

The Self-concept, Self-efficacy, and Academic Achievement of Prospective Mathematics and Biology Teachers

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ABSTRACT

This study investigates the intricate interplay between self-concept, self-confidence, and academic achievement among aspiring mathematics and biology teachers. Through a quantitative research approach and survey design, we explore the relationships among these psychological factors and their potential influence on the educational paths of future educators in these distinct disciplines. Seventy-six prospective biology education teachers and 115 prospective mathematics education teachers voluntarily participated as respondents in filling out the provided survey. Utilizing standardized self-concept and self-efficacy assessments in conjunction with academic performance records, we gather comprehensive data to analyze these dynamics by inferential statistics, independent t-tests, and Pearson's correlation. Our findings show that there is a significant difference in the self-concept of prospective biology education teachers and mathematics education teachers when studying mathematics or statistics material, highlighting significant correlations between self-concept, self-efficacy, and academic achievement. However, the nature of these relationships varies between mathematics and biology domains, suggesting the need for tailored strategies in each field. While a positive self-concept and self-efficacy foster academic success, their impact differs based on the subject matter. The findings from these analyses can shed light on how self-concept and self-efficacy in mathematical understanding and problem-solving contribute to the academic achievement of prospective teachers in mathematics and biology. This information has implications for teacher training programs and educational strategies aimed at enhancing both self-perception and teaching efficacy in mathematics-related subjects.

Keywords: Academic achievement, self-concept, self-confidence, prospective teachers.

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I. INTRODUCTION

Education is undeniably a critical pillar in fostering the advancement and growth of any nation. Prospective teacher candidates hold a vital responsibility in molding a well-informed and skilled generation, thereby contributing to the future of the country. One indicator of an educated and competent generation can be observed through their academic achievements. Student achievement refers to the level of success or accomplishment attained by a student in their academic pursuits (Bakadorova & Raufelder, 2020; Burns et al., 2020; Perinelli et al., 2022). It is often measured by grades, test scores, or other indicators of academic performance. Academic achievement is a foundational aspect of the teaching profession, as teachers are responsible for facilitating learning and knowledge transfer. High academic achievement among prospective teachers can signify strong subject knowledge and competence.

The assessment of students' academic achievements involves the consideration of various factors, extending beyond academic and intellectual aspects. Psychological factors significantly impact their capacity to reach their highest potential and attain outstanding accomplishments. One of the psychological factors of concern in this context is students' self-concept and self-efficacy. Self-concept refers to a person's self-perceptions and evaluations of their own abilities, competence, and worth in a specific domain (Arens et al., 2020; Bakadorova & Raufelder, 2020; Burns et al., 2020; Martínez-Marín et al., 2021; Möller et al., 2020; Perinelli et al., 2022). Self-concept influences how individuals approach learning and teaching activities. A positive self-concept can lead to increased motivation, engagement, and resilience in facing challenges. Self-concept impacts teaching efficacy and instructional strategies employed by educators. In this study, self-concept is related to learning mathematics or statistics.

Self-efficacy refers to an individual's belief in their own

ability to accomplish specific tasks or goals (Arens et al., 2020; Burns et al., 2020; Zhu et al., 2018). Teaching self-efficacy is critical for educators as it affects instructional planning, classroom management, and student engagement. Higher self-efficacy contributes to more adaptive teaching practices and higher levels of student achievement. Self-efficacy beliefs shape how prospective teachers perceive their capability to teach specific subjects, such as mathematics or biology. In this study, self-efficacy is related to understanding mathematical concepts and problem-solving.

The relationship between self-concept, self-confidence, and academic achievement is an intriguing topic, as these three factors can interact and influence each other (Arens et al., 2020; Burns et al., 2020; Zhu et al., 2018). For instance, students with a positive self-concept and high self-confidence tend to exhibit greater motivation to achieve their academic goals, overcome learning obstacles, and accept constructive feedback. Positive self-concept contributes to higher self-efficacy as individuals who perceive themselves positively are more likely to believe they can succeed (Arens et al., 2020; Céspedes et al., 2021; Holenstein et al., 2022; Peiffer et al., 2020). Individuals with a strong self-concept are more willing to take on challenges, contributing to higher self-efficacy beliefs. High self-efficacy leads to enhanced effort, persistence, and motivation in learning and teaching (Holenstein et al., 2022; la Velle, 2021; Trautner & Schwinger, 2020). Positive self-efficacy influences academic achievement by encouraging proactive problem-solving and resource utilization (Arens et al., 2020; Zheng et al., 2021). Positive self-concept is associated with higher academic achievement due to increased motivation and task engagement (Schnitzler et al., 2021; Supervía et al., 2020). Self-concept affects goal-setting, effort allocation, and coping strategies, all of which impact academic outcomes (Bakadorova & Raufelder, 2020; Lee et al., 2017; Tan, 2019).

This, in turn, can impact their overall improvement in academic performance. However, despite the potential relationship between self-concept, self-efficacy, and academic achievement being acknowledged, further research is necessary to comprehend the interplay and the extent of influence each factor holds within the context of prospective teachers. Moreover, individual variability and other factors such as social background, learning environment, and intrinsic motivation can also impact this relationship. Despite numerous prior studies that have explored the relationship between self-concept, self-efficacy, and academic achievement among various groups of students, research specifically focused on prospective teachers remains limited. Prospective teachers hold a distinct role as future educators, making a profound understanding of the psychological factors influencing their academic achievements particularly relevant and significant.

This study concentrates specifically on prospective biology and mathematics teachers, whereas previous research might have encompassed different student groups or lacked a dedicated focus on this specific category. By honing in on the specific cohort of prospective teachers, this research carries a more direct relevance to the educational context and the pivotal role these students will undertake as

educators in the future. Hence, this study aims to fill the research gap by examining the relationship between self-concept, self-efficacy, and academic achievement among prospective teachers. In more detail, the purpose of this research is to analyze the differences between the self-concepts of prospective biology and mathematics teachers in mathematics or statistics instruction and the relationship between self-concept, self-efficacy, and academic achievement of prospective biology and mathematics teachers.

II. METHOD

A. Design

This study employs a quantitative approach with a survey research design. This design allows for the identification of differences in self-concept between prospective biology and mathematics teacher candidates and relationships between the variables of self-concept, self-efficacy, and academic achievement without manipulating the variables (Creswell, 2017).

B. Participants

The participants in this study are prospective teacher education students majoring in biology and mathematics who voluntarily agree to participate. The total number of participants is 76 from the biology education program and 115 participants from the mathematics education program.

C. Instruments

Research data is collected through a questionnaire using Google Forms, consisting of three sections. The first section pertains to participant identity and their academic achievements in the form of obtained grade point averages. The second section includes a self-efficacy questionnaire related to comprehending material and solving mathematical problems, each containing 8 and 9 statements, respectively, with confidence levels/ratings ranging from 0 to 10 (Bandura, 2006). The third section comprises a self-concept questionnaire regarding learning mathematics, consisting of 10 statements—seven positive and three negative (items no. 4, 8, and 10)—with confidence levels/ratings ranging from 0 to 10 (Ahn & Bong, 2019).

D. Data Analysis

The collected data will be analyzed using the statistical software JASP 0.16.3.0 to identify differences in self-concept between prospective biology and mathematics teacher candidates, as well as the relationships between self-concept, self-efficacy, and academic achievement among these students. Independent t-tests and correlation analyses will be employed to measure the extent of the differences in self-concept and the extent to which self-concept and self-efficacy influence academic achievement among prospective teacher education students. All analyses will use a significance level of $p = 0.05$.

III. RESULTS AND DISCUSSION

A. Self-concept (SC) and Achievement of Prospective Biology and Mathematics Education Teachers

In this case, the self-concept and academic achievement are described descriptively. Furthermore, the study elaborates on whether there is a difference in self-concept regarding the learning of mathematics/statistics between prospective teachers majoring in biology and mathematics. The descriptive statistical results of self-concept are presented in Table I.

TABLE I: DESCRIPTIVE STATISTICS

	Group	N	M	SD
Self-concept	Bio student	76	48.79	10.82
	Math student	115	55.72	9.37
Achievement	Bio student	76	3.60	0.28
	Math student	115	3.38	0.35

Table I shows that the average self-concept of prospective biology education teachers is lower than that of prospective mathematics education teachers in the context of learning mathematics/statistics. This suggests that, within the context of mathematics/statistics education, prospective biology education teachers tend to possess a lower self-perception of their abilities to comprehend the subject matter compared to prospective mathematics education teachers. In other words, prospective biology education teachers might experience a lower sense of confidence or assurance when facing mathematical or statistical content as opposed to prospective mathematics education teachers. This phenomenon could potentially influence their approach to and delivery of this content when teaching students in the future.

The implications of these findings suggest that educational institutions for teachers need to pay special attention to the self-development of prospective biology education teachers when it comes to dealing with mathematical and statistical content. Training programs or mentoring initiatives aimed at boosting their confidence and self-concept regarding their ability to teach mathematics and statistics could be implemented. This needs to be carefully considered and executed with an appropriate approach to effectively support the professional growth of prospective biology and mathematics education teachers.

Furthermore, the difference in self-concept between prospective teachers' biology and mathematics in learning mathematics/statistics is elucidated using an independent t-test, with the results presented in Table III. However, prior to conducting the t-test, the data was assessed for normality using the Shapiro-Wilk test, the results of which are displayed in Table II. Based on the p-value > 0.05, as seen in Table II, the data meets the normality assumption, a prerequisite for the t-test. Meanwhile, the outcomes of the t-test are presented in Table III.

TABLE II: RESULTS OF THE TEST OF NORMALITY (SHAPIRO-WILK)

	Group	W	p
Self-concept	Bio student	0.98	0.50
	Math student	0.97	0.16

Note. Significant results suggest a deviation from normality.

TABLE III: RESULTS OF THE INDEPENDENT SAMPLES T-TEST

t	df	p
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Self-concept	-4.70	189	<0.001
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Note. Student's t-test.

Based on Table III, the significance level is $p < 0.05$. This implies a significant difference in the self-concept of prospective mathematics and biology education teachers when studying mathematics/statistics. This difference indicates that the self-perception or self-concept of prospective mathematics education teachers is significantly distinct from that of prospective biology education teachers when facing mathematical/statistical material. This suggests that prospective mathematics education teachers tend to exhibit a higher level of confidence or self-concept when it comes to learning mathematics/statistics compared to their counterparts in biology education. The significant difference could encompass variations in self-confidence, perceptions of proficiency in mathematics or statistics, feelings regarding the relevance of the material to their field of study, and so forth. Thus, the results of this analysis indicate that prospective mathematics and biology education teachers have differing perspectives about themselves when facing mathematics or statistics material. These differences may reflect variations in experience, understanding, and confidence when teaching and engaging with mathematical/statistical aspects.

Prospective mathematics education teachers might have more positive or in-depth learning experiences in mathematics, which could bolster their self-concept in this area (Karlen et al., 2021; Mandt, 2021). Conversely, prospective biology education teachers might have limited exposure to mathematics during their education or may feel less confident due to prior experiences (Nurkanti et al., 2021; Santos et al., 2021). Prospective biology education teachers might feel less confident in mathematics or statistics due to a perceived lack of proficiency. This can act as a barrier to developing a positive self-concept. Prospective mathematics education teachers might have a higher baseline level of general self-confidence, which can influence how they approach challenges in mathematics or statistics. An approach that supports interactive, exploratory, and creative learning in mathematics may encourage prospective biology education teachers to improve their self-perception of the subject (Takaria & Palinussa, 2020).

These findings have important implications that need to be considered. Prospective biology education teachers could benefit from self-development programs, or training focused on strengthening their self-concept when dealing with mathematics/statistics content. This could assist them in enhancing their confidence and preparedness for teaching these topics in the classroom. Additionally, educators and teachers should pay attention to these differences in self-concept when planning instruction. Different approaches might be necessary to help prospective biology education teachers feel more confident and prepared to teach mathematics/statistics. Overall, understanding the meaning and implications of these analytical results will aid in designing effective strategies to support the professional development and teaching preparedness of prospective mathematics and biology education teachers.

B. Relationship Among Self-concept, Self-efficacy, and Achievement

In this section, the relationship between self-concept, self-efficacy in understanding mathematical concepts and problem-solving, and academic achievement among prospective mathematics and biology teachers is elucidated. Before conducting the analysis, data normality was assessed using the Shapiro-Wilk test, presented in Table IV for prospective mathematics teachers and Table VI for prospective biology teachers. The Pearson correlation, on the other hand, is presented separately in Table V for prospective mathematics teachers and Table VII for prospective biology teachers. The examination of these relationships aims to uncover how self-concept and self-efficacy in mathematics-related cognitive processes influence academic achievement for teacher candidates in both mathematics and biology domains.

The Shapiro-Wilk test (Table IV and Table VI) serves to ascertain the normality of the data distribution, which is essential for conducting subsequent statistical analyses. A p-value above 0.05 indicates that the data follows a normal distribution, providing the necessary assumption for the correlation analysis.

1) Prospective Mathematics Teachers

The Pearson correlation is a statistical measure that quantifies the linear relationship between two variables. In this context, it provides insights into the degree and direction of the relationship between self-concept, self-efficacy in understanding mathematical concepts and problem-solving, and academic achievement.

TABLE IV: SHAPIRO-WILK TEST FOR MULTIVARIATE NORMALITY	
W	p
0.97	0.24

TABLE V: PEARSON'S CORRELATIONS OF PROSPECTIVE MATHEMATICS TEACHERS				
Variable	SE-MM	SE-PM	SC	GPA
SE-MM	1			
SE-PM	0.80***	1		
SC	0.35***	0.28	1	
GPA	0.04	0.10	-0.10	1

Note. ***p < 0.001.

Based on the results in Table V, the relationship among self-concept, self-efficacy, and academic achievement of prospective mathematics education teachers is obtained as follows:

1. There is a positive and significant moderate correlation ($r = 0.35$) between self-concept (SC) in learning mathematics and self-efficacy in understanding materials mathematics (SE-MM) among prospective mathematics teachers. This implies that prospective mathematics teachers who have a more positive self-concept regarding their abilities in teaching and explaining mathematical learning also tend to have greater self-efficacy in comprehending mathematical materials. The moderate level of correlation indicates that, although a positive correlation exists, not all mathematics teacher candidates with positive self-perceptions automatically exhibit high levels of confidence in

teaching mathematics. Looking at the value of $r^2 = 0.1225$, it can be deduced that only 12.25% of the variance in SE-MM can be explained by SC. The remaining variance, approximately 87.75%, might be influenced by other factors not considered in this analysis. This suggests that while self-concept plays a role in influencing self-efficacy in understanding mathematical concepts and teaching (Arens et al., 2020; Lau, 2022; Takaria & Palinussa, 2020), it is not the sole determinant. There could be additional factors, such as teaching methodologies, prior teaching experiences, and personal teaching beliefs, that contribute to a mathematics teacher candidate's self-efficacy. These results underscore the complexity of the relationship and the need to consider multiple aspects when addressing the enhancement of self-efficacy and teaching efficacy in mathematics education. Additionally, there is a positive and significant low correlation ($r = 0.28$) between self-concept (SC) and self-efficacy in problem-solving (SE-PM) for prospective mathematics teachers. A positive correlation indicates that prospective mathematics teachers with a positive self-perception are more likely to have greater self-confidence in solving mathematical problems. However, the low level of correlation (not strong) implies that despite the correlation, other factors could also influence self-efficacy in problem-solving (SE-PM). In this context, the value of $r^2 = 0.0784$ indicates that approximately 7.84% of the variation in self-efficacy in Problem-Solving (SE-PM) can be explained by the variation in self-concept (SC). The remaining 92.16%, roughly, might be influenced by other factors not included in this analysis. These analysis results depict the relationship between self-concept (SC) and self-efficacy in problem-solving (SE-PM), highlighting that the extent to which SC can explain the variation in SE-PM is relatively low. Other factors also play a role in shaping self-efficacy in solving mathematical problems. This result provides evidence that there is a weak yet significant positive relationship between self-concept and self-efficacy among prospective mathematics education teachers (Burns et al., 2020; Karlen et al., 2021; Mendoza et al., 2022; Zhu et al., 2018).

2. There is a strong positive and significant correlation ($r = 0.80$) between self-efficacy in understanding mathematical concepts (SE-MM) and self-efficacy in problem-solving (SE-PM) for prospective mathematics teachers. This signifies that prospective mathematics teachers with high self-confidence in understanding mathematical concepts are likely to have strong self-confidence in solving mathematical problems. Self-confidence in understanding mathematical concepts seems to play a pivotal role in shaping self-confidence in problem-solving. Examining the coefficient of determination ($r^2 = 0.64$), it can be deduced that 64% of the variance in self-efficacy in problem-solving (SE-PM) can be explained by self-efficacy in understanding

mathematical concepts (SE-MM). The remaining 46%, approximately, may be influenced by other factors not included in this analysis. These analysis results have potential implications for professional development among teachers and for enhancing the quality of teaching and learning outcomes in mathematics. It emphasizes the significance of building strong self-efficacy in understanding mathematical concepts, as it appears to contribute significantly to fostering self-efficacy in solving mathematical problems among prospective mathematics teachers.

- Furthermore, there is a positive but not significant correlation between academic achievement (GPA) and self-efficacy in understanding mathematical concepts ($r = 0.04$), as well as between academic achievement and self-efficacy in mathematical problem-solving ($r = 0.1$) for prospective mathematics teachers. This indicates that although there is a positive correlation between academic achievement and self-efficacy in understanding mathematical concepts and problem-solving, the relationship is not strong or consistent enough to be considered to have a significant influence on the subject under study. The levels of self-efficacy in understanding mathematical concepts and problem-solving do not consistently predict or affect academic achievement among prospective mathematics teachers (Ampofo, 2019; Ayotola & Adediji, 2009; Kaskens et al., 2020; Küçükalioglu & Tuluk, 2021). Finally, there is a negative but not significant correlation between academic achievement (GPA) and self-concept ($r = -0.1$) for prospective mathematics teachers. Although there is a negative correlation between academic achievement and self-concept, the relationship is very weak, so it cannot be considered to have a significant influence in the context under study. There is no strong basis to assert that self-concept directly affects academic achievement among prospective mathematics teachers in this context (Kaskens et al., 2020; Njoki et al., 2019; Perinelli et al., 2022).

2) Prospective Biology Teachers

Based on Table VII, the relationships between self-concept in learning mathematics/statistics, self-efficacy in understanding mathematical concepts and problem-solving, and academic achievement are as follows:

- There is a positive and significant moderate correlation between self-concept (SC) and self-efficacy in understanding mathematical concepts (SE-MM) ($r = 0.43$), as well as self-efficacy in mathematical problem-solving (SE-PM) ($r = 0.43$) for prospective biology teachers with a p -value < 0.05 . Examining the coefficient of determination ($r^2 = 0.1849$), self-efficacy in understanding mathematical concepts and self-efficacy in mathematical problem-solving can be explained by self-concept by 18.49%. The remaining 71.51%, approximately, might be influenced by other factors not included in this

analysis. This finding suggests that for prospective biology teachers, a positive self-concept in learning mathematics/statistics is related to a moderate level of self-efficacy in understanding mathematical concepts and problem-solving (Burns et al., 2020; Mendoza et al., 2022; Zhu et al., 2018). However, the self-concept explains only a portion of the variance in these self-efficacy measures, indicating the potential influence of other unexamined factors.

TABLE VI: SHAPIRO-WILK TEST FOR MULTIVARIATE NORMALITY

W	p
0.93	0.21

TABLE VII: PEARSON'S CORRELATIONS OF PROSPECTIVE BIOLOGY TEACHERS

Variable	SE-MM	SE-PM	SC	GPA
SE-MM	1			
SE-PM	0.43***	1		
SC	0.43***	0.72***	1	
GPA	0.25*	0.26*	0.24*	1

Note. *** $p < 0.001$; * $p < 0.05$.

- There is a strong positive and significant correlation ($r = 0.72$) between self-efficacy in understanding mathematical concepts (SE-MM) and self-efficacy in problem-solving (SE-PM) for prospective biology teachers. This indicates that prospective biology teachers with high self-confidence in understanding mathematical concepts are likely to have strong self-confidence in solving mathematical problems. Self-confidence in understanding mathematical concepts appears to play a crucial role in shaping self-confidence in problem-solving. Examining the coefficient of determination ($r^2 = 0.5184$), it can be inferred that 51.84% of the variance in self-efficacy in problem-solving (SE-PM) can be explained by self-efficacy in understanding mathematical concepts (SE-MM). The remaining 48.16%, approximately, may be influenced by other factors not included in this analysis. These analysis results have potential implications for professional development among teachers and for enhancing the quality of teaching and learning outcomes in mathematics. It underscores the significance of building strong self-efficacy in understanding mathematical concepts, as it appears to contribute significantly to fostering self-efficacy in solving mathematical problems among prospective biology teachers.
- There is a weak positive and significant correlation between academic achievement (GPA) and self-concept ($r = 0.25$), academic achievement and self-efficacy in understanding mathematical concepts ($r = 0.26$), as well as academic achievement and self-efficacy in mathematical problem-solving ($r = 0.24$) for prospective biology teachers with p -values < 0.05 . A positive correlation signifies that if one variable (academic achievement or self-concept, self-efficacy in understanding mathematical concepts, and self-efficacy in mathematical problem-solving) increases, the likelihood is that the other variable will also increase. A significant correlation indicates that this correlation is not merely due to random chance but

holds valid statistical significance. Although the correlation is weak, it remains important as it can provide insights into how these factors interact in the context of mathematics education. These findings highlight that academic achievement is modestly linked to self-concept and self-efficacy in understanding mathematical concepts and problem-solving among prospective biology teachers (Chytrý et al., 2020; Shimizu, 2022; Shkëmbi & Treska, 2023; Wu et al., 2021). Despite the modest strength of these relationships, they can offer valuable insights into how these factors interact and potentially impact mathematics education for these candidates.

IV. CONCLUSION

This study sheds light on the intricate differences in self-concept and connections between self-concept, self-confidence, and academic achievement among prospective mathematics and biology teachers. The examination of these psychological factors within the context of teacher preparation underscores their significance in shaping the educational journey of individuals aspiring to teach these distinct subjects. However, the study also reveals that there is a significant difference in self-concept between prospective mathematics and biology teachers when studying mathematics or statistics material, with positive correlations observed between self-concept, self-efficacy, and academic achievement, with the exception between self-concept and learning achievement for prospective mathematics teachers. The nuanced nature of these relationships implies that the impact of self-concept and self-efficacy on academic achievement may vary between the mathematics and biology domains.

The findings of this research hold implications for educational policymakers, teacher educators, and practitioners. By fostering positive self-perceptions and self-confidence in prospective teachers, educational institutions can potentially enhance the effectiveness of teacher training programs. In future research, a longitudinal approach could offer deeper insights into how self-concept and self-efficacy evolve over time and impact long-term teaching outcomes. Additionally, qualitative studies might provide a richer understanding of the personal experiences and perceptions that underlie these psychological constructs.

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CONFLICT OF INTEREST

The authors declare that they do not have any conflict of

interest.

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