

Pacific Northwest Agricultural Educators' Perceived Teacher Efficacy toward Enhancing Mathematics

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Abstract

Oregon and Washington agricultural educators were surveyed to determine the level of confidence in their mathematics problem solving ability and their perceived level of teaching efficacy. Personal mathematics efficacy and personal teaching efficacy were further analyzed in an effort to determine which factor had a greater influence on mathematics teaching efficacy. The constructs were measured using the Mathematics Enhancement Teaching Efficacy questionnaire developed specifically for the study. Using structural equation modeling, correlations were determined among the three constructs.

The results of the study concluded Oregon and Washington agricultural educators perceived themselves to be very efficacious in personal mathematics and teaching ability. In addition, the teachers reported a high degree of confidence in teaching mathematics within their curricula. Statistical analyses determined personal mathematics efficacy had a stronger correlation to mathematics teaching efficacy than personal teaching efficacy. The findings suggest a teacher's content knowledge, and not pedagogical knowledge, had more influence on efficacy related to enhancing interdisciplinary mathematics. This conclusion is important for designing professional development activities and determining the needs of pre-service agriculture teachers as efforts to enhance mathematics in agricultural education increase.

Introduction

With all good inventions, if people feel they don't know how to use the invention they likely will not have the desire to try it. Enhancing mathematics in agriculture lessons could share a similar fate. If agriculture teachers perceive they are not efficacious in their abilities to teach mathematical concepts embedded in their lessons, then efforts to enhance mathematic connections in agricultural education may be futile.

Career and Technical Education (CTE) will face many struggles for resources and identity in a standards-based environment stressing higher student achievement in core academics such as mathematics and science (Case, 2006). The struggles have prompted research in pedagogical methods and curriculum content for all of CTE instruction. The goal is to strengthen the academic rigor of interdisciplinary connections between CTE and core-academic subjects, such as science and mathematics.

The National Research Center for Career and Technical Education (NRCCTE) published the results from a multi-state project examining mathematics enhancement of CTE (Stone, Alfeld, Pearson, Lewis, & Jensen, 2006). The NRCCTE study found evidence to conclude student scores in mathematics could be improved using a prescribed pedagogical method that enhances

mathematics in CTE coursework. Mathematics performance was improved on standardized tests, and no significant difference in test scores for CTE content knowledge was determined between a control and experimental sample. The conclusions of the NRCCTE study provided evidence that CTE lessons can enhance student performance in mathematics without sacrificing CTE content objectives in the process.

Aspects the NRCCTE study did not examine were the effects of CTE teacher readiness or efficacy related to enhancing mathematics. Wu and Greenan (2003) suggest success and failure of student mathematics achievement in CTE programs is dependent on the confidence CTE teachers have toward the instruction of mathematical concepts. Wu and Greenan found that CTE teachers did not feel efficacious in their abilities to teach mathematics and suggested that CTE teachers be provided specific professional development aimed at integrating mathematics into their lessons.

Theoretical Framework

Teacher efficacy is rooted in self-efficacy theory most notably associated with the research of Albert Bandura. Self-efficacy is described as the beliefs in one's own ability to perform a task can affect his or her willingness to participate and influence the level of proficiency at which the individual will complete the task (Bandura, 1977). It was in later work that Bandura (1997) summarized the relationship among three interrelated components (environment, personal factors, and personal behavior) that he identified as the essential influences on self-efficacy beliefs of individuals.

Bandura's theory proposes that a person would alter their behavior toward a task depending on the perceptions they have about the environment and their own personal talents related to the task. For example, when applied to enhancing mathematics in agricultural education, a teacher may be more willing to add relevant instruction on mathematics concepts to their lesson if the school administration is encouraging the interdisciplinary connections and the teacher feels confident in their personal ability to perform mathematics. If one of those conditions is not positive, such as a low confidence in mathematics ability of the teacher, then the teacher may not feel as willing to promote mathematic applications in their lessons.

The specific environmental and personal factors that contribute to teacher efficacy vary widely and have dynamic characteristics based on the individual teacher (Tschannen-Moran & Woolfolk Hoy, 2001). However, once research provides the evidence of contributing factors, professional development programs, and other assistance can be targeted more specifically to improve teacher practice (Guskey, 1981).

Conceptual Framework

A teacher's perception of their efficacy towards classroom practice could have many interconnected factors. This study proposed to measure two constructs that literature provided evidence of direct links for having an influence on mathematics teaching efficacy. Personal mathematics efficacy is intended to measure a teacher's perceptions of their content knowledge mastery, and personal teaching efficacy measures pedagogical perceptions.

Because structural equation modeling was the mode of statistical analyses for our study, a hypothetical model must be derived from theory as the basis for determining model goodness of fit. The *a priori* model proposed is illustrated in figure 1.

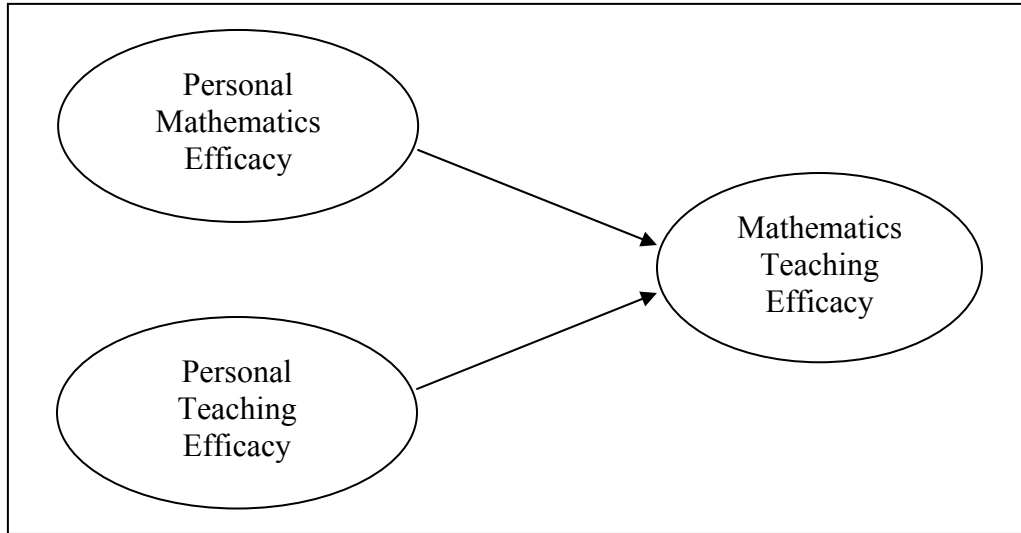


Figure 1. A conceptual model depicting relationships among personal mathematics efficacy and personal teaching efficacy with mathematics teaching efficacy.

The literature on mathematics teaching and teaching efficacy provided several instruments already developed to measure the constructs included in the hypothetical model. Of the many instruments, three were chosen because of their strong reliability and proven validity for measuring the intended constructs identified for this model.

Personal mathematics efficacy was measured using eight questions to solicit the perceptions teachers had toward their ability to solve mathematical problems. This scale was used initially by Schulz (2005, April) in a study of international college students. The original instrument has three parts, for the METE instrument only the eight questions pertaining to mathematics self-efficacy scale were used with slight modifications for the target population included in this study.

Tschannen-Moran and Woolfolk Hoy (2001) developed the Teachers' Sense of Efficacy Scale (TSES), an instrument design to determine pedagogical efficacy for three constructs including instructional strategies, classroom management, and student engagement. The short-form version of this instrument was used to measure personal teaching efficacy.

To provide the final test for correlating construct measures, mathematics teaching efficacy was measured using a third instrument component. The personal mathematics teaching efficacy subscale of the Mathematics Teaching Efficacy Beliefs Instrument (MTEBI) provided the data for the dependant variable in the model (Enochs, Smith, & Huinker, 2000). For the specific purposes of this study, slight modification to wording was done to reflect mathematics enhancement rather than teaching.

Purpose of Study

The purpose of this research study was to determine teacher efficacy beliefs that agricultural educators have toward enhancing mathematics in their curricula. Baseline knowledge regarding mathematics efficacy for Oregon and Washington agricultural educators was not available from previous studies. By surveying the population of teachers, valuable evidence was collected supporting conclusions for the perceptions of readiness of teachers to enhance mathematics concepts in their lessons. Data from this instrument was used to validate a conceptual model constructed to determine the most probable influences on teacher efficacy for this population.

Research Questions

Stone, et al. (2006) discovered a prescriptive system that was effective in achieving desirable results of student performance when enhancing interdisciplinary studies in mathematics. However, the results call into question what a teacher must know in order to be effective at teaching mathematical concepts in their lessons. This study focuses on two questions inspired, but not addresses by the NRCCTE study. Specifically, the research questions that were investigated included:

1. What is the current level of personal mathematics efficacy, personal teaching efficacy, and mathematics teaching efficacy of Oregon and Washington agricultural educators?
2. Which factor, personal mathematics efficacy or personal teaching efficacy, establishes the strongest correlation with a teacher's confidence in their ability to enhance mathematics in agricultural education?

Methods for Data Collection and Analyses

The Mathematics Enhancement Teaching Efficacy (METE) instrument was developed to assess teacher efficacy related to constructs pertaining to the enhancement of mathematics in interdisciplinary curricula (Jansen, 2007). The METE instrument contained 33 items that measured teacher efficacy associated with personal teaching efficacy, personal mathematics efficacy, and mathematics teaching efficacy. The METE instrument was used in a web-based format to survey Oregon and Washington agricultural educators. The results from the survey provided necessary data required to conduct structural equation modeling analyses.

A pilot study of Utah agricultural educators was conducted to field test the instrument. All aspects of the questionnaire administration were monitored during the pilot test to ensure clarity and effectiveness of questions, instructions, and delivery of questionnaire using the web-based format.

The target survey was intended to include the entire population of Oregon and Washington agriculture teachers. Teacher education institutions for the respective states provided contact information for potential participants. From these lists, 375 secondary agricultural education teachers were verified. The questionnaire was emailed to each agricultural educator teaching in these two states. A second email was sent to non-responders 10 days following the first survey period. A total of 230 responses were received to achieve a 61.3% response rate.

The data collected was screened for missing responses before statistical analyses were conducted. Of the 230 cases, 17 cases were found to be missing responses for efficacy related questions. The method chosen to deal with the missing data sets was to eliminate any cases that were incomplete. Kline (2005) suggests in large sample sizes (over 200 cases); it is justifiable to delete a few incomplete cases from the data set. For structural equation modeling analyses, the recommended sample size is 200 or more cases (Grimm & Yarnold, 1995; Kline, 2005). Therefore, it was determined dropping the 17 incomplete cases would be the most practical way of handling missing data and by doing so the sample size would be large enough not to compromise structural equation modeling analyses.

Following the data screening process, non-response error was controlled for because of the absence of a perfect response rate. MANOVA tests were used to compare responses from early respondents and late respondents. Research provides evidence to support the notion that non-responders and late-responders are similar; therefore if no significant difference is found between early and late responders the results can be generalized to the entire population (Miller, Torres, & Linder, 2005).

Structural equation modeling (SEM) provided the statistical analyses necessary to draw the conclusions for this study. SEM is a two-step process involving confirmatory factor analysis followed by the determination of correlations within a structural path model (Kline, 2005). Because SEM relies on confirmatory factor analysis to determine appropriate model fit, factors to be measured must be determined *a priori* from the literature and theory (Grimm & Yarnold).

Results

The following section reports the results for reliability, validity, descriptive statistics, and the structural equation path model derived from the statistical analyses conducted using EQS® software.

Reliability

Reliability of the METE instrument was assessed for the instrument as a whole and each contributing parts representing separate constructs of efficacy. The instrument in both the pilot and the target study proved to be very reliable at .927 and .905 respectively. Table 1 provides a summary of the reliability determinations for both the pilot study and the target study.

Table 1.

Reliability Analyses of Pilot Study Survey Instrument

Section Title	Pilot Study <i>alpha</i> Coefficient (N = 23)	Target Study <i>alpha</i> Coefficient (N = 213)
Mathematics Teaching Efficacy	.916	.884
Personal Mathematics Efficacy	.888	.836
Personal Teaching Efficacy	.908	.908
Overall Combined Efficacy Instrument	.927	.905

Validity

To establish face and content validity for the METE instrument, a panel of expert reviewers analyzed the questions and format for appropriateness and clarity. A field test of the instrument was conducted with Utah agricultural educators prior to administration of the survey to the target population in an effort to determine any potential changes to the questionnaire. Because the instrument was comprised of scales determined in previous studies found to be reliable and valid, only minor format and wording changes were made to the questionnaire instructions.

The first phase of structural equation modeling is confirmatory factor analysis (CFA). By conducting CFA, the researcher can determine if the items included in the questionnaire are measuring the intended factors as defined by theory. CFA is testing the goodness of fit of a model and differs from exploratory factor analysis (EFA). In EFA, items are grouped together and the groupings signify a factor. Because the researcher assigns specific items to a factor during CFA, construct validity is confirmed if the goodness of fit falls within acceptable parameters determined in CFA literature.

As a guide for the interpretation of the CFA results, Kline (2005) suggests chi-square, Comparative Fit Index (CFI), and Root Mean-Square Error of Approximation (RMSEA), as the three major considerations to determine a model's goodness of fit using the robust method. Table 2 presents the results for the instrument from the analyses using EQS® software.

Table 2.

Confirmatory Factor Analysis Results (N = 213)

Fit index	Statistic
Chi-square	627.932
CFI	.945
RMSEA	.037

Chi-square fit index, also referred to as the likelihood ratio, tests for the over-identification of a model. A *p*-value is calculated based on the chi-square statistic and the degrees of freedom for the test. The *p*-value significance level is typically set at .05 or .01 according to Bentler (1980). The analysis for this study concluded the *p*-value was .00002 based on the scaled chi-square

statistic and 489 degrees of freedom. Therefore, the null hypothesis is rejected and the model is found to be a good fit based on this specific fit index.

Bentler (1990) sets the minimum level of Comparative Fit Index at .90. CFI assesses the relative improvement in fit of a hypothetical model and a baseline model. For this study, the CFI was determined at .945 meeting the minimum threshold of acceptance. The RMSEA measures the error of approximation, or how well the model fits in relationship to the population covariance matrix (Kline, 2005). The higher the determined RMSEA value indicates evidence of a poor fitting model. Browne and Cudeck as cited by Kline suggest that the thumb rule for interpreting a good model fit is to determine a RMSEA index is value of $\leq .05$. Therefore, it can be concluded that all three tests for model fit fall into appropriate ranges of acceptability for CFA.

Another important aspect involved with CFA analyses is to determine the robustness of individual items used to measure factors. Coefficient values for measurement paths between the item and the factor were evaluated to the standard of $\pm .4$ as the minimum threshold for acceptance (Bentler, 1980). Only one item, MTE 1, was found to have a coefficient below the acceptable threshold of .400.

Descriptive Statistics

Each component included on the METE instrument used a specific scale to measure perceived efficacy. Table 3 provides an overview of the combined mean scores for each scale and reference to the specifics defining each scale. The results indicated in Table 3 report means at the upper end of the scales. This skewness suggests the respondents indicated a high level of perceived confidence in their abilities for each measure.

Table 3.
Means for Scales for Mathematics Enhancement Teaching Efficacy Instrument

Measurement	<i>M</i>	Scale
Personal Mathematics Efficacy (PME)	3.72	1-4 Confidence Scale (Not Confident to Very Confident)
Personal Teaching Efficacy (PTE)	7.30	1-9 Influence Scale (Nothing to A Great Deal of Influence)
Mathematics Teaching Efficacy (MTE)	3.71	1-5 Agreement Scale (Strongly Disagree to Strongly Agree)

Table 4 provides a complete summary of the means, standard deviations, and confirmatory factor analysis standardized factor loadings for each item included in the survey. The standardized factor loading is the estimated correlation coefficient determined for the relationship between the item and the factor for which the item measures.

Table 4.
Item Statistics with CFA Standardized Factor Loadings (N = 213)

Item	<i>M</i>	<i>SD</i>	Standardized Factor Loading	Item	<i>M</i>	<i>SD</i>	Standardized Factor Loading
MTE 1	3.91	.696	.338*	PME 5	3.83	.475	.824
MTE 2	3.42	1.182	.617	PME 6	3.64	.594	.763
MTE 3	3.52	.810	.730	PME 7	3.32	.777	.823
MTE 4	3.78	.836	.693	PME 8	3.82	.419	.753
MTE 5	3.93	.777	.729	PTE 1	8.05	1.081	.769
MTE 6	4.31	.751	.502	PTE 2	6.59	1.306	.794
MTE 7	3.73	.985	.608	PTE 3	7.06	1.141	.833
MTE 8	3.89	.709	.562	PTE 4	6.90	1.203	.790
MTE 9	3.33	1.085	.709	PTE 5	7.36	1.118	.678
MTE 10	3.39	1.226	.637	PTE 6	7.69	1.119	.834
MTE 11	3.90	.815	.708	PTE 7	7.52	1.101	.823
MTE 12	4.06	.850	.610	PTE 8	7.53	1.184	.889
MTE 13	3.06	.975	.532	PTE 9	7.47	1.147	.798
PME 1	3.63	.548	.786	PTE 10	7.68	1.015	.752
PME 2	3.88	.342	.729	PTE 11	6.45	1.389	.455
PME 3	3.84	.404	.644	PTE 12	7.29	1.148	.766
PME 4	3.83	.388	.701				

* Standardized factor loading is below the .400 acceptance threshold.

Structural Equation Model

Confirmatory factor analysis determined construct validity and provided evidence to accept the hypothetical model derived from the literature. The second and final step of structural equation modeling is to determine the strength of correlation among factors. In CFA, factor variances were set to unity for estimation of the variables and their variances. Structural models attempt to explain the variance for factors; therefore, this standardization step is not used. Also with CFA, measurement error estimation was important to determine covariance structure. The calculation of variable error values are replaced in a structural model by the calculation of prediction error of factors. This alteration is represented by the addition of disturbance estimates to the model.

Figure 2 provides an illustration of the structural model analysis. Coefficient estimates predicting the strength of correlations among the three factors under investigation are provided. A second order analysis for personal teaching efficacy was included because personal teaching efficacy is comprised of three independent constructs. The illustration shows a coefficient of .569 between personal mathematics efficacy and mathematics teaching efficacy and a coefficient of .233 between personal teaching efficacy and mathematics teaching efficacy.

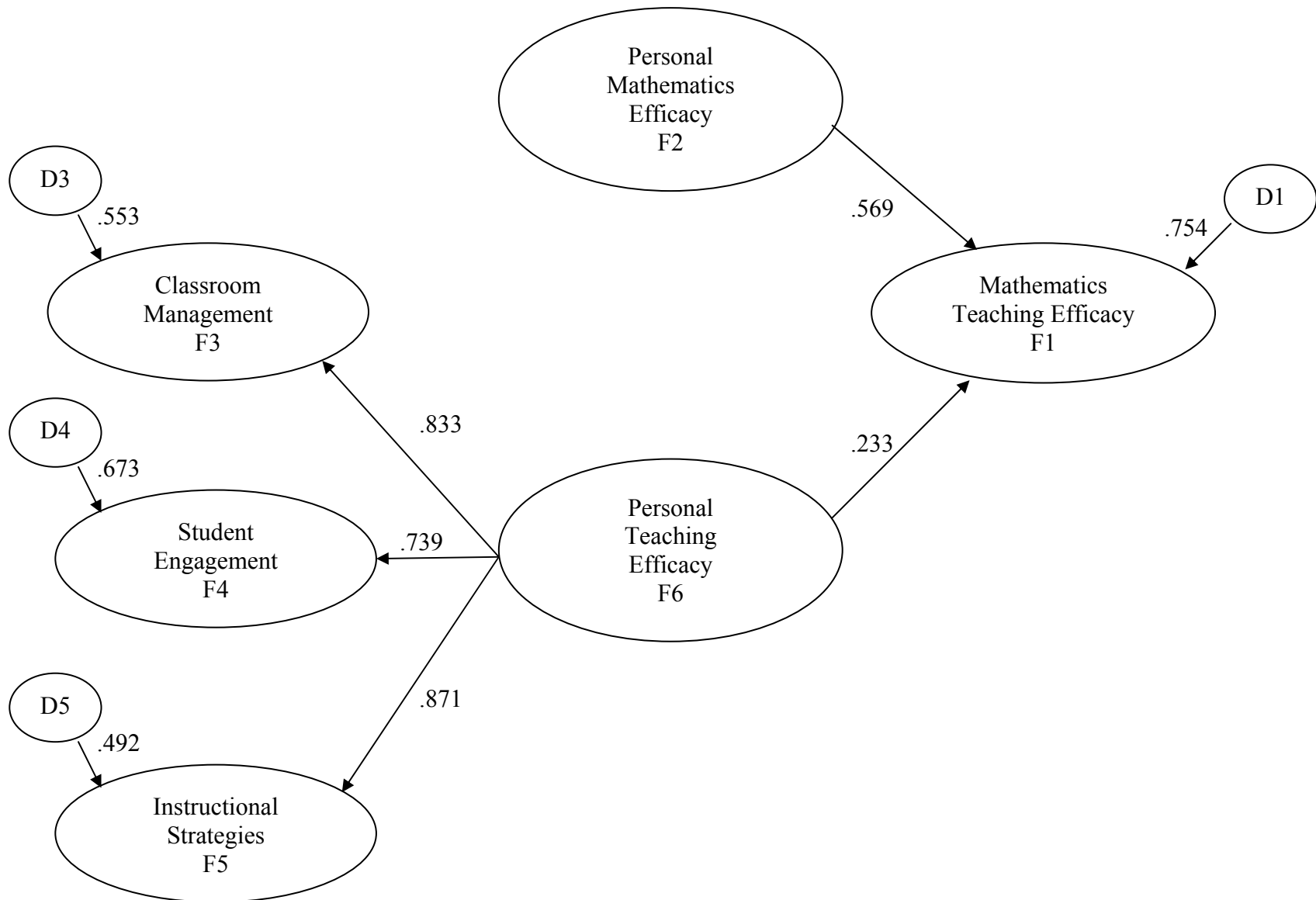


Figure 2. Structural equation model for mathematic enhancement teaching efficacy of Pacific Northwest agriculture education teachers.

Conclusions

The METE instrument was determined to be a reliable and valid instrument for measuring the constructs examined in this study. The survey included the entire population of Oregon and Washington agricultural educators and yielded 230 responses (61.3%). Steps to control non-response error determined that no significant difference existed between early and late responders; therefore, theory suggests that the study results can be generalized to the entire target population.

An expert panel of researchers verified the face and content validity of the METE instrument. Statistical analyses determined the alpha level for reliability of the METE instrument at .905. Confirmatory factor analysis verified the instrument items measured the intended constructs of efficacy identified by the literature. One item, MTE 1, was determined to have a correlation coefficient value below the acceptable .400 threshold. This item is suspect for removal from the instrument, however model fit indices were very acceptable, and analysis of model respecification was not significant to warrant removing the item.

The specific descriptive statistical findings indicate that Oregon and Washington agricultural educators perceive themselves as very confident in mathematics problem solving. Additionally, the respondents reported they had a high degree of confidence in their ability to engage students, use instructional strategies, and control classroom management, all issues comprising personal teaching efficacy. The teachers also tended to agree that they had confidence in their ability to enhance mathematics in lessons.

These findings indicate Pacific Northwest agricultural educators perceive themselves to be efficacious for the defining constructs related to mathematics enhancement included in this study. This conclusion addresses the first research question for the study. The second question was to determine which construct, personal mathematics efficacy or personal teaching efficacy, established the strongest relationship with mathematics teaching efficacy.

The second phase of structural equation modeling was used to estimate the correlation coefficient among factors. From this analysis, determinations can be made as to which construct of efficacy relates the strongest to mathematics teaching efficacy. The strongest relationship was indicated between personal mathematics efficacy and mathematics teaching efficacy with a coefficient of .569. This finding would suggest that personal mathematics efficacy has a greater impact on confidence to enhancing mathematics in agriculture lessons than efficacy in teaching practice.

Implications

Findings from the structural equation modeling analyses suggest that efficacy to enhance mathematics in lessons was largely associated with the teacher's perceived ability in doing mathematics rather than the perceived ability in pedagogy. Although a teacher may be very confident in their ability to teach, in this case subject knowledge has a stronger implication on their confidence to enhance mathematics.

Such a finding provides the evidence that Guskey (1981) suggests can be useful in determining how to narrow the focus for professional development activities. The METE instrument determined content knowledge specifically related to mathematics seems to have a greater influence on mathematics teaching than pedagogical techniques and strategies. These findings should influence the selection of programming for future professional development activities aimed to enhance mathematics in agricultural education lessons.

Another important implication that emerged from the findings in this study concerns pre-service preparation of agricultural educators. A closer examination of program requirements related to the level of mathematics exposure and proficiency in mathematics is called for. As agricultural education becomes a viable avenue for increasing the rigor and relevance of core-academic connections, pre-service teaching requirements in mathematics may need to be increased to meet the demands of interdisciplinary instruction.

Recommendations

Collective efficacy, as defined by Bandura (1997), asserts that efficacy has many influences which are shared among the culture that people interact in. Complete isolation is usually not a realistic condition for practicing teachers, they are influenced in ways to promote or hinder efficacy by the settings, people, individual goals for attainment, and resources they encounter in their lives.

Collective efficacy involves much more than subject matter content and pedagogical traits examined in this study. Alterations in teachers' culture, for example creating a professional learning community among mathematics and agriculture teachers, could produce very rapid changes in their perceptions of concerns related to the adoption of a new instructional strategy (Jansen, Enochs, & Thompson, 2006). Further investigation into traits that define efficacy of agricultural educators is very important to discover how best to establish confidence in teaching practices to improve mathematics enhancement of lessons.

Because of the challenges faced with researching collective efficacy, more case studies are needed to clearly grasp the complexities of agricultural educators. One important reason to warrant the call for observational studies is the value of qualitative data to support self-reported survey responses. Ross, McDougall, Hogaboam-Gray, and LeSage (2003) challenged the constraints to validity that self-reported surveys have in defining teacher habits relative to their reported self-beliefs. Their research found self-reported teacher results tended to differ from what the researchers observed first hand. By employing a qualitative assessment of mathematics enhancement activities, teacher needs toward professional development may have a more defined target.

The true measure of teacher efficacy is determining if the improvement in a teacher's confidence will result in positive changes in student achievement. A final recommendation would be a study comparing student mathematics achievement scores of two or more groups of teachers with varying levels of mathematics teaching efficacy. Such a study could provide another validation for the effectiveness of the theory and for the instrument designed to measure a teacher's confidence toward enhancing mathematics in their lessons.

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