CTU Journal of Innovation and Sustainable Development
ISSN 2588-1418 | e-ISSN 2815-6412

DOI:10.22144/ctujoisd.2025.027

Exploring the relationship between grit and mathematical ability among pre-service teachers: A HP Model A "Hard work and Passion" (HP) Model

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Article info.

Received 10 Jul 2024
Revised 7 Aug 2024
Accepted 12 Jan 2025

Keywords

Grit, growth mindset, hard work and passion mathematical ability, mathematics pre-service teachers

ABSTRACT

The main thrust of this study is to identify the grit level and its correlation to the mathematical ability of the mathematics pre-service teachers of Bohol Island State University System. This mainly used a descriptive-correlational method to assess the grit and mathematical ability. Using the total enumeration sampling method, the study purposively involved one hundred two (102) Mathematics pre-service teachers. Then, important data were gathered using questionnaires adopted from Duckworth et al. (2007), Kilic (2010) and MTAP 2017. Using the PPMC and multiple regression analysis, the researchers found out a moderate positive significant correlation as well as the indicators, perseverance of effort and time spent, from grit towards mathematical ability. The study generated an emergent model called "HP Model" that postulated that mathematical skills can be developed by hard work and passion. Thus, the researchers concluded that grit consisting of hard work and passion showed a direct impact towards their mathematical ability. It was highly recommended the need to assess the grit level of the mathematics pre-service teachers as well as incorporating programs and seminars on how to be grittier to enlighten them up to strive for success in their mathematics teaching career.

1. INTRODUCTION

Teaching mathematics needs more than rote knowledge and memorization. Also, for a long time, intelligence is considered as the core key to succeed in the field of teaching (Duckworth, 2016). However, it is not only a critical measure to develop skills, especially in teaching mathematics in the classroom. It must also possess the ability of perseverance and self-motivation in acquiring and developing mathematical skills needed to succeed in mathematics teaching (Vecaldo et al., 2017). To understand why some mathematics teachers are more prepared and more successful in the field of teaching than others, there is a growing amount of research on non-cognitive traits such as grit, which has potential to support mathematical skills. Researchers are looking at what roles this trait plays in contributing to and predicting the mathematical ability of the mathematics teachers.

Grit can be defined as "tenacity, perseverance, hanging in, and not ever giving up" (Hoerr, 2017) and also exerting effort and sustaining drives for long-term goals (Duckworth, 2016). It is also a tendency to sustain interest in and effort towards long-term goals and despite of failures, adversities and plateaus, it will persistently and tirelessly work towards overcoming challenges and developing skills (Duckworth et al., 2007). Grit provides an indicator of teachers' readiness for mathematics class. Teachers who demonstrated grit are more

likely to persevere in their teaching work and persist in repetitive practice on the mastery of the subject matter and pedagogy in teaching mathematics (Hoberecht, 2017).

The Teaching and Learning International Survey 2014, as published by the Organization for Economic Cooperation and Development reported that 89% of U.S. mathematics teachers in their first year of teaching show hard work and passion in teaching their field with notable skills in integrating the subject matter and pedagogy higher than the average of 78% among all TALIS countries. It further emphasized that mathematical competence should be understood in its sense as integrated qualities that delineate the capacity to find answers to raising mathematical issues in teaching by not just creatively using one's knowledge, personal and professional experiences but the value of persistence and enthusiasm that lead to proper and desirable outcomes (TALIS, 2014).

In the Philippine Education, as accentuated by the Commission on Higher Education (CHED), "The vital element in Philippine education is providing quality pre-service teaching education", the teaching education curriculum is expected to make sure that the unrelenting needs of the pre-service teachers is provided through quality of training that adapts to the general demands of the Philippine society. However, the Philippine Council of Mathematics Teachers and Educators (MATHTED) emphasizes that mathematics education is not solely about content knowledge and skills but also about fostering persistence and motivation in teaching. For pre-service teachers, these qualities are essential in deepening their understanding of both mathematical concepts and the art of teaching, enabling them to effectively impart knowledge to their students (Vecaldo, et. al., 2017). In line with the vision and mission of the Bohol Island State University System, it is aiming to produce mathematics teachers graduates fully equipped with remarkable knowledge and high competence to prepare them in the field of teaching. Conversely, a mathematics teacher does not instantly attain these skills in mathematics that would facilitate their teaching practices and pedagogy. It requires continuous efforts to achieve such skills (Kaya & Karakoc, 2022). Although the assumption of developing mathematical ability needs to gain more experience in teaching (Murphy et al., 2021), the researchers believed that pre-service teachers would know about the concept of pedagogy content knowledge as a measure of mathematical ability and try to seem sensible of it through their perseverance and passion in order to be ready for their future teaching profession.

Therefore, the researchers designed this study to probe the potential connection between grit and mathematical ability of the pre-service teachers of the Bohol Island State University System.

To achieve the above aim, this study sought to answer the following questions:

1. What is the grit level of the pre-service teachers as to:

    1.1 Perseverance of effort

    1.2 Consistency of interests and,

    1.3 Time spent in accomplishing the mathematics ability questionnaire?

2. What is the profile of the mathematical ability of the mathematics pre-service teachers in terms of pedagogy content knowledge?

3. Is there a significant correlation between the grit and mathematical ability of the mathematics pre-service teachers?

4. What subscale/s and variable of grit is/are indicator/s of the mathematics pre-service teacher's mathematical ability?

5. What model can be developed based on the findings of the study?

1.1. Theoretical basis

In order to explore the possible connection between degrees of mathematics pre-service teachers' grit and their mathematical skills, the theory of growth mindset by Dweck (2006) was critical in this research study. This theory connects the belief that abilities and skills are not permanent, but can be based upon the influence of the environment. "Growth mindset", a term coined by Dweck (2006), which an individual considered the acquisition of skill and ability, was only a starting point so it can be further enhanced through hard work and passion. On the other hand, the fixed mindset, as she also termed, contrast the previous one in which these same assets are assumed to be fixed at birth and still remain constant throughout life.

Moreover, she emphasized that people with growth mindset would value effort and hard work as well as see failure as a sign and a tool for more effort to extend needed for success in teaching career, but those who see failures and disappointments as

struggles as well as viewing hard work as a negative, believing that extending hard work degrades their innate abilities were those individuals who possess fixed mindset. In one of her studies, she further distinguished between the mindsets towards the primary and secondary school teachers. At the end of the research, she concluded that those teachers who exert effort harder and longer compared to other group of teachers began to display growth mindsets, which means that setbacks were no longer saw as disappointments, the challenges were encompassed as well as their skills in teaching were improved. However, the other group prompted to show indications of having fixed mindsets like dreading failure, evading risks and finally even showing doubt about their own competency.

This theoretical construct was based on the belief that mathematical ability can be influenced and developed based on the degree of effort exert and passion in teaching experiences (Duckworth, 2016). Additionally, mathematics pre-service teachers with a growth mindset believe that their mathematical skills and abilities are not pre-planned; rather, they are able to make choices to develop their skills and they can make those choices based upon their perseverance and passion (Hoerr, 2017). There is more to mathematical skills than intelligence and an additional part of the puzzle is the belief that in the face of difficulties, one can still succeed in developing such mathematical skill or ability in teaching mathematics (Duckworth, 2016). The concept of improvement, in spite of failing; the perseverance to "shake it off" and start over again requires a growth mindset and the belief that one can achieve based on decisions that continue the opportunity to grow.

According to Duckworth et al. (2007), grit is operationalized as scale consisting of two (2) sub-constructs: the perseverance of effort and the consistency of interest. Working collaboratively, the perseverance of effort viewed as the proclivity to overcome initial failures to achieve long-term goals, skills and abilities, while consistency of interest focuses on pursuing the same goals across time.

Grit as defined as "perseverance and passion for long-term goals". Also, it is a key factor in determining the intellect and the success (Sigmundsson et al., 2020). Synchronously, West et al. (2016), and Akos and Kretchmar (2017) have emphasized that a non-cognitive and non-academic grit is much more reliable and significant predictors of achievement. Likewise, there is much more effective than academic scores for explaining the individual's achievement in life, career or profession, and that is grit (Duckworth & Quinn, 2009, Beyhan 2016).

These facets theoretically work together to influence an individual's attitude and behavior towards long-term goals. One of the attractive features of grit is the lack of correlation with other measures of intelligence and that it is a trait that can be potentially changed (Duckworth, 2016; Duckworth et al., 2007). Consequently, grit can theoretically help all students succeed. Previous research has correlated grit with outcomes like persistence in higher education and success in achieving long-term skills (Duckworth, et al., 2007; Duckworth & Quinn, 2009). However, the grit concept has been criticized from a variety of perspectives (Ris, 2015; Credé et al., 2017).

To make this investigation unique, a distinctive feature of this study is the incorporation of time as a crucial measure of grit. Previous studies, such as those by Duckworth et al. (2007) and Duckworth and Quinn (2009), have operationalized grit primarily through the perseverance of effort and consistency of interest. However, these studies did not explicitly consider the temporal dimension of grit. By integrating time, this study acknowledges that the development and manifestation of grit are not static but dynamic processes that evolve over time. This perspective allows for a more nuanced understanding of how grit influences the acquisition and enhancement of mathematical abilities among pre-service teachers.

Despite criticisms regarding the concept of grit, new research by Duckworth (2016) suggests that there is a certain progression in regard to how grit is acquired. It is noted that since there appears to be a sequence, that grit must, to some degree, be environmentally developed. Individuals develop the factor of "interest" prior to other components. Interest begins with determining what provides passion and is different for each individual.

By targeting pre-service teachers as the main participants in this study, it could fill a critical gap in the literature. It provides insights into how the development of grit during the formative years of teacher training can influence future teaching efficacy and potential career success. This focus is particularly relevant for the preparation of future mathematics educators, as it addresses the early stages of professional development that would lead to a validated model that can be used by teacher

training programs to design interventions that foster grit and ultimately enhancing the mathematical abilities and teaching effectiveness of pre-service teachers.

As deliberated from the study of Duckworth and Quinn (2009), the concept of grit concealed the prominence of hard work and passion to accomplish tasks even if the circumstances are challenging and at some point, also not interesting (Usher et al., 2018). If teachers never encountered failure and never been face up to challenges in their teaching profession, they would not be able to enhance their endurances that are needed to strive as well as the perseverance and motivation in challenging conditions (Dweck & Master, 2009). Hence, individuals with a high degree of grit will work tirelessly to overcome obstacles in the way of their goal of obtaining skills in teaching mathematics as well as success in their teaching career. Thus, grit is necessary to prepare mathematics pre-service students to develop their mathematical skills for careers that have not been created.

2. MATERIALS AND METHOD

2.1. Research design

The study mainly employed a descriptive-correlational method. Bhat (2020) defined descriptive correlational research as a type of research design that tries to explain the relationship between two or more variables without making any claims about cause and effect. Concerning the current study, this research design is appropriate to assess and describe the mathematics pre-service teachers' level of grit and mathematical ability, as well as how they are related to each other.

2.2. Research Instrument

A 12-item Grit-O scale questionnaire established by Duckworth et al. (2007) was employed in this study comprising two subscales: Perseverance of Effort and Consistency of Interests. To construct a composite measure of the pre-service teachers' perceived level of Grit, the responses of the participants were averaged, with reverse coding applied as needed.

The participants' mathematical ability was measured using the Kilic (2010) and 2017 Metrobank-Mathematics Teachers Association of the Philippines-Department of Education (MTAP-DepEd) Math Challenge questionnaires. The 14-item Kilic (2010) questionnaire comprised the situational problems that would reflect how the pre-service teachers analyze, articulate and solve some mathematical issues, misconceptions and difficulties in mathematics class and the twenty (20) items mathematical problem-solving tests are from MTAP-DepEd 2017. The statements and problems were made and used to embody the Pedagogy Content Knowledge (PCK) as a measure of mathematical ability. Total time spent working on accomplishing this instrument was added as an additional variable as the measure of grit (La Voie, 2017).

For content validity and cross-checking to see if the items were aligned with the specific problems of the study, the researchers presented the questionnaires to the adviser and to the panel of experts in the mathematics department. Further, pilot testing was administered to the random mathematics pre-service teachers of the selected private higher institutions in the province. Through Confirmatory Factor Analysis and Cronbach's alpha test, the items were tested, and the results showed that the survey instrument was considered valid (Grit-O scale: p-value = 0.000, CFI = 0.996, TLI = 0.995, and; Mathematical ability: p-value = 0.000, CFI, 0.991, TLI = 0.970), and the higher values of alpha made these items more reliable (raw $\alpha = 0.97$ and 0.95, respectively). Thus, the instrument is considered valid and reliable.

2.3. Research participants

Participants in this study were fourth-year undergraduate students of the degree program Bachelor in Secondary Education major in Mathematics (BSEd – Mathematics), commonly termed "mathematics pre-service teachers", of Bohol Island State University System. There was a total of one hundred two (102) mathematics pre-service teachers who were officially enrolled across all five (5) campuses purposively selected in this study. The total enumeration sampling method was employed, since gathering information from the entire population often provides deeper insights into the target group than partial samples can achieve (Lavrakas, 2008). This comprehensive approach allows the researchers to create a more complete picture and significantly reduces guesswork. It also eliminates the risk of biased sample selection commonly found in random samples. The Table below shows the distribution of study participants.

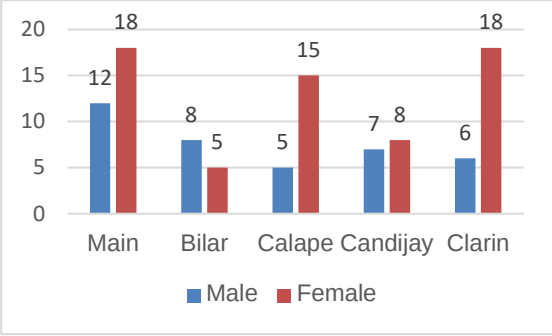

Figure 1. Distribution of the Mathematics pre-service teachers of BISU across five (5) campuses

2.4. Research Ethics

The researchers followed the ethical standards and guidelines set by the university's Research and Development Office and showed the necessary ethical issues. All means of communication were given to the research participants and partner institutions to guarantee consent for the conduct of the study and thus observe ethics in the behavior of the research. Consent letters were sent to the University President and Campus Directors of the main and satellite campuses affixing their approval in the conduct of the study. Upon approval, consent forms were also given to the participants to demonstrate voluntary participation in the study. Information confidentiality was rigorously followed because humans were chosen to take part in the study to guarantee the preservation of the rights, dignity, and privacy of the respondents.

2.5. Data analysis

After the data needed was collected, the Microsoft Excel was used since it was explicitly designed for a general-purpose spreadsheet program that would help easily input and organize the data needed, and the file that would be saved could be imported to the Minitab 17 software for further statistical testing. The weighted mean, Pearson r correlation and multiple regression analysis through Minitab 17 software would be used to analyze data and find relationships between variables. This feature is particularly useful for researchers who want to study the effect of one or more independent variables on a dependent variable. Also, it has a feature that can be used to determine if the measurement system can measure the actual value of a product or if there is bias in the system.

3. RESULTS AND DISCUSSION

3.1. Results

The following tables present a comprehensive analysis of the grit levels and mathematical ability of mathematics pre-service teachers within the BISU System. The tables provide insights into various aspects of grit and its correlation with mathematical ability.

Table 1 shows the weighted means and interpretations for statements related to perseverance of effort among mathematics pre-service teachers.

Table 1. Grit level of the Mathematics pre-service teachers as to perseverance of effort

Statements	WM	DV	Interpretation
I am a hard worker.	3.18	ML	Most likely gritty
I finish whatever I begin.	3.15	ML	Most likely gritty
I am diligent. (I consistently put forth effort to do things well)	3.02	ML	Most likely gritty
I have overcome setbacks to conquer an important challenge.	3.00	ML	Most likely gritty
Setbacks don't discourage me.	2.96	ML	Most likely gritty
I have achieved a goal that took years of work.	2.93	ML	Most likely gritty
Composite mean	**3.04**	**ML**	**Most likely gritty**

Legend:

Scale	*Description*	*Interpretation*
3.26 – 4.00	*Very much like me (VL)*	*Extremely gritty*
2.51 – 3.25	*Mostly like me (ML)*	*Most likely gritty*
1.76 – 2.50	*Not much like me (NL)*	*Not much gritty*
1.00 – 1.75	*Not like me at all (NA)*	*Not at all gritty*

It presents that statement "I am a hard worker." got the highest weighted mean of 3.18 with a description of "mostly like me". Also, the statement "I have achieved a goal that took years of work." obtained the lowest weighted mean of 2.93 with a description of "mostly like me". Overall, the composite mean is 3.04 with an interpretation of "most likely gritty". This signifies that the mathematics pre-service

teachers of the BISU System show high perseverance level for long-term goals but can be discouraged by setbacks.

Table 2 highlights the consistency of interest among mathematics pre-service teachers, measured by their ability to maintain focus on long-term goals despite potential distractions.

Table 2. Grit level of the Mathematics pre-service teachers as to consistency of interest

Statements	WM	DV	Interpretation
I often set a goal but later choose to pursue a different one.*	2.78	ML	Most likely gritty
I have been obsessed with a certain idea or project for a short time but later lost interest.*	2.63	ML	Most likely gritty
I have difficulty maintaining my focus on projects that take more than a few months to complete.*	2.55	ML	Most likely gritty
My interests change from year to year.*	2.51	ML	Most likely gritty
New ideas and projects sometimes distract me from previous ones.*	2.32	NL	Not much gritty
I become interested in new pursuits every few months.*	1.91	NL	Not much gritty
Composite mean	**2.45**	**NL**	**Not much gritty**

*items with * are reverse coded*

Legend:

Scale	*Description*	*Interpretation*
3.26 – 4.00	*Very much like me (VL)*	*Extremely gritty*
2.51 – 3.25	*Mostly like me (ML)*	*Most likely gritty*
1.76 – 2.50	*Not much like me (NL)*	*Not much gritty*
1.00 – 1.75	*Not like me at all (NA)*	*Not at all gritty*

As shown in the table, the statement that has the lowest mean score of 1.91 having a description of "not much like me" is the reversed of the statement "I become interested in new pursuits every few months." On the other hand, the statement that got the highest mean score of 2.78, with a description of "mostly like me", is the reversed of the item "I often set a goal but later choose to pursue a different one." In general, the composite mean is 2.45 with an interpretation of "not much gritty". This indicates that the mathematics pre-service teachers are distinguished by having low passion for long-term goals and they can easily be discouraged by setbacks.

Figure 2 presents the distribution of the grit level of the mathematics pre-service teachers of BISU as to the time spent in accomplishing the pedagogical content knowledge (PCK) questionnaire and mathematical word problems.

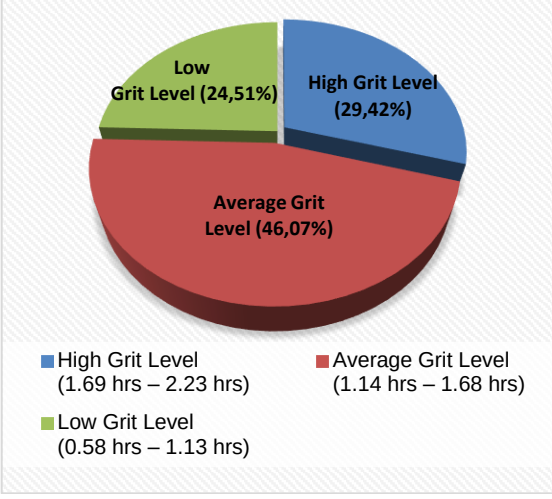

Figure 2. Grit level of the Mathematics pre-service teachers as to time spent in accomplishing the mathematics ability questionnaire

The figure shows that the majority of BISU mathematics pre-service teachers (46.07%) spent between 1.14 and 1.68 hours on the task, this duration reflects a moderate degree of sustained effort and focus on a particular goal or activity suggesting that these pre-service teachers exhibit an average level of grit in their academic tasks as reflected on the time they spent in answering the pedagogy-content knowledge (PCK) questionnaire. Over this period, in greater perspective also indicates a steady and unwavering interest and persistence in their mathematical studies.

Figure 3 categorizes the mathematical ability of mathematics pre-service teachers based on their scores in the pedagogy-content knowledge

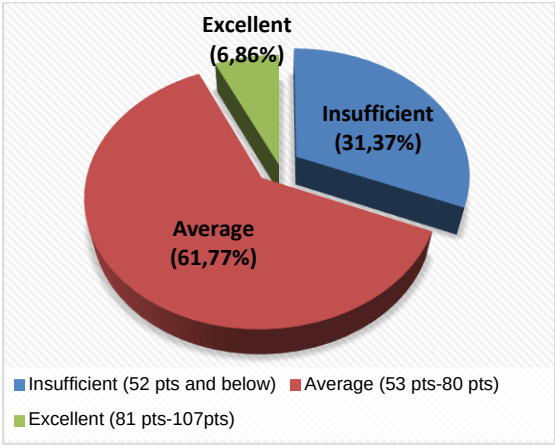

Figure 3. Profile of the mathematical ability of the mathematics pre-service teachers in terms of pedagogy content knowledge

This shows that the majority of the mathematics pre-service teachers of BISU system (61.77%) have an average level of mathematical ability based on the scores they obtained. Meaning, they have an average mathematical ability in terms of pedagogical content knowledge in teaching mathematics and through solving given mathematical problems.

Table 3 explores the relationship between grit and mathematical ability.

Table 3. Correlation between Grit and Mathematical Ability

	Mean	SD	r	p – value
Grit	2.81	0.296		
Mathematical Ability	59.52	14.86	0.349	0.000*

**p < 0.05*

As reflected, it can deduce the existence of a significant moderately positive correlation between grit and mathematical ability of the mathematics pre-service teachers of the BISU system ($r = 0.349$, $p < 0.05$). It is also reflected from the results of their means and SD's, "most likely gritty" level of grit ($\bar{x}$=2.81,SD=0.296) implies an "average" mathematical ability ($\bar{x}$=59.52,SD=14.86). In short, the more grit improved, the more the mathematical ability is affected in a positive way.

Table 4 presents the results of a multiple regression analysis to identify the impact of grit subscales and time spent on mathematical ability.

Table 4. Multiple regression analysis of grit subscales and variable on mathematical ability

Source	Df	Adj SS	Adj MS	F-Value	P-Value
Regression	3	4923.6	1641.2	9.25	0.00*
Perseverance of Effort	1	2528.7	2528.7	14.25	0.00
Consistency of Interest	1	256.1	256.1	1.44	0.23
Time Spent	1	1268.5	1268.5	7.15	0.01
Model Summary:		*R= 0.4698*		*R^2= 0.2207*	
	Coef	***SE Coef***	***T-Value***	***P-Value***	
Perseverance of Effort	14.63	3.88	3.78	*0.00**	
Consistency of Interest	3.37	2.80	1.20	*0.23*	
Time Spent	8.73	3.27	2.67	*0.01**	

**p < 0.05*

As reflected in table 6, the results of multiple regression analysis were given to determine the possible indicators of the mathematics pre-service teachers' mathematical ability from grit subscales and variable. The model has been estimated to have a positive and moderate correlation among variables (R=0.4698) and was found out to be significant, $F(3,102) = 9.251$, $p = 0.000$. As a whole, it explained approximately 22.07% of the variance in mathematical ability ($R2 = 0.2207$). This means that grit is a significant indicator of the mathematical ability of the mathematics pre-service teachers.

The model generated in this research undertaking, as shown in Figure 4, developed from the findings of the study that had been discussed and validated.

Emergent Model Generated

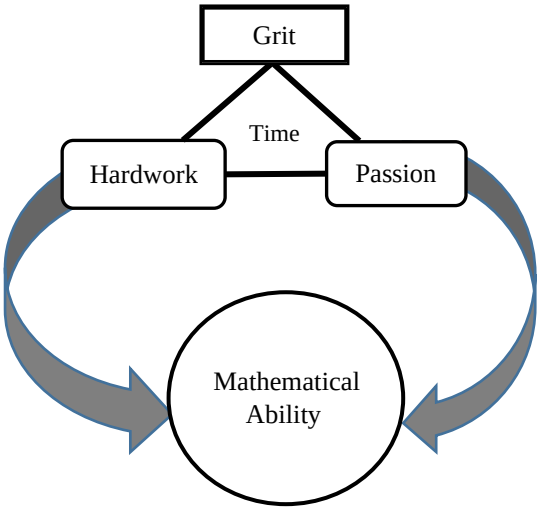

Figure 4. "Hard work and Passion" (HP) Model

This model illustrates that in order to develop the basic skills like the mathematical ability of mathematics pre-service teachers, they should demonstrate hard work and passion for improving proficiency in content knowledge and having well-founded pedagogical skills in mathematics. Passion and hard work fuel and motivate mathematics pre-service teachers toward specific goals, most notably teaching career success, and improving their skills in both the art of teaching and knowledge of mathematical content, regardless of the challenges they face. This combination creates the eagerness and persistence necessary to overcome the largest obstacles and the most stubborn trials they may encounter in the real field of teaching.

The model emphasizes that hard work and passion, as key components of grit, do not emerge on their own and must be actively cultivated. Additionally, the amount of time spent on tasks is integral to this process. The more time pre-service teachers dedicate to deliberate practice, the more they can set goals that push beyond expected limits and work meticulously toward their desired achievements in enhancing their mathematical skills and teaching careers. Time spent practicing and refining these skills is crucial in developing the consistency of interest and perseverance of effort required for long-term success in their professional journey.

3.2. Discussions

Perseverance of effort

Mathematics pre-service teachers, regardless of their intelligence, are demonstrating high levels of perseverance of effort to achieve higher academic ratings and excel in their student teaching tasks. This signifies a strong level of perseverance, essential for reaching and achieving long-term goals, particularly in their future teaching careers. Hoberecht (2017) supports this by noting that, when controlling for IQ, most students exhibit hard work and diligence, dedicating their best efforts to meet school requirements. However, their persistence is often directed toward short-term goals, which can serve as building blocks for achieving long-term ambitions. Ericsson (2016) emphasizes that stating with short, well-defined goals, believing in full effort, seeking immediate and specific feedback, and adjusting based on this feedback are crucial steps. Highly determined individuals approach problems analytically and work diligently (Willis, 2008). It further implies that the mathematics pre-service teachers showed a high level of persistence and resilience, indicating that they continue to pursue their teaching career goals despite challenges, setbacks, disappointments, failures and hardships (Kaya & Yüksel, 2013; Hoer, 2017). However, there exist also unexpected finding that the persistence observed was more oriented toward short-term goals rather than long-term ones. This suggests that, while pre-service teachers are diligent, they may need more support in setting and pursuing long-term goals.

Consistency of interest

When mathematics pre-service teachers set goals, they maintain their interest and focus on achieving them. Interest, which varies for each individual, starts with identifying what ignites passion and is sustained by continuously following this path over a long period. Duckworth (2016) suggests that maintaining long-term passion and interest requires recognizing the capacity needed for sustained effort. However, achieving goals often demands significant drive and motivation, leading teachers to set easier objectives initially. This result may be attributed to the situations and the level of difficult conditions they faced and encountered (Dumfart & Neubauer, 2016). Researchers observed that many pre-service teachers do not solely focus on becoming professional mathematics teachers due to perceived challenges which may hinder their concentration. Pursuing seemingly unsolvable or near-impossible

tasks can lead to dissatisfaction, suggesting that aiming for more attainable goals is often more beneficial (Dweck & Yeager, 2021). The researchers believed that many pre-service teachers were observed to shift their interest to easier goals due to the challenges of maintaining focus on becoming professional teachers, like passing board exams, which highlights this finding as a potential barrier to achieving long-term teaching goals.

Time Spent as a Variable of Grit

This finding underscore pre-service teachers who are persistent and maintain strong interest in tackling mathematical problems tend to invest more time and effort, leading to improved problem-solving skills and overall competence in mathematics. It further implies that mathematics pre-service teachers can estimate the time they think they spent according to the difficulty of the mathematical problems and issues. The current finding also supports the study of Crede, Tynan and Harms (2016) stating that students can assess their working time in answering the mathematical ability questionnaire as to its level of difficulty. They also believed that they are pursuing and surpassing obstacles more diligently than they actually were. Mathematics pre-service teachers that have higher Likert scores in the area of perseverance are predictive of higher time spent on mathematical word problems (Kaya & Karakoc, 2022). Similarly, mathematics pre-service teachers at BISU System who value spending more time and working hard actually do spend more time on mathematical problems, contributing to the development of their skills in teaching mathematics. However, there was a discrepancy between pre-service teachers' perceived and actual diligence in overcoming obstacle, suggesting an overestimation of their efforts. Incorporating assignments that require effective time management, giving pre-service teachers opportunities to practice and refine these skills.

Mathematical Ability in terms of Pedagogy-Content Knowledge (PCK)

The current result is also attributed to the reasons of the mathematics pre-service teachers themselves. they already forgot the subject content as well as the pedagogy-based application thus, they found difficulty in explaining how mathematical concepts are related to content as well as assessing the students' mathematical misconceptions and errors Another reason also was, they were not able to teach mathematics subjects during their field teaching experience due to insufficiency of vacancies for teaching mathematics but they taught other subjects instead of their field of expertise. This then implies that the pre-service teacher mentors and supervisors should organize a plan that will provide teaching experiences to realize the knowledge content and pedagogy of the mathematics pre-service teachers, and constantly provides feedback that will help them persevere and be motivated in teaching their field expertise. In the same way, Guo (2024) found out that having an average to a greater level of mathematical ability is truly necessary in order to become productive and prepared in teaching mathematics subjects. Thus, it is also recommended that more persistence will be exerted, and mentors should give the pre-service teachers more clear advice and criticisms about their performance and instructional choices in order for them to extend extra efforts, maintain drives and concentration and improve their subject content and pedagogical skills in teaching mathematics.

Relationship of Grit and Mathematical Ability

Mathematics pre-service teachers with higher levels of grit tend to have significantly higher mathematical ability. This correlation is attributed to their extended efforts and sustained interest in becoming productive professional mathematics teachers, coupled with their excitement to teach in the near future. When pre-service teachers focus on developing their mathematical skills in terms of pedagogy content knowledge, they may encounter temporary difficulties or experience moments where their resolve is tested. However, despite these challenges, those who are determined often achieve success in their teaching careers (Hill et al., 2014). Gritty pre-service teachers are more likely to persist and succeed in their teaching careers (Bowman et al., 2015; Duckworth et al., 2007; Clark & Malecki, 2019). Wong & Chapman (2024) also found a positive relationship between grit and teaching content and pedagogy among secondary mathematics pre-service teachers, with these associations being stronger when measured concurrently. Eteng-Uket and Ezeoguine (2024) further recommended assessing grit while pre-service teachers are actively engaged in their courses to better understand the relationship between grit and mathematical skills.

Grit is a significant indicator of the mathematical ability of mathematics pre-service teachers. This suggests that the sustained efforts and concentration of these pre-service teachers, even in the face of

disappointments, failures, and hardships, can determine their mathematical skills, including their pedagogy content knowledge, which is crucial for their future teaching careers. Akın and Arslan (2014) concluded that pre-service teachers' grit predicts their mathematical teaching skills and overall success in their teaching careers. Thus, the determination and eagerness of mathematics pre-service teachers to teach in the future, despite adversities and unexpected circumstances, create a clear path leading to a successful teaching career (Bazelais et al., 2016).

Among the three independent variables studied, only Perseverance of Effort and Time Spent were found to be significant indicators of mathematical ability. This indicates that the positive impact of perseverance on mathematical ability implies that mathematics pre-service teachers who are determined and passionate about fulfilling long-term goals are more likely to become professional mathematics teachers and actively teach in the near future. Consistent with La Voie's (2017) predictions, the Perseverance of Effort (PE) subscale emerged as significant in relation to pedagogy content knowledge, while Consistency of Interest (CI) did not. Additionally, the positive impact of time on mathematical ability suggests that when pre-service teachers encounter problems, hardships, and challenges, they persist with the task and carefully assess their time to overcome these obstacles. LaVoie (2017) found that the time spent on mathematical tasks significantly predicts the mathematical ability of primary mathematics pre-service teachers.

However, although grit is an indicator of the mathematical ability of mathematics pre-service teachers, its effects were not attributed to the consistency of interest (Bowman et al., 2015). This finding suggests that an individual does not need to maintain constant interest in achieving long-term goals to be considered gritty. It is likely that gritty mathematics pre-service teachers in an interdependent context can remain passionate about accomplishing long-term academic and important life goals even without steady interest in these goals, as they possess cognitive styles that enable them to manage multiple and conflicting interests (Datu et al., 2015; Dangkulos et al., 2024).

Even if a mathematics pre-service teacher encounters stressful circumstances and troubles, this resistance manifests as a distinctive power combined with a passion that drives them to develop their mathematical skills. Despite difficulties and unwanted judgments, grit involves continuous hard work and passion. Mathematics pre-service teachers with higher levels of grit do not feel tired and continue to struggle through undesirable circumstances, pursuing the development of their skills where others may have already given up.

The findings of this study have several practical implications for teacher education. First, teacher education programs should implement mentoring and goal-setting workshops to help pre-service teachers set and achieve long-term goals. Resilience and perseverance training should be provided to help pre-service teachers maintain their efforts over extended periods, which is essential for their future careers. Additionally, practical time management training should be included to align pre-service teachers' perceptions with their actual practices, enhancing their effectiveness. Providing robust support systems, such as board exam tutoring and stress management workshops, can help pre-service teachers maintain their interest in long-term goals.

For educators, personalized support and feedback should be offered to pre-service teachers to help them navigate challenges and stay motivated. Grit training should be integrated into the curriculum, focusing on perseverance, time management, and resilience. Policymakers should allocate funds to develop support programs, such as mentoring and resilience workshops, to aid pre-service teachers in maintaining their career focus. Implementing policies that emphasize the importance of grit in teacher education programs will ensure that teacher training institutions prioritize these aspects, ultimately contributing to better educational outcomes.

Unexpected findings, such as the lack of significant impact of consistency of interest on mathematical ability, highlight the need for further research to understand how pre-service teachers can balance multiple interests while maintaining their commitment to long-term goals. These findings also suggest that teacher education programs should focus more on developing perseverance and effective time management skills rather than solely on fostering consistent interest. Future studies should examine also the long-term career outcomes of pre-service teachers with high levels of grit on a wider scope of participants for better generalization of the study. Understanding how grit influences career progression, job satisfaction, and professional development in teaching could provide

valuable insights for educator preparation programs. By addressing these unexpected findings and their implications, teacher education programs can refine and improve their approaches to better prepare pre-service teachers for their future careers.

4. CONCLUSIONS

Grit has a direct positive impact as well as an indicator of the mathematical ability of the mathematics pre-service teachers. Therefore, the Mathematics pre-service teachers of Bohol Island State University System showed higher level of grittiness and it was also an indicator of their mathematical ability. Also, students who value time are crucial in developing the consistency of interest and perseverance of effort required for long-term success, which would lead toward their desired achievement in their mathematics teaching careers. With an emergent model that has been generated called as "HP Model", this study could be of great help for educators and policy makers to develop mathematical abilities through hard work and passion over time being exerted. To realize this model, it is highly recommended that teacher education institutions may assess the grit level of the mathematics pre-service teachers as well as may incorporate programs and seminars on how to be grittier to enlighten them up to strive for success in their teaching career.

CONFLICT OF INTEREST

The researchers confirmed that there are no conflicts of interest.

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