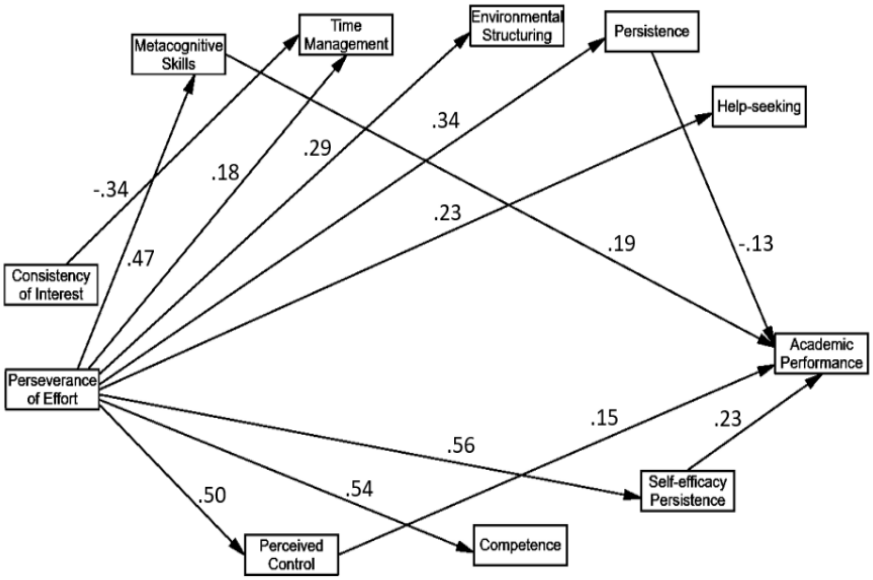

Fig. 1. Hypothesized model with significant paths

Table 4. Statistical Values Related to the Fitting of the Hypothesized Model

Measure	Level of Acceptance	Acceptable Fit	Fit Index Values of the Model
(X^2/df)	< 5	< 5	15.139
RMSEA	< 0.08	Range 0.05 to 0.1 is acceptable	.256
GFI	> .90	0.85 – 0.89	.685
AGFI	> .90	0.85 – 0.89	.258
CFI	> .90	0.80 – 0.85	.556
TLI	> .90	0.85 – 0.89	.128
NFI	> .90	0.85 – 0.89	.552

Based on Hair et al. (1996); Joreskog and Sorbom (1996) [26,27]

Table 5. Index category and the level of acceptance for every index

Name of Category	Name of Index	Level of Acceptance	Comments
Absolute Fit	Chi-square	p > 0.05	Sensitive to sample size > 200
	RMSEA	RMSEA < 0.08	Range .05 to 0.1 is acceptable
	GFI	GFI > 0.90	GFI = 0.95 is a good fit
Incremental Fit	AGFI	AGFI > 0.90	AGFI = 0.95 is a good fit
	CFI	CFI > 0.90	CFI = 0.95 is a good fit
	TLI	TLI > 0.90	TLI = 0.95 is a good fit
	NFI	NFI > 0.90	NFI = 0.95 is a good fit
Parsimonious Fit	X^2/df	Chi-square/df < 5.0	The value should be less than 5

Based on Hair et al. [26]; Joreskog and Sorbom [27]

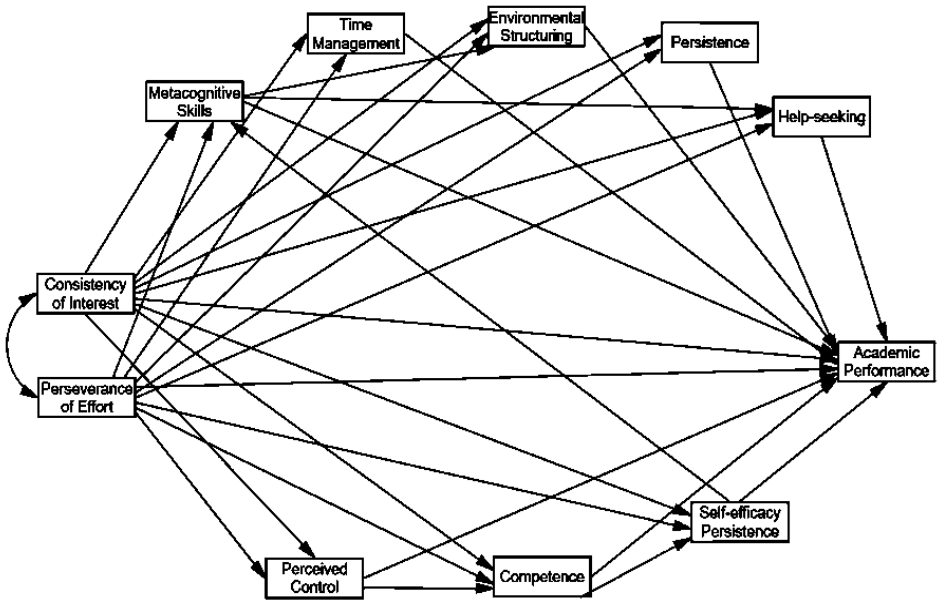

Fig. 2. The revised path model

The revised model was then subjected to investigation and analysis. Fig. 3 shows the final path model, and non-significant paths were removed. The path model includes the standardized beta coefficients.

The Chi-square value ($\chi 2$ =111.988, p=.000) of the revised model has remained significant after modifications were made. However, all other fit indices ($\chi 2$/df) = 4.869; RMSEA = .134; GFI = 0.911; AGFI = 0.743; CFI = 0.900; TLI = 0.761;

NFI = .882 seem to have improved. However, it is important to note that among all the fit indices, the (χ2/df), GFI, CI, and NFI are within the acceptable range, although the RMSEA may be ignored for a sample size greater than 200 [26,27]. This signaled that the revised model indicated a relatively perfect fit for the data. Hence the revised model was then accepted as the best solution.

4.5 Path Analysis

Path analysis has also provided direct and indirect effects of the variables in the study. Table 6 shows the decomposition of the effects of the final model. With the given data, interpretation about the final path model can be made and shows how each variable provides impact or effect upon each other.

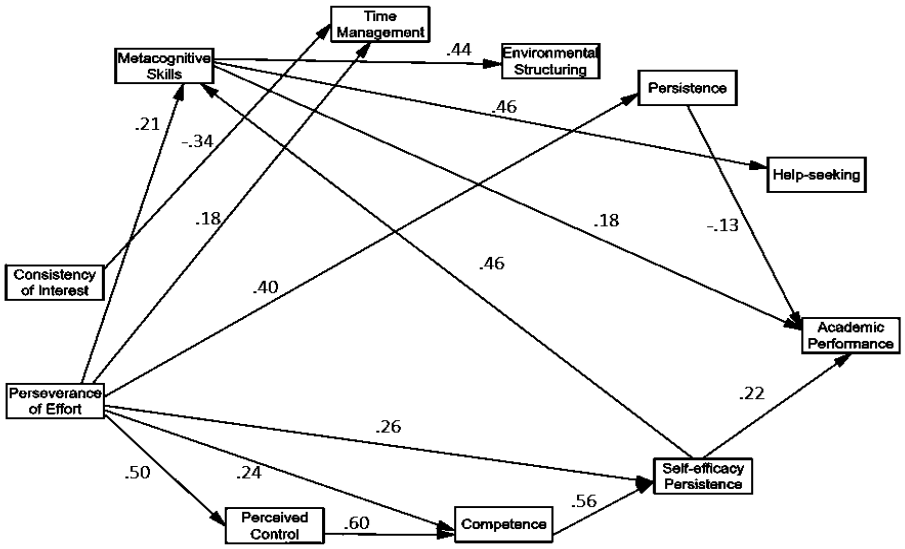

Fig. 3. The final path model with significant paths

Table 6. Decomposition of effects of the final model

Effect	Direct	Indirect	Total Effect
On Academic Performance			
- Of Perseverance of Effort		0.11	0.11
- Of Metacognitive Skills	0.18		0.18
- Of Self-regulation Persistence	-0.13		-0.13
- Of Self-efficacy Persistence	0.22		0.22
On Metacognitive Skills			
- Of Perseverance of Effort	0.21		0.21
- Of Self-efficacy Persistence	0.46		0.46
On Time Management			
- Of Consistency of Interest	-0.34		-0.34
- Of Perseverance of Effort	0.18		0.18
On Environment Structuring			
- Of Metacognitive Skills	0.46		0.46
- Of Perseverance of Effort		0.09	0.09
On Self-Efficacy Persistence			
- Of Perseverance of Effort	0.40		0.40
On Help-seeking			
- Of Metacognitive Skills	0.46		0.46
- Of Perseverance of Effort		0.10	0.10
On Self-efficacy Persistence			
- Of Persistence of Effort	0.26	0.30	0.56

Consistency of interest exhibited a negative direct effect on time management, as shown in Fig. 4. Previous research suggests grit is typically associated with effective time management [29]. Wolters and Hussain [12] found that consistency of interest predicts time management skills. Other studies indicated a positive correlation between consistency of interest and academic engagement, productivity, and time management [30]. Moreover, consistency of interest is linked to self-regulated learning indicators such as time and study environment structuring and procrastination [12]. While generally positive, consistency of interest is negatively associated with procrastination [31].

This study found an unexpected inverse effect between consistency of interest and time management among students who took online classes during the pandemic. Hodge et al. [31] reported that high levels of effort in the grit component correlate with excellent productivity, suggesting that consistency of interest does not necessarily predict positive time management. Students with strong, fixed interests may not prioritize time management, focusing instead on goal adherence. Research supports this, showing students may not follow schedules strictly but still complete tasks [25]. Thus, an increase in consistency of interest may decrease time management. The negative direct path shown in Fig. 4 is derived from students who took online classes during the COVID-19 pandemic.

Additionally, a direct effect is seen from metacognitive skills to environmental structuring and help-seeking (Fig. 5). Increased metacognitive skills result in better environmental structuring and more help-seeking. Students with high metacognition evaluate their learning environment well and seek assistance when needed. Kaur et al. [32] found that the learning environment correlates with academic achievement, implying high-achieving students exhibit high metacognition.

Perseverance of effort indicated positive direct effects on metacognitive skills, time management, and persistence (Fig. 6). This suggests that increased perseverance of effort leads to enhanced metacognitive skills, time management, and persistence. Students exerting durable effort develop strategies to overcome challenges by thinking metacognitively. As perseverance of effort increases, so does time management. Students who persevere in overcoming challenges have good time management skills, knowing how to prioritize [12]. The perseverance of effort positively affects time management in an online class, confirming that effort, not interest, is the strongest predictor of time management and productivity [31].

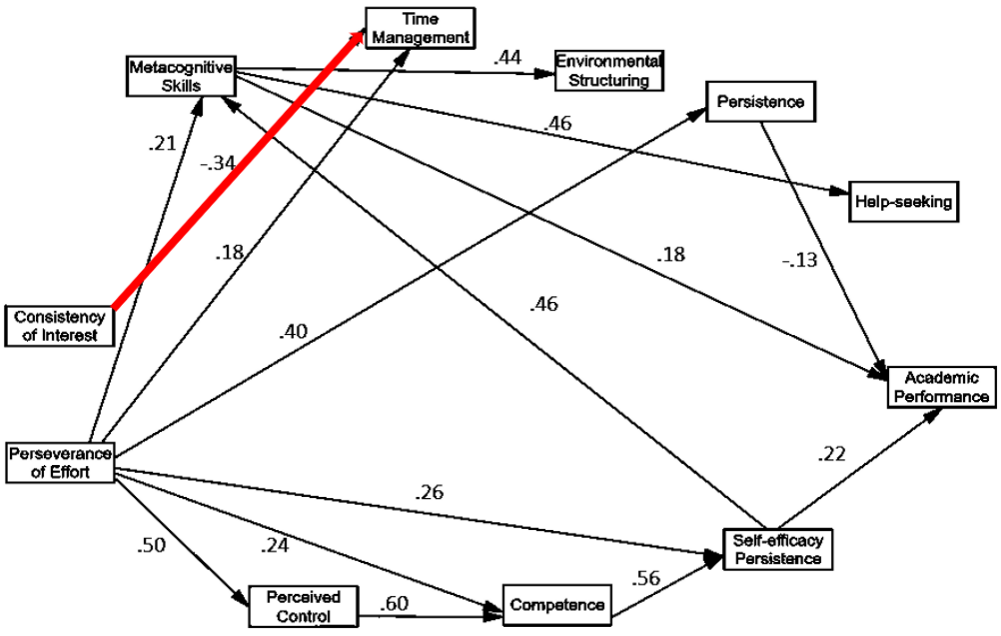

Fig. 4. Direct path from consistency of interest to time management

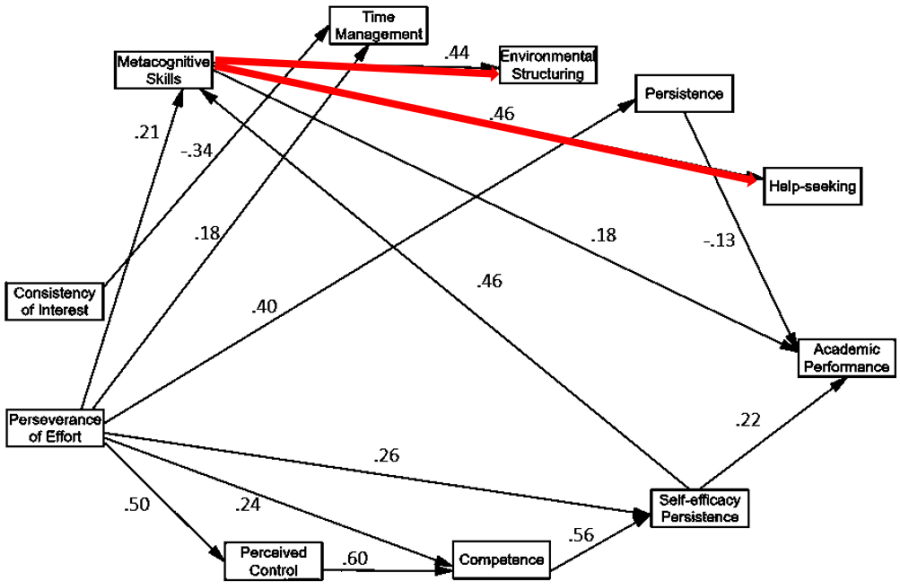

Fig. 5. Direct paths from metacognitive skills to environmental structuring and help-seeking

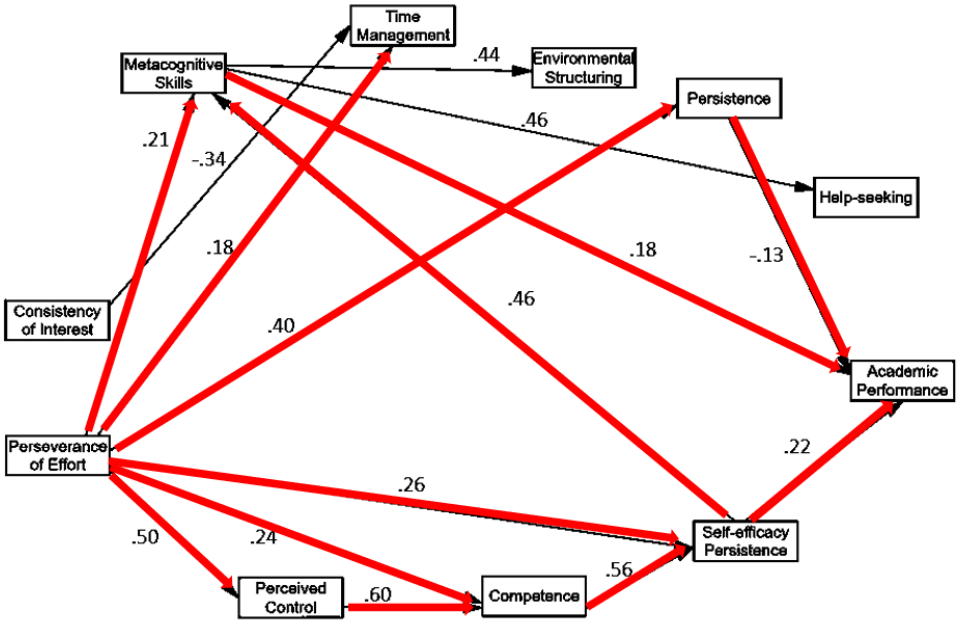

Fig. 6. Indirect paths from the perseverance of effort to academic performance

An increase in perseverance of effort also results in increased persistence. Highly perseverant students work continuously on challenging tasks. Self-regulation enables students to achieve goals by managing thoughts and behaviors related to persistence [33]. No direct effects were observed on environmental structuring, but indirect effects via metacognitive skills were seen. This indicates metacognition mediates the relationship between perseverance of effort and environmental structuring. A student with high perseverance of effort can have high metacognitive skills, though this does not guarantee high environmental structuring.

The absence of a direct path from perseverance of effort to academic performance is supported by Dixson et al. [34] who found that grit was not a

significant predictor of academic achievement. Similarly, grit did not show a significant correlation with academic achievement in Science [35]. These findings suggest no mediating effects from perseverance of effort to academic performance (Fig. 6). However, a positive direct path was observed from perseverance of effort to self-efficacy persistence, with indirect paths to academic performance through perceived control and competence. Perceived control and competence mediate the effects of self-efficacy persistence. To impact Science academic performance significantly, perseverance of effort must be coupled with perceived control and competence.

The model also showed a negative direct effect of persistence on Science academic performance, indicating increased persistence does not necessarily lead to better academic performance. The negative direct effect of persistence on Science academic performance observed in this study may be attributed to students completing tasks simply to fulfill academic requirements rather than engaging in meaningful learning. In online learning environments, students may feel pressured to meet deadlines and submit assignments without fully understanding the material. As a result, their persistence in completing these tasks does not necessarily lead to improved academic performance, as the focus shifts from learning to merely passing the subject. This suggests that persistence alone is not always a reliable indicator of academic success, particularly when it lacks genuine engagement and understanding. This finding is new to the literature, and further research is needed on the mediating effects of perceived control and competence on self-efficacy persistence. The presented research can form a foundation for understanding relationships in online learning setups.

5. CONCLUSION

This study investigated the relationships between grit, self-efficacy, self-regulation, and Science academic performance among junior high school students in an online learning environment during the COVID-19 pandemic. The findings reveal that while students exhibited average levels of grit, they showed moderately high levels of self-efficacy and self-regulation. Importantly, grit did not demonstrate a direct effect on Science academic performance, and neither self-regulation nor self-efficacy mediated this relationship. These results underscore the complexity of academic performance determinants in online settings, suggesting that multiple factors interact to influence outcomes. Significant interrelationships were observed among the components of grit, self-efficacy, and self-regulation. Specifically, the study found that consistency of interest, a component of grit, had an unexpected negative relationship with time management. This indicates that students with strong, fixed interests may struggle with effective time management in an online learning context. Conversely, perseverance of effort positively influenced metacognitive skills, time management, and persistence, highlighting the critical role of sustained effort in achieving academic success.

The study also suggests that self-regulation and self-efficacy are essential for adapting to and performing well in an online learning environment. Students with high levels of these attributes were more likely to engage actively in their studies, demonstrating better task control and persistence despite challenges. Interestingly, time management did not significantly impact academic performance, indicating that other factors, such as goal setting and intrinsic motivation, may be more crucial. While grit, self-efficacy, and self-regulation are vital for student development, their direct impact on academic performance in online learning contexts needs further exploration. These findings highlight the necessity for educational strategies that foster these non-cognitive skills, thereby enhancing students' academic outcomes across various learning environments. It is recommended that Education sector, alongside school administrators and stakeholders, should train teachers to foster students' grit, self-efficacy, and self-regulation, particularly in an online learning setup. Teachers should provide motivation and create a supportive environment that encourages these qualities. Science teachers can enhance students' grit by embedding perseverance and interest into Science activities to improve attitudes and passion for learning. Further research should continue to unravel the complexities of these relationships in different learning modalities and specially this post-pandemic to inform more effective educational practices and policies.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The author hereby declares that generative AI technology (ChatGPT, GPT-4, OpenAI) was utilized during the editing process of this

manuscript specifically for formatting the reference list. The input prompt provided to the AI was: “With the guidelines provided, format this reference list.” The content produced by the AI was carefully reviewed and verified to ensure that no changes were made to the original references, and only the formatting was adjusted in accordance with the provided guidelines.

CONSENT

Written informed consent from participants were taken and ensuring the confidentiality of their responses.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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