Modeling Primary Pre-service Teachers' Sense of Efficacy, Attitudes, and Anxiety about Statistics

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Abstract: This study used structural equation modeling to examine the effects of noncognitive factors on primary preservice teachers' self-efficacy to teach statistics. The results indicated that positive attitudes toward statistical knowledge significantly increased confidence in teaching statistics, and low anxiety about statistics predicted positive attitudes toward statistics. Mediation analysis revealed that low anxiety enhanced both attitudes and intellectual skills toward statistics, which, in turn, increased teaching efficacy. These findings underscore the significance of noncognitive factors in teaching statistics in primary grades. Teacher preparation programs may effectively promote students' statistical literacy by fostering preservice teachers' confidence and enthusiasm for teaching statistics.
Keywords: Teach Statistics, Anxiety, Pre-service Teachers, Primary Grades

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Introduction

Students are introduced to statistical concepts in primary school (grades K–5) (Bargagliotti et al., 2020, National Council of Teachers of Mathematics, 2000). Starting in kindergarten, students develop a deeper understanding of the statistical investigative cycle as they progress through grade levels. Students learn to decide what data is needed, design experiments, collect data, analyze and interpret data, and report conclusions. Thus, teachers who teach statistical content need to understand it and be able to teach it in ways that promote conceptual understanding. These teachers are typically generalists rather than specialists in mathematics or statistics. Research indicates that primary preservice teachers (PSTs) often have limited conceptual understanding due to insufficient coursework and preparation (Franklin et al., 2007; Lovett & Lee, 2017; National Council on Teacher Quality, 2016, 2018). Although previous studies have emphasized teachers' content knowledge, factors such as efficacy, attitudes, and anxiety also influence their preparedness to teach statistics effectively (Groth, 2017).

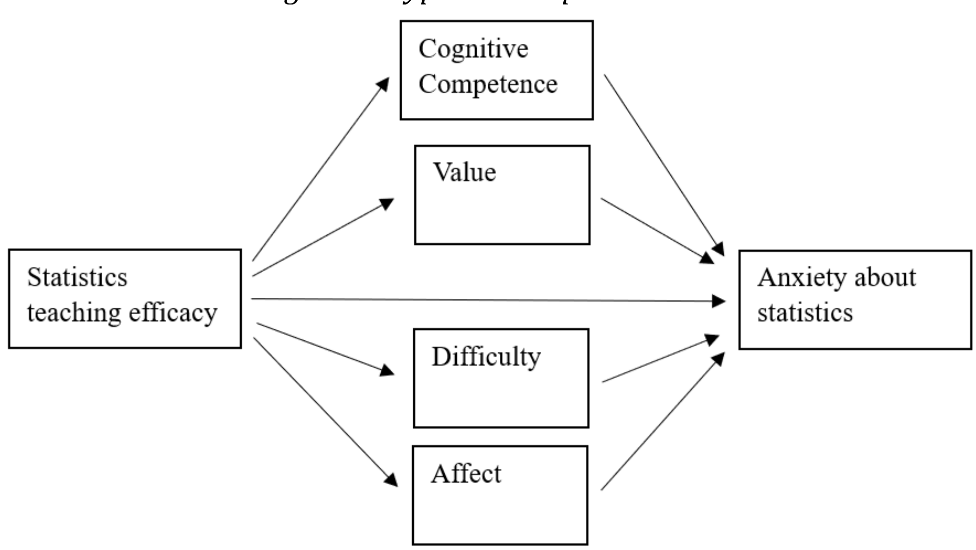
Noncognitive factors, including statistics teaching efficacy, attitudes toward statistics, and anxiety about statistics, influence instructional decisions and student outcomes. Statistics teaching efficacy refers to teachers' confidence in their ability to support students' learning of statistical concepts (Harrell-Williams et al., 2014). Attitudes toward statistics include individuals' feelings, perceived value, and sense of competence regarding the subject (Schau et al., 1995). Anxiety about statistics is characterized by feelings of concern or tension when engaging with statistical content or tasks (Pretorius & Norman, 1992). Teachers with higher efficacy, more positive attitudes, and lower anxiety are more likely to approach statistics instruction confidently, which can enhance student engagement and learning.

Purpose

Research suggests that noncognitive factors play a role in teaching and learning. Higher self-efficacy and positive attitudes are linked to more constructive engagement, and anxiety is associated with avoiding the content and poor performance (Aydin, 2021, Gómez-Chacón, 2000). Findings from mathematics education should not be generalized directly to statistics. Statistics anxiety was recognized as distinct from mathematics anxiety and should be considered a separate, though related, construct (Paechter et al., 2017). Few studies have investigated the relationships among statistics teaching efficacy, attitudes toward statistics, and statistics anxiety in primary PSTs. Akin and Kurbanoglu (2011) proposed a model in which mathematics self-efficacy predicted anxiety and attitudes among university students. Whether a similar model is applicable to statistics education remains an open question that this study seeks to address.

This study addresses the following research questions: RQ1: Is the hypothetical path model, as shown in Figure 1, which describes the causal effects among PSTs' attitudes toward statistics and statistics teaching efficacy on anxiety about statistics, consistent with the observed correlates among these variables? RQ2: If the hypothetical path model is consistent, what are the estimated direct, indirect, and total effects among PSTs' attitudes toward statistics and statistics teaching efficacy on anxiety about statistics?

Figure 1. Hypothetical path model.



Method

This study employed a nonexperimental, correlational research design using structural equation modeling to test how the constructs are theoretically linked and the directionality of the relationships. Path analysis examined the relationship between the exogenous variable, mediator variables, and the endogenous variable. The exogenous variable in the hypothetical model was statistics teaching efficacy. The mediator variables in the hypothetical model were the four subscales of attitudes toward statistics (affect, cognitive competence, value, and difficulty). The endogenous variable in the hypothetical model was anxiety about statistics. All variables were measured on the interval level scale.

The accessible population was primary PSTs enrolled in a primary teacher education program at a 4-year accredited non-profit university or college in the state. Forty-five universities or colleges were approached to participate in the study, and 11 schools agreed. Of the 11 schools, approximately 1,200 primary PSTs were approached to participate, and 358 primary PSTs (29.83%) responded to the survey. Two hundred ninety-seven data cases met the requirements for data analysis.

The study consisted of four demographic characteristic variables and three instruments measuring PSTs' statistics teaching efficacy, attitudes toward statistics across four subscales, and anxiety about statistics. Anxiety about statistics was measured using the Statistical Anxiety Scale (SAS) developed by Pretorius and Norman (1992). The SAS is a 10-item instrument measured on a 5-point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree. Low scores indicate high levels of anxiety about statistics. The SAS was originally validated in general university populations with strong internal consistency (α = .90). Its application to primary PSTs is justified due to its conceptual alignment with statistics anxiety and length.

Attitudes toward statistics were measured using the SATS-28 (Schau et al., 1995), a widely used 28-item instrument designed to assess four subscales: affect (6 items), cognitive competence (6 items), value (9 items), and difficulty (7 items). Items are rated on a 7-point Likert scale ranging from 1 = strongly disagree to 7 = strongly agree. SATS-28 has a validated four-factor structure confirmed by factor analysis, strong model fit, and good internal consistency (α=.70-.85).

Statistics teaching efficacy was measured using the Self-Efficacy to Teach Statistics (SETS) instrument developed by Harrell-Williams et al. (2014). The full instrument includes 26 items across two subscales: reading data and reading between the data. The instrument was rated on a 6-point scale from 1 (not at all confident) to 6 (completely confident). For this study, only subscale reading data (11 items) was used, as it aligns with statistical content taught at the primary school level. A pilot study (n = 32) was carried out to confirm the reliability of measuring primary PSTs' statistics teaching efficacy using the 11 items from subscale reading data (α=.92).

Results

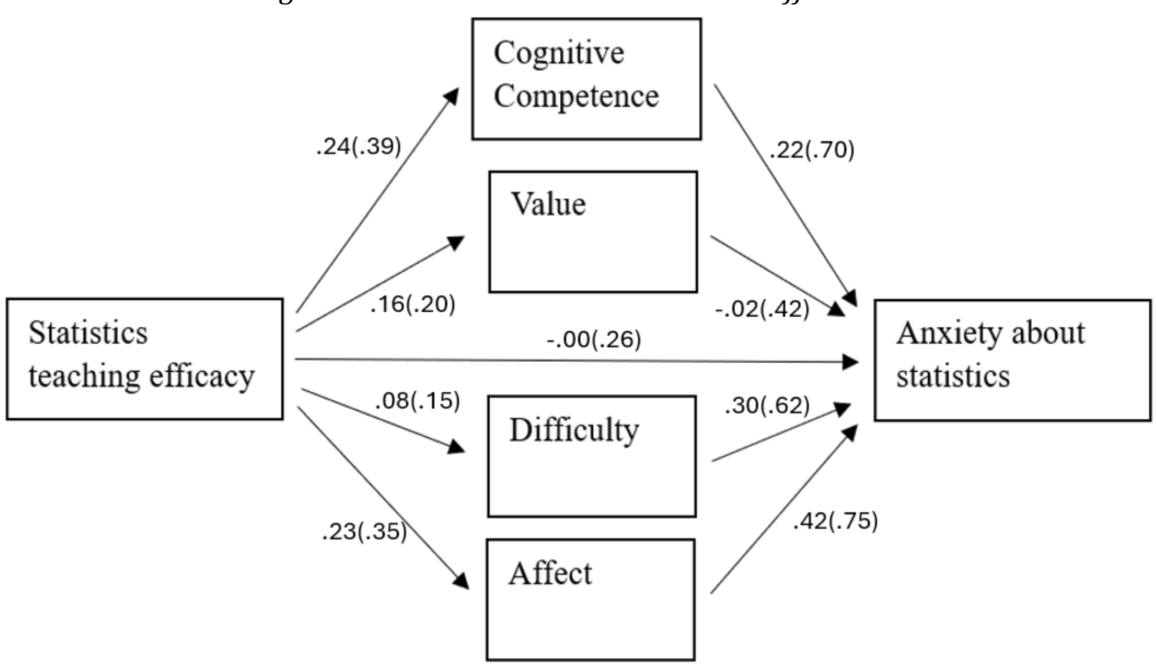
In this sample, 91.25% of primary PSMTs were female (n = 271). This finding is consistent with national teacher-demographic data (National Center for Education Statistics, 2023). All respondents had completed at least one college-level mathematics and statistics course, including AP, IB, or dual-enrollment courses taken in high school. Regarding their teacher preparation, the median number of years completed in a primary education training program was three (IQR = 2), with the highest number of respondents (n = 77, 25.92%) reporting three years and the fewest (n = 41, 13.80%) reporting one year.

Cronbach's alpha coefficient was used to assess the internal consistency of the scales. Cronbach's alpha ranged from .71 to .93, indicating acceptable to excellent reliability of each scale: statistics teaching efficacy (α = .93), affect (α = .85), cognitive competence (α = .83), difficulty (α = .71), value (α = .82), and anxiety about statistics (α = .92). The variables' mean total scores ranged from 20.79 to 40.91.

The strongest correlation was between affect and cognitive competence ($r(297) = .85$, $p < .001$), suggesting that students who feel more positively about statistics also tend to believe they are intellectually capable in the subject. This strong association suggests that emotional and cognitive dimensions of students' attitudes are closely linked. In contrast, the weakest correlation was between statistics teaching efficacy and perceived difficulty ($r(297) = .16$, $p < .01$), suggesting that confidence in teaching statistics is only minimally related to how difficult primary PSTs find the subject. Similarly, weak positive correlations were observed between teaching efficacy and value ($r(297) = .20$, $p < .001$), and between difficulty and value ($r(297) = .32$, $p < .001$). These findings suggest that while attitudes and efficacy are connected, they may operate as distinct factors in shaping primary PSTs' experiences with statistics.

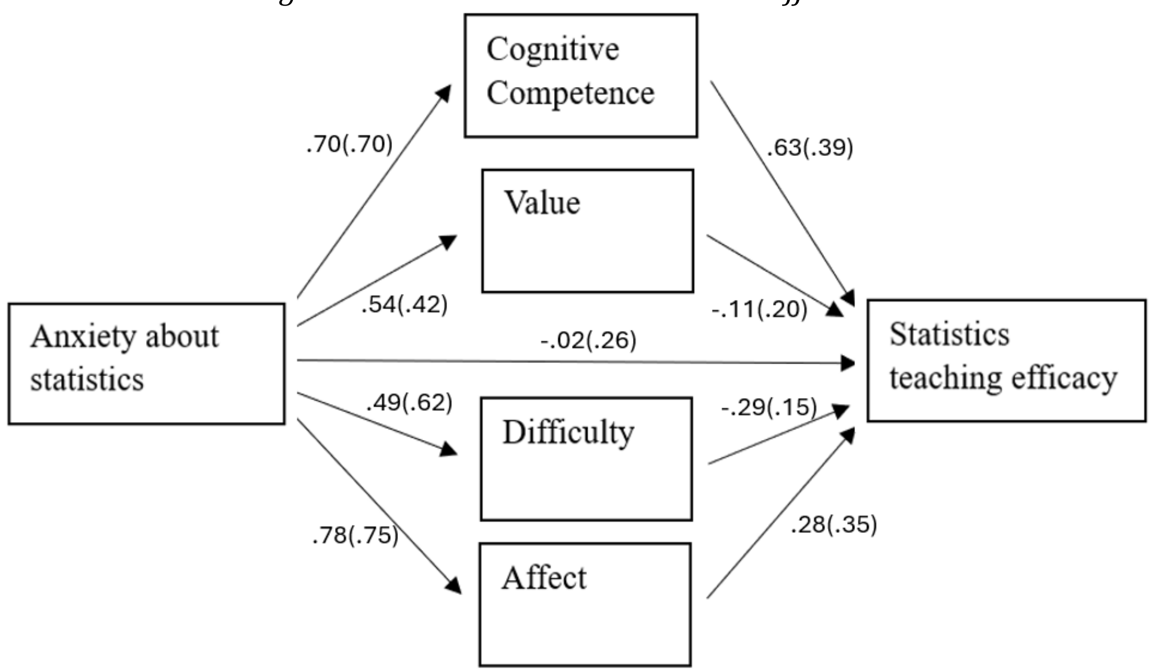
The model fit criteria considered in this study included the chi-square (X2), the root-mean-square error of approximation (RMSEA), and the standardized root mean square residual (SRMR). Model comparison was based on the comparative fit index (CFI) and Tucker-Lewis index (TLI). The model parameters, including path coefficients and variance estimates, were estimated using the maximum likelihood (MLM) estimation. The Satorra-Bentler scaled test statistic and scaled, robust fit indices are reported for each model. Figure 2 displays the results of the path analysis on Model 1, including standardized coefficients and correlation coefficients (in parentheses) for each pair of variables.

Figure 2. Model 1 with standardized coefficients.



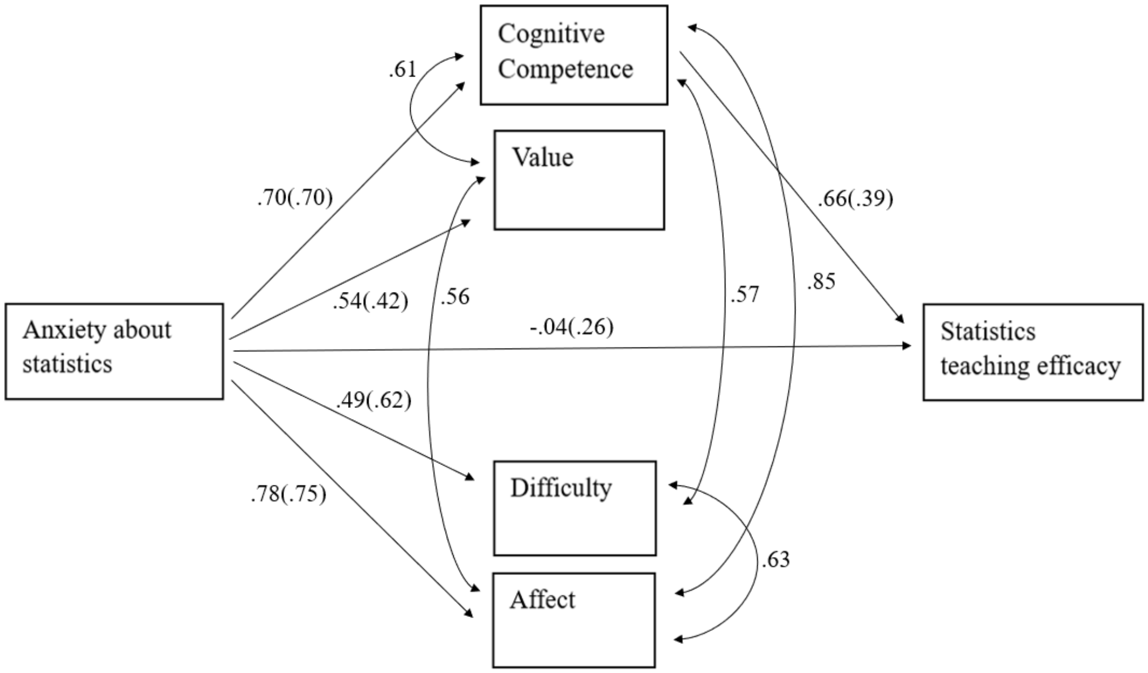
The Satorra-Bentler chi-square results, X2(df = 6) = 621.92, p < .001, and fit indices indicated Model 1 did not fit the observed data. Conducting modifications to Model 1 became necessary because of the poor fit of the data to the model. Guided by modification indices and rational thought, the model fit would improve if anxiety about statistics had a direct path to statistics teaching efficacy and had an indirect path to statistics teaching efficacy through affect, cognitive competence, difficulty, and value. This resulted in a second model, Model 2, that provided a better fit compared to Model 1. Figure 3 displays the results of the path analysis on Model 2, including standardized coefficients and correlation coefficients (in parentheses) for each pair of variables.

Figure 3. Model 2 with standardized coefficients.



The Satorra-Bentler chi-square results, X2(df = 6) = 621.92, p < .001, and fit indices indicated Model 2 did not fit the observed data. Modifications to Model 2 were tested by adding covariances among the mediator variables (affect, cognitive competence, difficulty, and value). This resulted in a saturated (just-identified) model with zero degrees of freedom. While a saturated model inherently provides a perfect fit to the data, it lacks parsimony. Upon inspection of the estimates in this saturated model, the path coefficients for affect, difficulty, and value were found to be statistically non-significant when regressed on statistics teaching efficacy. As seen in Figure 4, to achieve a more parsimonious model, these non-significant paths were removed, resulting in Model 3.

Figure 4. Model 3 with standardized coefficients.



In the final model, all fit measures agreed that Model 3 fits the observed data well, which indicates the hypothesized relationships among variables in Model 3 adequately represent actual patterns observed in the dataset. The Bollen-Stine bootstrapping method (Bollen & Stine, 1992) was employed to impose Model 3 on the sample data so that bootstrapping is done under Model 3. Five thousand bootstraps were performed, and results did not reject the null hypothesis of perfect fit (X2(df = 4) = 6.88, p = .18), suggesting Model 3 fits the data well. Table 1 presents a summary of the model fit indices across the three models.

Table 1. Summary of the model fit indices for each path model.

Model	X^2	df	*p* value	CFI	TLI	RMSEA	SRMR
Model 1	621.92 (328.30)	6	< .001 (.00)	0.38 (0.47)	-0.55 (-0.31)	0.59 (0.43)	0.33 (0.33)
Model 2	305.49 (219.68)	6	< .001 (.00)	0.70 (0.65)	0.25 (0.13)	0.41 (0.35)	0.13 (0.13)
Model 3	6.88 (6.24)	4	.14 (.18)	1.00 (1.00)	0.99 (0.99)	0.05 (0.04)	0.05 (0.04)

Note: Robust, scaled indices are listed in parentheses.

After determining whether the model fits the data and is theoretically consistent, the parameter estimates and individual tests of significance of each parameter estimate were interpreted. The results show evidence of a statistically nonsignificant path between anxiety about statistics and statistics teaching efficacy (β = -.04, Z = -0.23, p = .82). Cognitive competence had a significant positive path coefficient in its prediction on statistics teaching efficacy ($\beta = .66$, $Z = 4.47$, $p < .001$). This may imply that primary PSTs' positive attitudes toward knowledge and intellectual skill in using statistical knowledge (cognitive competence) significantly predicted high confidence in teaching statistics. Anxiety about statistics had significant positive path coefficients in its' prediction of affect ($\beta = .78$, $Z = 17.14$, $p < .001$), cognitive competence ($\beta = .70$, $Z = 14.90$, $p < .001$), difficulty ($\beta = .49$, $Z = 11.48$, $p < .001$), and value ($\beta = .54$, $Z = 7.40$, $p < .001$). This may imply that primary PSTs' who possessed low anxiety about statistics significantly predicted positive attitudes toward statistics through affect, cognitive competence, difficulty, and value.

Mediation analysis was conducted to test the effect of cognitive competence as a mediator in the prediction between anxiety about statistics and statistics teaching efficacy. Cognitive competence was significantly predictive of statistics teaching efficacy ($\beta = .66$, $Z = 4.47$, $p < .001$). Anxiety about statistics was not significantly predictive of statistics teaching efficacy in the absence of mediator cognitive competence ($\beta = -.04$, $Z = -0.23$, $p = .82$). However, anxiety about statistics was significantly predictive of statistics teaching efficacy through mediator cognitive competence ($\beta = .46$, $Z = 4.15$, $p < .001$). This may imply that low anxiety about statistics significantly predicted positive attitudes toward knowledge and intellectual skill in using statistical knowledge (cognitive competence), which, in turn, significantly predicted high confidence in teaching statistics. The total effect of anxiety about statistics on statistics teaching efficacy through mediator cognitive competence was significant ($\beta = .43$, $Z = 6.09$, $p < .001$).

Discussion

This study examined the relationships among primary PSTs' statistics teaching efficacy, attitudes toward statistics, and anxiety about statistics. We used structural equation modeling (SEM) to test a hypothesized model. Initial results showed poor model fit. Modifications were made based on statistical indices and rational thought. The revised model showed good fit and offered insight into how noncognitive factors contribute to pedagogical content knowledge in statistics.

Correlational analysis revealed weak but statistically significant positive associations between teaching efficacy and all four attitude toward statistics subscales. The strongest were with cognitive competence ($r(296) = .39$, $p < .001$) and affect ($r(296) = .35$, $p < .001$), suggesting that confidence in teaching statistics is modestly related to how capable and emotionally comfortable primary PSTs feel about statistics. However, path analysis showed that only cognitive competence significantly predicted teaching efficacy ($\beta = .66$, $Z = 4.47$, $p < .001$). This suggests that positive attitudes toward one's ability to understand and apply statistical knowledge play a critical role in developing confidence in teaching it.

The study also explored attitudes toward statistics using four subscales: affect, cognitive competence, difficulty, and value. Findings were similar to those of Batanero et al. (2005) and Hannigan et al. (2013). Specifically, primary PSTs reported positive emotional responses and confidence in their statistical ability. The strongest correlation was between affect and cognitive competence ($r(296) = .85$, $p < .001$), indicating that positive feelings about statistics are closely tied to perceived intellectual competence.

Path analysis revealed that anxiety significantly predicted all four attitude subscales. Lower anxiety was associated with more positive emotional responses ($\beta = .78$, $p < .001$) and greater cognitive competence ($\beta = .70$, $p < .001$). It was also linked to lower perceived difficulty (β = .49, $p < .001$) and higher perceived value (β = .54, $p < .001$). This supports the conclusion that anxiety plays a central role in shaping how primary PSTs feel about and interpret statistical content.

Statistics anxiety had moderate to strong correlations with all attitude subscales, especially affect ($r(296) = .75$, $p < .001$) and cognitive competence ($r(296) = .70$, $p < .001$). The direct relationship between anxiety and statistics teaching efficacy was weak ($r(296) = .26$, $p < .001$) and not statistically significant in the path model (β = –.04, $p = .82$). Thus, while anxiety is related to how primary PSTs think and feel about statistics, it does not directly influence their confidence in teaching. Instead, cognitive competence mediated the relationship between anxiety and teaching efficacy (β = .46, $Z = 4.15$, $p < .001$). Specifically, lower anxiety increases beliefs in statistical ability, which in turn boosts teaching confidence. In summary, anxiety affects teaching efficacy indirectly by shaping attitudes.

These findings highlight the importance of addressing noncognitive factors that may influence teaching and learning of statistics. Building primary PSTs' confidence in understanding and applying statistics is key to preparing them to teach statistics effectively. Interventions that reduce statistics anxiety and strengthen cognitive competence may help create more confident, capable future teachers.

Limitations

The study was limited to primary PSTs within teacher education programs in a southeastern state in the United States of America. This restricts the generalizability of the findings to this specific demographic. Extending these results to the broader population should be done cautiously. Since this research explored correlations between the constructs, causation cannot be established.

Structural equation modeling assumes relationships are linear and variables are measured without error. It also requires sufficiently large sample sizes. The sample size in this study met the assumptions; however, it remained small, which could have led to overfitting and less precise estimates. Additionally, misspecification of the model could have led to biased results. Therefore, future analyses and alternative statistical methods should be employed in future studies to confirm the findings of this study and add to the body of research.

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