Analysis of Gender Difference of Factors Affecting Academic Performance of Mathematics Doctoral Students

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Abstract
This study aimed to investigate the gender differences in the factors affecting the academic performance of mathematics doctoral students. A total of 147 participants were surveyed using a questionnaire that included items such as fear of delay, doctoral student engagement, support from parents and teachers, facilitating conditions, stress levels, and well-being. this study aimed to investigate the impact of various factors on the academic performance of mathematics doctoral students and whether there were any gender differences in these factors. Structural equation modeling (SEM) and Multiple group analysis approach were adopted to analyze the questionnaire data. The results showed that the fear of being delayed did not have a significant impact on the academic performance of doctoral students in mathematics, but it did heighten their stress levels. The level of engagement of students had a positive impact on their academic performance, and teacher support had a significant impact on academic performance, particularly for male students. However, there were no significant gender differences in the factors affecting academic performance. These findings suggest the importance of creating a supportive environment and promoting student engagement to enhance academic performance. The study's findings also have practical implications for institutions, supervisors, and parents seeking to enhance the academic performance of different-gender doctoral students.

Keywords: Academic Performance, Mathematics Ph.D. Students, SEM

Introduction: Analysis of Gender Difference of Factors Affecting Academic Performance of Mathematics Doctoral Students

The OECD reported in 2015 that women made up almost half of all doctoral students in their jurisdiction. While the number of female doctorate recipients has been increasing, the field of mathematics remains an exception to this trend (Su & Rounds, 2015). It has been historically believed that gender differences in math Ph.D. participation and achievement were due to differences in ability or interest (Charles, 2011). However, research in the US and Sweden has shown no differences in math performance between boys and girls in primary, middle, and high school (Brandell et al., 2007). This conclusion was also supported by a meta-analysis of international assessments in math. Despite this parity in performance, there is still a significant gender gap in female participation in Ph.D. studies and beyond, leading to the so-called “leaky pipeline” phenomenon (Else-Quest et al., 2010; Moss-Racusin et al., 2012).

It is extremely difficult to attain academic achievement in doctoral studies, resulting in a significant number of dropouts and low satisfaction levels among students pursuing a doctorate degree (Zhang et al., 2022). So, there is many research focusing on digging deeper on doctoral students’ academic performance. Most previous studies measured students' academic performance in terms of the number of high-quality publications and the time to complete the Ph.D. program (Ceci et al., 2009). Few studies have used process evaluation to assess student academic performance. Comparative studies have shown an increase in doctoral education in East Asia, as reported by Shin and his colleagues (2018). However, these studies have mainly focused on developed countries and have not given much attention to developing countries. So, It is important to identify gender-based differences in factors that affect the performance of mathematics Ph.D. students in order to offer improved assistance or aid for postgraduate students in other East Asian settings.

Literature Review

There are many research explained gender-based performance differences in Ph.D. students (Brandell et al., 2007; Heffron et al., 2021; Wan Chik et al., 2012). Most previous studies measured students' academic performance in terms of the number of high-quality publications and the time to complete the Ph.D. program. Fisher and his team found that the women included in their study finished their Ph.D. training approximately six months later than their male peers and published about one paper less during their doctoral studies. It also has been observed that males have a higher probability of completing their studies compared to females (Strayhorn, 2005; Wao & Onwuegbuzie, 2011).

However, Previous studies have not fully considered the intricacies of attaining a postgraduate degree when examining the factors that facilitate the success of doctoral students. Bagaka and colleagues (2015) have argued that the “All But Dissertation” approach undermines the true objectives of successful doctoral programs, which should prioritize factors such as mastery of material, commitment to excellence, writing and communication skills, study skills, knowledge of professional literature, and critical thinking abilities.

Other research has also suggested that women's academic performance can differ significantly depending on the field of research (Ceci et al., 2009; Su & Rounds, 2015). While previous reports have focused on doctoral students from different fields, such as kinesiology (Young et al., 2019), STEM (Fisher et al., 2020), communication (Carpenter et

al., 2015), and education (Spaulding & Rockinson-Szapkiw, 2012). There is still limited literature on mathematics postgraduates.

In conclusion, the objective of this research is to investigate and identify whether there is gender difference that impact the academic progress of doctoral students in mathematics. A survey was conducted on 147 postgraduate students from Indonesia, and a range of quantitative analysis methods were utilized, including structural equation modeling.

Theoretical Background

Doctoral Academic Performance Indicators

Researchers in the field of higher education have made numerous efforts to examine the academic performance of doctoral students. Recent studies have focused on different indicators of success, such as attrition rates (Castelló et al., 2017; Leijen et al., 2016), retention rates (Ames et al., 2018), completion rates (Bekova, 2021), and on-time graduation (Ndayambaje, 2018). Although these indicators are reasonable, some scholars (Bagaka et al., 2015) have argued that success in doctoral education should also focus on the competencies of postgraduates as scholars, their knowledge of specific areas, and their personal abilities. The definition of academic success at the doctoral level varies across different subjects, and a comprehensive definition of doctoral success is highlighted as a combination of internal and external factors.

To provide a comprehensive assessment of doctoral students' academic performance, multiple indicators are prioritized instead of solely relying on degree completion rates. According to Olehnovice's (2015) theories, academic competence can be divided into three categories:

- F1: Informative competencies: determine structure, content, and strategy of experiments or research.
- F2: Communicative competencies: the ability to collaborate and participate in the academic environment, both locally and globally.
- F3: Instrumental competencies: determine the appropriate procedures and patterns of interpretation for data.

Factors Affect Ph.D. Student Academic Performance

Numerous prior reports have investigated various factors that influence academic success of postgraduate students, highlighting the complex core of doctoral studies (Leijen et al., 2016) Wollast et al., 2018). Leijen and colleagues (2016) identified three categories of factors that contribute to doctoral students' progress, including personal characteristics, supervisory arrangements, and the broader learning community. Castelló et al. (2017) also examined institutional and personal variables that affect doctoral students' dropout rates. Despite the importance of institutional support, family support was found to be a significant source of social support, particularly in East Asian countries where students have high levels of family support and comfort (Choi & Nieminen, 2013). In this study, the model focuses on various predictors that have been derived from previous theories, such as fear of delay, doctoral student engagement, support from parents and teachers, facilitating conditions, stress levels, and well-being. It is anticipated that these factors will have an effect on the academic achievement of mathematics doctoral students, and they are discussed in detail in the following paragraphs.

Student Engagement

Student engagement refers to the level of investment a student makes in their education, including time, energy, and cognitive efforts. The concept is broken down into: behavioral, cognitive, and emotional three perspectives. It is a crucial aspect that impacts a student's learning outcomes, grades, and accomplishments. At the K-12 level, student engagement is closely tied to academic success and educational abilities (Shuck & Reio Jr, 2014). In this study focused on mathematics doctoral students, engagement is defined as their ability to read literature, seek opportunities, collaborate with peers, create learning tools, discuss with mentors, conduct research, and publish results. Higher levels of engagement in these activities are believed to reduce stress and directly impact academic performance.

Parental Support

Previous studies (Mata et al., 2018) have consistently shown that parental support is strongly linked to student academic achievement and is a crucial factor in shaping their learning success. This type of support can impact a student's motivation to learn, attendance, and overall behavioral attitudes. It can be divided into two categories: academic and emotional support. Dityawati's meta-analysis (2019), revealed that receiving support from parents had a notable and favorable impact on the academic accomplishment of students. However, another study suggested that helping with homework and assisting with learning did not have a significant impact on educational abilities (Wu, 2001). Therefore, it appears that parental support does not always have a significant influence on a student's learning progress. The present research, which centers on mathematics doctoral students, hypothesizes that parental support will effectively decrease stress levels and enhance academic achievement.

Facilitating Conditions

Facilitating conditions are the circumstances that enable students to pursue a graduate degree and have access to individuals who can assist them in resolving academic issues. To improve the academic skills of these students, educational institutions should provide a variety of amenities, such as workshops and training sessions. Previous research (Wijaya et al., 2022) has indicated that facilitating conditions can indirectly impact student academic achievement during a pandemic by influencing their behavior. For this study, it is predicted that facilitating conditions will have a positive effect on well-being and improve their academic performance.

Teacher Support

Parental and teacher support are critical factors in determining students' abilities. Prior research conducted by Mata’s team (2018) explored the correlation between teacher support and academic success among students in elementary and secondary schools. In this particular study, teacher support refers to the suitable guidance given by mentors and professors to all postgraduate mathematics students. Since collaboration skills are essential in the 21st century, teacher support can also motivate doctoral students to work with professionals or peers, leading to significant improvements in their academic performance through mutual learning. Our hypothesis suggests that teacher support will have a constructive and noteworthy effect on the academic accomplishment and overall welfare of mathematics doctoral students.

Student Well-Being

Student well-being is a critical factor that affects various aspects of the academic world, including learning abilities, engagement, achievement, and teamwork capability (Ansong et al., 2020). It is important for educators to understand that student well-being significantly influences academic achievement (Mehta, 2011). In addition to preventing students from exhibiting problems such as stress and frustration, well-being also helps them grow and learn from educational challenges. The term “well-being” in this context is defined as the ability and resources to regulate emotions effectively and maintain a constructive and optimistic attitude while engaging in the learning process. Some institutional policymakers place a strong emphasis on student well-being during classroom learning, believing that students can only achieve maximum academic performance when they are educationally satisfied and supported (Pietarinen et al., 2014). This study predicts that facilitating conditions and teacher support on campus will influence student well-being and that it will be significantly and positively associated with the academic performance of mathematics doctoral students.

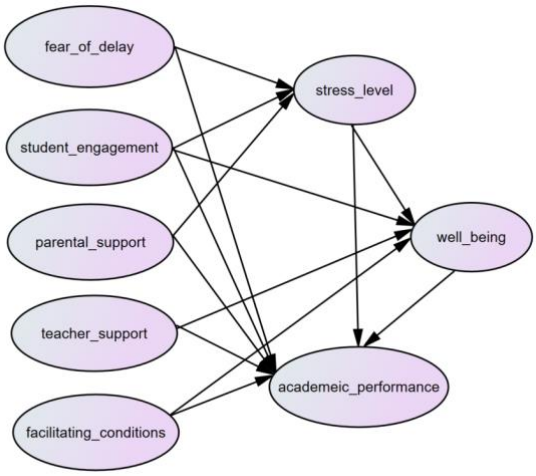
Stress Level

Stress has a great impact on a person's psychology (Salanova et al., 2010). Studies (Wang et al., 2021; Westphal et al., 2022) have explored the relationship between stress and academic performance due to its effect on students' health. Surprisingly, this study found that stress is rarely beneficial for individuals, which is consistent with existing literature (Abdullah et al., 2022; S. Liu & Onwuegbuzie, 2012). While stress can sometimes motivate people to learn more and improve their abilities, it can also have negative consequences on their overall well-being.

However, stress can also improve coping strategies that may be useful in solving other problems in the future. Despite this, the present study predicts that stress levels will significantly reduce the academic performance of mathematics postgraduates. Parent support and student engagement are predicted to reduce stress levels for doctoral students.

Based on the literature review, 14 initial hypotheses containing 5 independent, 2 intermediate, and 1 dependent variable are shown in Figure 1. Based on analysis above, this research tends to explore how do these factors impact the academic performance of male and female Ph.D. students and gender difference of factors affecting academic performance of mathematics doctoral students.

Figure 1: A Proposed Framework for Factors Affecting Mathematics Doctoral Student's Academic Performance



Methodology

Participants

There are 147 Indonesian mathematic doctoral students engaged in this study. The study informed consent from study participants. All the participants were provided with complete information regarding the study's objectives, methodologies, potential advantages, and risks, and they were given the chance to ask any questions and opt-out of the study at any given time. Table 1 provides detailed data of the participants.

Table 1: Demographic Respondents' Data

Demographics		N	Percentage
Gender	Male	59	40.14%
	Female	88	59.86%
Age	20–24 years old	41	27.89%
	25–29 years old	86	58.50%
	30 years old and above	20	13.61%
Academic year	First	23	15.65%
	Second	41	27.89%
	Third	52	35.37%
	Fourth year above	31	21.08%
Marital status	Married	91	61.90%
	Not yet Married	56	38.10%
Job status	Not Yet Working	119	80.95%
	Already Working	28	19.05%

Data Collection Tool and Procedure

Using Google Docs, a set of online questionnaires was created. The questionnaires was designed based on the literature review, which had a 5-point Likert scale ranging from strongly disagree (1) to strongly agree (5). All of the questionnaire items were taken from previous reports and were modified to fit the context of this study, ensuring that the questionnaire had good validity and reliability.

The questionnaire was reviewed by three professors before it was distributed to participants from August to September 2022. The questionnaire was randomly distributed through email, WhatsApp groups, and university professors. Participants were not compelled to fill out the questionnaire and were not required to provide their names, which ensured the anonymity of the data. The information obtained from the questionnaire was kept for study purposes only and was not disseminated. It took an average of 9 minutes to fill out the questionnaire.

The questionnaire used in this study had two parts. The first part collected basic information about the doctoral students, such as their gender, age, and academic year. The second part consisted of 27 measurement items that were taken from previous reports and focused on various factors including fear of delay, engagement, parental and teacher support, facilitating conditions, stress level, well-being, and academic performances.

Data Analysis

The data obtained were processed and analyzed using SPSS 23 and AMOS 26, Firstly, the data were initially assessed and sorted, with the descriptions of the participants carried out through SPSS 23. The subsequent phase of the study focused on analyzing the measurement model to verify its reliability and validity, with a particular emphasis on the Composite Reliability (CR), as well as the factor loading and AVE estimations. Furthermore, AMOS was used to apply structural equation modelling (SEM) which was more suitable for explaining the difference between gender difference of factors affecting academic performance. This study also examined the measurement invariance of the scale in male and female groups. The measurement invariance includes four aspects of invariance: configural invariance, metric invariance, scalar invariance, and strict invariance. When evaluating the measurement invariance, if the change in the RMSEA index is less than 0.01, it is considered as passing the measurement invariance test. So, we can say that the results (Table 2) of the measurement invariance test showed an acceptable result.

Table 2: Measurement Invariance Result

Model	χ^2	*df*	CFI	RMSEA	Model Compare	$\Delta\chi^2$	Δdf	*p*	ΔRMSEA
M1: Configural invariance	2487.42	866	0.63	0.16					
M2: Metric invariance	2635.76	928	0.61	0.16	M2−M1	147.94	62	< .001	−0.001
M3: Scalar invariance	2686.96	951	0.60	0.16	M3−M2	51.60	23	< .001	-0.001
M4: Strict invariance	2787.71	985	0.59	0.16	M4−M3	100.75	34	< .001	-0.001

Validity

The CMIN/DF value is 2.82 < 3, which indicates an acceptable fit (Kline, 1998). Comparative Fit Index also shows a very good fit (close to 1), (Hu & Bentler, 1999). (See Table 3 and Table 4).

Table 3: CMIN

Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	121	1145.89	406	0	2.82
Saturated model	527	0	0		
Independent model	62	280	465	0	6.88

Table 4: Comparative Fit Index

Model	NFI	RFI	IFI	TLI	CFI
Default model	0.642	0.59	0.74	0.69	0.73
Saturated model	1.00		1.00		1.00
Independent model	0.00	0.00	0.00	0.00	0.00

Analysis Measurement Model

Validity was tested by observing the value of factor loadings This was accompanied by the values of AVE and CR, which should be greater than 0.50 and 0.70 respectively. We can see that except for facilitating condition (0.434) and engagement (0.456), other factors have acceptable AVE value. Besides, the Composite Reliability exceeded the 0.70 limitation. Detailed results of analysis are provided in Table 5.

Table 5: Standardized Regression Weights

Indicator			Std. Estimate	AVE	CR
STRESS1	<---	Stress	0.822		
STRESS2	<---	Stress	0.908		
STRESS3	<---	Stress	0.798	0.523	0.837
STRESS4	<---	Stress	0.529		
STRESS5	<---	Stress	0.447		
WELL BEING1	<---	Well-being	0.678		
WELL BEING2	<---	Well-being	0.683	0.586	0.849
WELL BEING3	<---	Well-being	0.856		
WELL BEING4	<---	Well-being	0.828		
Facilitating Condition1	<---	Facilitacting-conditions	0.631		
Facilitating Condition2	<---	Facilitacting-conditions	0.550	0.434	0.700
Facilitating Condition3	<---	Facilitacting-conditions	0.550		
PARENTS1	<---	parents'support	0.312		
PARENTS2	<---	parents'support	0.872	0.620	0.807
PARENTS3	<---	parents'support	1.001		
FEARPOST1	<---	Fear of postpone	0.792	0.578	0.732
FEARPOST2	<---	Fear of postpone	0.728		

ACAPER1	<---	Academic performance	0.609		
ACAPER2	<---	Academic performance	0.806		
ACAPER3	<---	Academic performance	0.690	0.563	0.810
ACAPER4	<---	Academic performance	0.589		
ACAPER5	<---	Academic performance	0.686		
Teacher support1	<---	Teacher support	0.796		
Teacher support2	<---	Teacher support	0.720		
Teacher support 3	<---	Teacher support	0.838	0.586	0.876
Teacher support 4	<---	Teacher support	0.737		
Teacher support 5	<---	Teacher support	0.731		
ENGAGEMENT1	<---	Student Engagements	0.728		
ENGAGEMENT2	<---	Student Engagements	0.681	0.456	0.765
ENGAGEMENT3	<---	Student Engagements	0.778		
ENGAGEMENT4	<---	Student Engagements	0.477		

Result

Multiple group analysis in AMOS is a powerful tool for comparing models across different groups and identifying any differences that may exist (Byrne, 2016). So multiple group analysis was used to identify the differences between different genders. From Table 5, we can see that $P > .05$, indicating that the model is not significantly different on different gender groups.

Table 6: Multiple group analysis

Model	DF	CMIN	P	NFI	IFI	RFI	TLI
Structural weights	12	2.636	0.056	-0.004	-0.005	-0.004	-0.005

Figure 2 and 3 show the result of structural model of male and female. Table 7 and 8 show the results of regression weights of male and female, $p<.05$ means that the path is significant, and in the case of a significant path, a positive coefficient means that the independent variable has a significant positive effect on the dependent variable, and a negative coefficient means that the independent variable has a significant negative effect on the dependent variable.

Table 7: Result of male

			Estimate	S.E.	C.R.	P
Stress	<---	Fear of postpone	0.467	0.49	4.541	***
Stress	<---	Student Engagements	-0.132	-0.088	-0.837	0.403
Stress	<---	Parent support	-0.227	-0.144	-1.201	0.23
Wellbeing	<---	Teacher support	0.01	0.011	0.077	0.938
Wellbeing	<---	Facilitating conditions	1.046	0.955	5.668	***

Academic performance	<---	Fear of postpone	-0.058	-0.085	-0.939	0.348
Academic performance	<---	Student Engagements	1.251	1.163	3.03	0.002
Academic performance	<---	Parents support	-0.06	-0.053	-0.522	0.601
Academic performance	<---	Teacher support	0.521	0.512	2.26	0.024
Academic performance	<---	Facilitating conditions	-1.806	-1.388	-2.872	0.004
Academic performance	<---	Wellbeing	0.955	0.804	2.736	0.006
Academic performance	<---	Stress	-0.011	-0.015	-0.305	0.761

Table 8: Result of female

			Estimate	S.E.	C.R.	P
Stress	<---	Fear of postpone	0.542	0.103	4.541	***
Stress	<---	Student Engagements	-0.069	0.158	-0.837	0.403
Stress	<---	Parents support	-0.096	0.189	-1.201	0.23
Wellbeing	<---	Teacher support	0.007	0.124	0.077	0.938
Wellbeing	<---	Facilitacting conditions	0.867	0.185	5.668	***
Academic performance	<---	Fear of postpone	-0.132	0.061	-0.939	0.348
Academic performance	<---	Student Engagements	1.288	0.413	3.03	0.002
Academic performance	<---	Parents support	-0.05	0.115	-0.522	0.601
Academic performance	<---	Teacher support	0.499	0.231	2.26	0.024
Academic performance	<---	Facilitating conditions	-1.974	0.629	-2.872	0.004

Academic performance	<---	Wellbeing	1.259	0.349	2.736	0.006
Academic performance	<---	Stress	-0.022	0.036	-0.305	0.761

Through the comparison of the two results, for the factor stress, only fear of postpone had a significant effect on stress ($p < .001$), and the effect of fear of postpone on women's perceived stress was greater than the effect on men's ($0.542 > 0.467$), student engagement and parental support had no significant influence on stress. It seems like men's stress is more likely to be influenced by parental support. In terms of well-being, only facilitating conditions had a significant effect ($p < .001$). There was almost no difference between male and female in terms of the effect of teacher support on well-being.

In terms of the dependent variable of academic performance, student engagement, teacher support, facilitating conditions, and well-being have a significant impact on academic performance. Among them, facilitating conditions have a negative impact on academic performance, while the others have a positive impact. Student engagement, facilitating conditions, and well-being have a greater impact on female academic performance than on male academic performance, while teacher support has a greater impact on male academic performance.

Figure 2: Structural Model Evaluation Result for Male

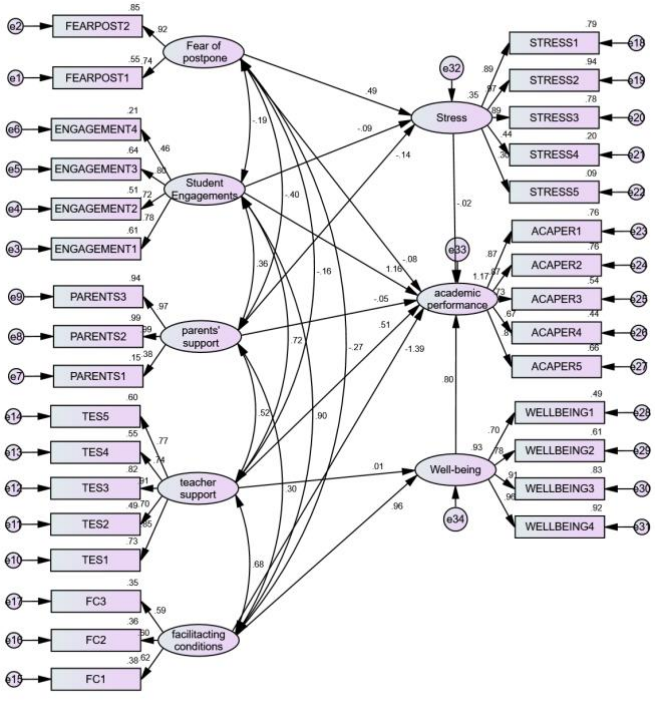
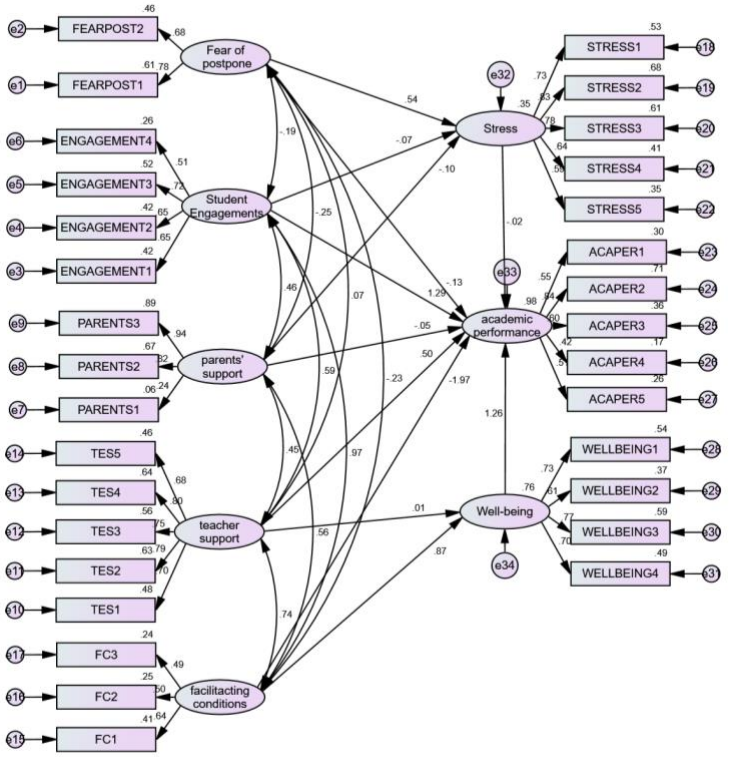


Figure 3: Structural Model Evaluation Result for Female



Discussion

Our research indicated that the fear of being delayed could heighten the stress levels of doctoral students in mathematics, but it did not have a significant impact on their academic performance. This finding contradicts previous studies that demonstrated how fear of failure and stress can motivate individuals to achieve their goals effectively (Liu et al., 2022; Putwain & Symes, 2011). Daniel (2020) suggested that anxiety levels increase when individuals experience fear, and this often drives them to perform better.

The result emphasizes that the academic performance of doctoral students in mathematics was positively impacted by their level of engagement. Those who were highly engaged had a better perception of their academic achievements. This finding is consistent with previous research that suggests students who are more passionate about their education tend to perform better academically (Gopal et al., 2018; Kossen & Ooi, 2021).

The significant impact of teacher support on academic performance has been found in this study which is consisitent with previous studies (Davidson et al., 2021). Furthermore, the conclusion of teacher support has a greater impact on males is also consistent with previous research (Fisher et al., 2020), which surveyed 227 alumni of STEM Ph.D. programs in 17 African countries and found that supervision had a stronger impact on men than women.

Our study found no significant difference between factors affecting males and females, which is consistent with previous research results (Seagram et al., 1998; Sheridan & Pyke, 1994; Wilson & Reschly, 1995). The academic environment and expectations for both genders are relatively similar at the doctoral level. However, some studies have found that female academic performance is worse than that of males, as evidenced by the fact that women take

longer to complete their doctoral-level requirements. If this is the case, it may be due, in part, to the accumulated microinequities that women experience as graduate students. Many authors have pointed out that the nature and quality of graduate education is not equivalent for men and women (Ceci et al., 2009; Feldon et al., 2017).

Conclusions

About the first research question, how do these factors impact the academic performance of male and female Ph.D. students. Our research found that the fear of being delayed did not have a significant impact on the academic performance of doctoral students in mathematics, but it did heighten their stress levels. The level of engagement of students had a positive impact on their academic performance, and teacher support had a significant impact on academic performance, particularly for male students. These findings suggest that universities and educators should prioritize creating a supportive environment for students and promoting student engagement to enhance academic performance.

About second research question, gender difference of factors affecting academic performance of mathematics doctoral students. our research found no significant difference between factors affecting males and females in doctoral-level mathematics. These findings suggest the importance of creating a supportive environment and promoting student engagement to enhance academic performance, regardless of gender.

Implication

The study's findings have practical implications for institutions, supervisors, and parents seeking to enhance the academic performance of doctoral students. The results indicate that the success of these students is closely linked to the involvement of parents, lecturers, and the students themselves. Therefore, these stakeholders must collaborate to reduce stress levels, promote well-being, and support doctoral students' academic progress. Institutions should develop programs that prioritize the well-being of doctoral students, encouraging them to view earning a doctoral degree as a worthwhile pursuit. Faculty members and supervisors should consider implementing strategies to improve students' engagement and well-being.

Limitation

First, our sample size was not large enough. Furthermore, it is probable that any disparities between genders are not connected to the elements we investigated in our study, but rather to external factors like societal and cultural influences. Our findings suggest that gender may not be a significant predictor of academic achievement in doctoral-level mathematics, but more research is necessary to comprehend the intricate interplay of factors that contribute to gender disparities in graduate education. Potential future studies could delve into other factors, such as mentoring, career goals, and work-life balance, and explore how they interact with gender and other demographic variables. This research could inform policies and practices that promote gender equality and diversity in mathematics doctoral education and beyond.

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