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Factors Influencing Confidence in STEM Practices among Preservice Teachers

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Abstract. Preservice teachers are more confident in teaching mathematics, specifically when they have a better understanding of the subject. In teaching and microteaching practices, content and understanding of mathematics pedagogy are monitored and evaluated. However, additional investigation on science, technology, engineering, and mathematics (STEM) skills and practices is needed to meet the current need to train teachers with 21st-century skills in order to educate future generations. Therefore, this study aimed to determine the way in which factors influencing effort, performances in algebra, and statistics were related to the self-confidence of preservice teachers in teaching STEM practices. To achieve this purpose, a correlational approach was used to collect information from 113 prospective science teachers at a public institution in Malaysia. In response to the questionnaire, participants provided impressions of the experience and level of confidence in using STEM. The result showed that the efforts of preservice teachers had a significant impact on the confidence in using STEM subjects in the mathematics classroom. Furthermore, the future of STEM education was in the collective and practical efforts to connect STEM with the real world.

Keywords: Algebra; Confidence; Effort; Statistics; STEM (Science, Technology, Engineering and Mathematics)

1. Introduction

Preservice teachers are evaluated based on subject knowledge, engagement in teaching, and application of teaching theory (Asare and Amo, 2023; Stinken-Rösner *et al.*, 2023; Cai, Zhu, and Tian, 2022; Diamah *et al.*, 2022; Baier *et al.*, 2021; Engin and Tasgin, 2021). Teachers are expected to guide future generations toward academic and professional excellence (VanDerHeide and Marciano, 2022; Koh and Tan, 2021; Van-Driel and Berry, 2010), thereby indicating the significance of STEM (science, technology, engineering, and mathematics) skills in the current rapidly evolving digital world (Ryu, Mentzer and Knobloch, 2019). With increasing attention being paid to STEM education, the integration of STEM subjects into the real world by preservice teachers has become critical for success (Syafril *et al.*, 2021).

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Learning and teaching STEM subjects presents unique challenges for preservice teachers, as they are in a transition period from practicing and supervising while preparing to teach students (Pimthong and Williams, 2018). The effectiveness of previous university studies in increasing the awareness of integrating STEM elements into the curriculum remains a significant study gap.

To effectively guide and inspire students, preservice teachers need to proactively develop 21st-century skills, particularly in STEM education. By connecting previous learning experiences and current teaching practices, novice teachers can obtain valuable insights to effectively guide the efforts. Additionally, teachers' participation in STEM education assists in bridging the gap between theory and practice and promotes the authenticity of STEM practices (Margot and Kettler, 2019; Holmlund, Lesseig, and Slavit, 2018). This implies that preservice teachers' willingness to put effort and actively engage in STEM practices is critical to building self-confidence, strengthening behavioral intentions, and creating more opportunities to engage students in these activities (Teoh *et al.*, 2022; Asvial, Mayangsari, and Yudistriansyah, 2021; Margot and Kettler, 2019).

A strong knowledge of algebra and statistics is essential for preservice mathematics teachers to excel in STEM classes (Ng, 2019). This is because a higher level of algebra knowledge helps in increasing confidence in teaching mathematics concepts, and also allows teachers to effectively introduce a broader range of STEM concepts. Therefore, preservice teachers who have strong knowledge of algebra can confidently guide students in the problem-solving process, such as when faced with a problem comprising the concept of inverse proportionality in algebra. These problem-solving activities are key to larger STEM activities, such as painting a house. By using algebra knowledge, teachers can easily integrate additional STEM components into the classroom by engaging students in discussions, such as a way of selecting paints and brushes to paint efficiently and considering various factors that influence painting speed.

Aside from the above, a strong foundation in algebra and statistics also enables mathematics preservice teachers to excel in teaching concepts and integrate a variety of STEM elements into the lessons, thereby providing students with a more comprehensive and engaging educational experience. However, these disciplines can be challenging and require more effort to develop future students' talents (Khalil and Kier, 2021; Mergler and Spooner-Lane, 2012).

Assessing preservice teachers' confidence and effort in teaching STEM practices, particularly algebra and statistics, provides an opportunity to increase competency. The ability of teachers to effectively integrate the basic mathematical concepts into real-world applications of STEM is critical to preparing students for the demands of a rapidly evolving world of work that relies heavily on STEM skills (Starr *et al.*, 2022; Black *et al.*, 2021; Ng, 2019). By focusing on the role of algebra and statistics in STEM education, educational institutions and policymakers can develop targeted interventions to strengthen preservice teachers' pedagogical skills and content knowledge in these areas, thereby cultivating more competent and confident STEM educators.

This study aims to observe and understand the confidence level of preservice mathematics teachers regarding their efforts and competence in teaching STEM practices, with a particular focus on algebra and statistics. Subsequently, this study provides answers for the following questions:

- First Research Question: What are the levels of confidence, effort, and achievement in algebra and statistics among preservice teachers?

- Second Research Question: Is there a significant model that explains the relationship between confidence in STEM practices and the independent variables of effort, algebra, and statistics performance?

The results provide valuable insight into the factors influencing the confidence of prospective teachers in STEM teaching practices and help educational institutions and policymakers develop more effective strategies to support and enable teachers to become competent. In general, the goal is to improve the total quality of STEM education and create a more dynamic and innovative learning environment for students.

2. Methods

2.1. Study Design

This study used a correlational design to collect quantitative data. The quantitative approach focused on examining the relationship between variables, namely confidence, effort, and mathematics achievement (algebra and statistics).

2.2. Sampling

To collect quantitative data, this study used cluster sampling, where samples were selected randomly from existing categories. In this study, the cluster included the entire sample of 941 individuals who were divided into 37 clusters. The similarity between the individuals in the population was that they enrolled in a preservice program in the science and mathematics discipline at a Malaysian public university. Additionally, the individuals had comparable characteristics that met the selection criteria. These characteristics satisfied investigations, which required the application of basic scientific knowledge, particularly algebra and statistics. During the study period, this group of preservice teachers was exposed to relevant information. The similarity of these characteristics was important for cluster sampling because it allowed meaningful comparisons and conclusions to be made regarding the particular group being studied (Raifman *et al.,* 2022). Therefore, the cluster sampling was used to gain a better understanding of preservice teachers' experiences with STEM learning. Since all individuals in a given cluster shared similar characteristics, data collected from each cluster would possibly provide valuable insight into STEM learning experiences, attitudes, and perceptions.

The sample consisted of 6 clusters totaling 37 clusters, which were selected randomly. Random sampling was a fundamental principle because it helped ensure that the sample was representative of the entire population and reduced the possibility of bias during the selection process. Consequently, the number of participants from the 6 clusters was 113 people, depending on the willingness to participate. The sample size was considered sufficient from a statistical perspective. According to the central limit theorem, sample sizes generally had to be large enough to provide statistical power and accurate estimates (Stroock, 2010). Additionally, the clusters were homogeneous to each other due to the science and mathematics-focused nature of the studies at the university, but the internally heterogeneous grouping was apparent as they were all selected to enrol in the program through an entrance selection process. To eliminate possible bias due to the relatively small number of clusters, bootstrap sampling was used in data analysis (Cameron, Gelbach, and Miller, 2008). Bootstrap sampling is a resampling method that comprised repeatedly taking random samples and replacing the samples from the original data set. This method allowed the estimation of sample variability and helped increase the robustness of statistical inference, particularly with limited cluster sizes.

2.3. Data Collection

The largest selection of preservice teachers was in formation to hold a virtual meeting. Efforts were made to participate in the investigation to ensure proper accountability. At the meeting, the overview of the investigation was presented to preservice teachers and they responded to the instrument.

2.4. Instrumentation

Participants responded to two instruments, namely a questionnaire and a test. The primary instrument for questions concerned the perceptions in the context of beliefs and efforts in STEM practice. These building blocks were important aspects that needed to be changed in the transformation of STEM education (Ministry of Education Malaysia, 2013). Furthermore, the items were validated by two experts to establish valid conditions. Also, the construct validity of the questionnaire was established through factorial analysis. Based on the reliability test, Cronbach's alpha values for effort and confidence were 0.896 and 0.899, respectively.

In the context of construct validity, KMO tests showed adequate and high variability, with KMO = 0.889 > 0.50. This was because the value was closer to 1, indicating high variability in the data. Additionally, Bartlett test showed that there were sufficient correlations among the variables with chi-square = 981.455, df = 66, and significance < 0.05. The result signified that the associated probability was less than 0.05. Statistically, there were two extracted factors which referred to components account for the variance among the 12 variables. The percentage of variance accounted for by the component was 67.85% of cumulative variance.

In this study, the two components were rotated orthogonally, and the variable loadings (for some items) on the factors were shown in Table 1. Subsequently, only factor loadings greater than 0.5 were described. First, items 14, 15, 8, 6, and 7 were highly correlated to the first component (confidence) with factor loadings of 0.873, 0.800, 0.786, 0.730, and 0.685, respectively. In this analysis, item 9 was rejected because the variation in factor loadings between the two components was very small, namely 0.535 - 0.533 = 0.012, less than 0.2, which was called the limit value for determining the remaining significant factor loadings. Second, the analysis showed that items 1, 2, 3, 4, 12, and 13 for the second component (effort) were highly correlated with factor loadings (for several items) of 0.873, 0.800, 0.786, 0.730, and 0.685, respectively.

Table 1 Rotated Component with a sample of the items

	Component 1	Component 2
14. My confidence level in how to conduct STEM education is high.	0.873	0.228
15. I am confident enough to introduce STEM education to my friends or community.	0.800	0.384
13. I need to prepare myself to apply STEM in my practicum.	0.384	0.629
12. I will put a lot of effort into supporting the development of STEM education.	0.450	0.617

The second instrument was an algebra and statistics test. In this process, the test questions were adapted from standardized examinations (California Department of Education, 2008a; 2008b). Several examples of the items were shown in Table 2. In the reliability test, Cronbach's alpha values for statistics and algebra were 0.795 and 0.620, respectively.

Table 2 Sample items

	Sample item
Statistics	1. Rico's first three test scores in biology were 65, 90, and 73. What was his mean score?
Algebra	1. Lisa typed a 1000-word essay at an average rate of 20 words per minute. If she started typing at 6:20 p.m. and did not have any breaks, at what time did Lisa finish typing the essay? 2. Stephanie is reading a 456-page book. During the past 7 days, she has read 168 pages. If she continues reading at the same rate, how many more days will it take her to complete the book?

3. Results

3.1. Finding 1: Level of confidence in STEM practices

Finding 1 analyzed the data to provide descriptive statistics regarding levels of trust and other factors. Subsequently, the following questions were answered:

Question One: What are the levels of confidence, effort, and achievement in algebra and statistics among preservice teachers?

Confidence and effort were measured on a Likert Scale ranging from '1' for 'strongly disagree' to '5' for 'strongly agree'. Table 3 shows the level of confidence (mean = 4.263, standard deviation = 0.579) and effort (mean = 3.993, standard deviation = 0.704). The result implied that the level of confidence was rated slightly higher. Additionally, it was observed that preservice teachers needed to put more effort into studying algebra because their scores (in Table 3) were low, with mean = 5.080 (total score = 10 marks). The statistical performance was a bit higher (mean =6.204) than algebra score.

Table 3 Descriptive Statistics

			Bootstrap[a] (1000 bootstrap samples)			
					95% Confidence Interval	
		Statistic	Bias	Std. Error	Lower	Upper
Confidence	Mean, M	4.263	-0.001	0.0555	4.153	4.366
	Std. Deviation	0.579	-0.006	0.0528	0.477	0.681
	N	113	0	0	113	113
Effort	Mean	3.993	-0.003	0.067	3.853	4.110
	Std. Deviation	0.704	-0.005	0.047	0.602	0.792
	N	113	0	0	113	113
Algebra Achievement (total =10 marks)	Mean	5.080	0.002	0.211	4.655	5.513
	Std. Deviation	2.311	-0.007	0.130	2.035	2.550
	N	113	0	0	113	113
Statistics Achievement	Mean	6.204	0.004	0.272	5.664	6.735
	Std. Deviation	2.860	-0.011	0.134	2.581	3.109
	N	113	0	0	113	113

3.2. Finding 2: Model of confidence in STEM practices

Finding 2 analyzed the data to present the inferential statistics of confidence level and other factors. Subsequently, the following study question was answered:

Question Two: Is there a significant model that explains the relationship between confidence in STEM practices and the independent variables of effort, algebra, and statistics performance?

Least square Regression with the stepwise method was conducted on the set of data, which included dependent (confidence) and independent variables (effort, algebra, and statistics performance). Table 4 shows the regression model with $R^2 = 0.546$, indicating that

54.6% of the variation in the dependent variable (confidence) was explained in the independent variable of effort but not by other variables (algebra and statistics).

Table 4 Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.739[a]	0.546	0.542	0.392

a. Predictors: (Constant), Effort

The model was significantly presented since ANOVA analysis in Table 5 shows that F = 133.346 with $p < 0.05$.

Table 5 ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	20.459	1	20.459	133.346	<0.001[b]
	Residual	17.030	111	0.153		
	Total	37.489	112			

a. Dependent Variable: Confidence; b. Predictors: (Constant), Effort

According to Table 6, the model was significantly constructed with only one independent variable (effort) for the dependent (Confidence).

Table 6 The Regression Model

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.837	.213		8.613	<.001
	Effort	.608	.053	.739	11.548	<.001

a. Dependent Variable: Confidence

According to Table 7, algebra and statistics performance did not contribute to the model.

Table 7 Excluded Variables

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	Statistics Achievement	0.028[b]	0.433	0.666	0.041	0.977
	Algebra Achievement	0.060[b]	0.915	0.362	0.087	0.964

a. Dependent Variable: Confidence; b. Predictors in the Model: (Constant), Effort

Although algebra and statistics performance did not contribute to the level of confidence, these two variables showed a fairly significant relationship. Table 8 shows that the correlation coefficient for the two variables was 0.646, where $p < 0.05$. The results also showed a strong positive relationship between confidence and effort, with the correlation coefficient being 0.739 ($p < 0.05$). Meanwhile, the relationship between effort and algebra performance was weak and negative, with a correlation coefficient of -0.19 ($p < 0.05$).

Table 8 Correlations

The two Variables	Pearson Correlation	Sig. (2-tailed)	95% Confidence Intervals (2-tailed)[a] Lower	Upper
Confidence and Effort	0.739	<0.001	0.640	0.811
Confidence and Algebra Achievement	-0.083	0.385	-0.263	0.104
Confidence and Statistics Achievement	-0.085	0.372	-0.265	0.102
Effort and Algebra Achievement	-0.190	0.044	-0.361	-0.004
Effort and Statistics Achievement	-0.152	0.108	-0.327	0.034
Algebra Achievement and Statistics Achievement	0.646	<0.001	0.521	0.741

4. Discussion

The results suggested that preservice teachers could be more confident in STEM practices. Influencing factors showed that teachers obtained confidence by completing academic assignments and practicing independently. However, results in algebra and statistics did not contribute to the degree of certainty. Even though algebra and statistics were both important and related to each other, as shown by the correlation coefficient, they did not contribute to the level of confidence in STEM practices. The results showed a slightly negative correlation between effort and algebra. This could be interpreted as the need to try harder when teachers were weak in algebra. Therefore, preservice teachers relied heavily on the efforts for any improvement. Despite the results, teachers' commitment to STEM practices significantly influenced the development. It was suggested that universities needed to create more assignments and projects to support STEM practices for preservice teachers.

Further efforts were needed to develop pedagogy in STEM teaching for preservice teachers, as it was suggested that teachers should do more to develop the skills of the future students (Lee, Hsu, and Cheng, 2022; Khalil and Kier, 2021; Leung, 2020; Pellas *et al.*, 2020; Mergler and Spooner-Lane, 2012). However, equipping preservice teachers with comprehensive and high-quality STEM knowledge, particularly pedagogical knowledge, was a challenge. The challenges of teaching was in informal educational experiences, such as integrating technological tools into the learning environment (Gu *et al.*, 2023; Guan *et al.*, 2023; Love and Hughes, 2022; Neo *et al.*, 2022). This scenario also showed the importance of trying to acquire more experience in integrating STEM subjects into the classroom. The experience could come from informal activities, such as collaborative activities, which had been suggested to improve preservice teachers' STEM skills (Berisha and Vula, 2021; Kim and Keyhani, 2019).

Preservice teachers also had lower algebra scores compared to the statistics. The results suggested that preservice teachers needed training to improve algebra skills as highlighted in previous studies (Johar *et al.*, 2023). Although there was a relationship between the two variables, namely effort and algebra performance, the relationship was negative. This negative sign indicated that more effort was needed for improvement.

5. Conclusions

In conclusion, the implications of this study were categorized into three. First, it was suggested that preservice teachers could acquire confidence in STEM practices through their personal efforts, commitment, and practice. Therefore, universities should develop more assignments and projects that explicitly targeted STEM practices. This would enable preservice teachers to develop greater confidence and competence in teaching STEM subjects. Second, this study described the importance of developing pedagogical skills in STEM education for prospective teachers. To teach STEM subjects effectively, preservice teachers needed to have content and pedagogical knowledge that would enable teachers to teach complex concepts effectively and engage students in meaningful learning experiences. Several activitiess, such as integrating technology tools into the learning environment and engaging in collaborative activities could also contribute to preservice teachers' STEM knowledge. Third, this study described the lower algebra scores of preservice teachers compared to the statistics, and the negative correlation between effort and algebra performance. The results suggested the need for targeted training and support to improve preservice teachers' algebra knowledge. In summary, teachers could remain confident in implementing STEM subjects by acquiring additional STEM-related knowledge in order to have a strong foundation in both science and mathematics. Additionally, the future of STEM education relied on collaborative and practical efforts to connect STEM with real-world applications.

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