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Agricultural Educators' Personal Teaching Efficacy Towards Individual STEM Subjects

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Abstract

STEM (Science, Technology, Engineering, and Mathematics) education is becoming an integral part of modern agricultural education. If the integration of STEM into agricultural education is to succeed, it is vital that educators feel confident in their ability to teach such material. This study examines Mississippi and Tennessee agricultural educators' personal teaching efficacy towards STEM subjects. Analysis indicated that educators felt most confident in their ability to teach science, followed by technology, mathematics, and then engineering. Recommendations for future research and practice include exploring agricultural educators' perceptions of and methods for teaching engineering, understanding the experience of minorities in STEM, and developing new courses for STEM-enhanced postsecondary agricultural educator preparation programs.

Introduction

STEM education is an essential area of study involving the study, teaching and implementation of science, technology, engineering, and mathematics (Gonzales & Kuenzi, 2012, p. 1). The subjects comprising STEM are responsible for the development of modern society, and play an important role in the continued advancement of humanity in the face of global challenges such as dwindling resources and increasing populations (Hossain & Robinson, 2012). Inherently included in those subjects is the contextualized STEM nature of agriculture (Swafford, 2018). If the country is to continue providing its citizens with the high quality of life to which they are accustomed, it is essential the STEM workforce of tomorrow be well-prepared to face emerging issues head on (Gonzales & Kuenzi, 2021; Hossain & Robinson, 2012). STEM and agriculture have long been said to share natural ties with one another (The Council for Agricultural Education, 2015) and in many cases were even seen to be inseparable, (Stubbs & Myers, 2016, p. 93). Both areas share a common history and underlying educational philosophy based in experiential learning and career preparation (Glancy & Moore, 2013; Knobloch, 2003). The earliest STEM-focused schools taught content through an agricultural context that sought to not only improve the production and quality of food, fiber, and technology, but also help farmers and tradesmen master their respective crafts and improve their livelihoods through practical education (Berg, 2002; Reynolds, 1992; Stevens, 1921). This led to the passage of the 1862 and 1890 Morrill Land Grant Acts and other initiatives

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including the Hatch Act of 1887, the Smith-Lever Act of 1914, and the Smith-Hughes Act of 1917 all of which concerned aspects of the public benefiting from agricultural education programs rooted in STEM principles (Hillison, 1996; Phipps et al., 2008).

The latter half of the 20th century saw a great change for agricultural and STEM education. Global conflicts, shifting needs, increasing expectations, and growing populations required the nation to continually be on the forefront of production and industry. The 1983 publication *A Nation at Risk: The Imperative for Educational Reform* served as a clarion call to the United States on the condition of academics and sought to fight "a rising tide of mediocrity" threatening America's perceived dominance on the global stage in economics, trade, innovation and technological development (The National Commission, 1983, p. 9). Unprepared educators, decreased student performance, and a lack of higher-order thinking skills were all included as factors affecting the quality of education in the United States (The National Commission, 1983). This challenge required all of education to more closely bind itself to STEM principles and topics (National Research Council, 1988).

As a response to *A Nation at Risk,* numerous initiatives pushed for increased integration of STEM content into all aspects of education (President's Council, 2012). However, these mandates have experienced roadblocks and issues in their implementation. One of the largest challenges to the success of STEM integration has been a lack of teacher training and experience in teaching STEM topics (Gonzales & Kuenzi, 2012). Many teachers find themselves unprepared to teach STEM material, especially when that material is seen as newer or more difficult. Teachers have reported feeling unsure of how to motivate students in STEM fields and careers, and others are unaware of what the different STEM disciplines entail (Gonzales & Kuenzi, 2012; Granata, 2014; Hirsch et al., 2005; McKim et al., 2015; Seelman, 2003).

While some consider STEM education to be a distinct cross-curricular academic discipline (Bybee, 2013; Dalton, 2009; Scherer et al., 2019), STEM is still viewed by many educators as four independent subjects, with prominence given to one subject above the others (Bybee, 2013; Ring et al., 2017; Scherer et al., 2019). This hierarchy is usually determined by a teacher's background and educational experiences, and can result in teachers emphasizing only the areas they prefer or feel most efficacious towards (Ring et. al., 2017). Research shows that the most covered STEM subjects are typically science and mathematics, with much less emphasis on technology and engineering (Bybee 2010; Scherer et al., 2019). This segregated view of STEM means educators will have differing efficacy levels – and thus differing beliefs, teaching methods, and areas of emphasis – towards the four individual STEM subjects. Such variance in preference, knowledge, and approach influences how students see and experience STEM content as well. If the goal is to integrate STEM more fully into agricultural education, we must first understand where individual strengths and weaknesses lie.

The United States education system is a primary source of career preparation for students entering all U.S.-based STEM and agricultural careers (Gonzales & Kuenzi, 2012; The National FFA Organization, 2019). STEM and agriculture have had long standing relationship in secondary education as methods as mutual beneficial to students understanding in both courses (Chaisson & Burnett, 2001; Clark et al., 2013; Enderlin & Osborne, 1992; McKibben & Murphy, 2021, Myers & Dyer, 2006; Myers & Thompson, 2009; Ricketts et al., 2006)The modern field of agriculture relies heavily upon STEM principles and it is imperative that our schools continually produce a large number of students to become professional scientific agriculturists (Doerfert, 2011). It is these very scientists and professionals that drive the 10% of individuals involved in the agricultural industry into ever increasing levels of efficient production through sustainability, the development of innovations, and a drive toward discovery that feeds and cloths the other 90% (Doerfert, 2011, USDA ERS, 2019).

In order to understand how STEM material might better be integrated into agricultural education, we must explore how individual teachers approach the task (Clark et al., 2021, Roberts et al., 2020, Smith et al., 2015). Integrating STEM requires teachers to make decisions regarding subject matter, background context, instructional methods, and classroom environment. Recognizing how these choices are made can assist in identifying key factors playing into the success or failure of STEM integration.

Theoretical Framework

Social Cognitive Theory

This study examined agricultural educators' integration of STEM utilizing Bandura's (1986) Social Cognitive Theory. Social Cognitive Theory is one of the foundational theoretical frameworks that all aspects of agricultural education share and is ubiquitously understood across the discipline (Harder et al. 2021). Bandura's theory posits that human learning is an internal and self-regulated process developed by observing the actions of others and reflecting upon the outcomes. Information gathered during the observation phase is used to make decisions regarding one's future actions. The reflection process is governed by the interaction of three factors unique to each individual: personal characteristics, past behavior, and social environment (Bandura, 1986; McKim & Valez, 2016; Pajares, 2002). These three factors all interact with one another in what is known as a triadic reciprocality (Bandura, 1986; Pajares, 2002).

Self-Efficacy

Of the three factors, personal characteristics are often considered the most influential to Bandura's theory (Pajares, 2002). According to Bandura personal characteristics include a person's mental and emotional factors, their ability to understand their own thinking and behavioral processes, and their self-efficacy (Bandura, 1986; Snowman et al., 2000). Self-efficacy relates to a person's confidence in their ability to achieve desired outcomes within a specific context or domain. Self-efficacy can affect one's choices, goals, motivation, outlook, persistence, and response to challenges (Bandura, 1986; Pajares, 2002). People with high self-efficacy are more likely to appraise their skills and situations positively, take on difficult opportunities, manage stress effectively, and persevere over obstacles than those with low self-efficacy (Bandura, 1994).

Self-efficacy is developed from four sources of information: mastery experiences, vicarious experiences, social persuasion, and psychological reactions (Bandura, 1986; Pajares, 2002; Rittmayer & Beier, 2008). Mastery experiences describe a person's previous direct personal experience with or performance on a task. They are powerful influences which can significantly predict one's current self-efficacy level and ability to succeed (Rittmayer & Beier, 2008). Successful mastery experiences increase self-efficacy in related domains, while unsuccessful ones decrease it.

Vicarious experiences involve a person learning through observation alone. While less influential than mastery experiences, vicarious experiences help a learner develop an understanding of what must be done to complete the desired task correctly. Research shows that vicarious experiences are most effective when the observer can relate to the role model in some way and thus envision themselves performing the task (Bandura, 1986; Pajares, 2002).

Social persuasion is the impact that others have upon a learner's self-efficacy. Positive opinions, feedback, and encouragement build efficacy, while negative feedback reduces it. Social persuasion works best when the individual already has some confidence in their ability, and when it comes from someone the learner considers influential (Bandura, 1986; Pajares, 2002).

Physiological reactions are the fourth source of self-efficacy. Experiences – especially those where success is not certain – create emotional and physical reactions. If we interpret a reaction as positive, we are more likely to develop higher levels of self-efficacy. If we view the reaction as negative, the opposite occurs. Thus, it is important to help learners feel calm, in control, and optimistic towards their desired task (Bandura, 1986; Pajares, 2002).

Teaching Self-Efficacy

While people do possess an overall sense of general self-efficacy, self-efficacy can also be domain- or task-specific (Bandura, 1997). This mean's a person's self-efficacy may vary significantly depending upon what they are trying to achieve. One area of particular note is teaching self-efficacy. Tschannen-Moran et. al (1998) defined teacher self-efficacy as an educator's confidence in their ability to successfully manage and complete specific tasks in context.

There are two types of teacher self-efficacy: personal teaching efficacy and outcome expectancy (Tschannen-Moran et al., 1998). Personal teaching efficacy is a teacher's confidence level regarding their teaching ability and ability to overcome obstacles that hinder student learning (Protheroe, 2008; Tschannen-Moran et al., 1998). Outcome expectancy is a teacher's belief in their ability to influence factors that cannot be completely controlled (Tschannen-Moran et al., 1998). A teacher's level of efficacy is both situation- and subject-specific, and teachers have various levels of efficacy depending on the subject they teach or the student they are working with (Tschannen-Moran et al., 1998).

Higher levels of teacher efficacy are correlated with improved classroom performance, behavior management, enthusiasm, motivation, organization, patience, resilience, and positivity (Bandura, 1994; Protheroe, 2008; Tschannen-Moran & Woolfolk Hoy, 2001). Burris et al. (2010) found that fifth year agricultural educators had higher efficacy levels towards science topics than first year educators, agreeing with Bandura's (1994) theory that personal mastery experiences are effective at building efficacy. Ulmer et al. (2013) found that participation in a Curriculum for Agricultural Science Education (CASE) institute increased both personal teaching efficacy and outcome expectancy towards science-related subjects. Ferand et al. (2020) observed non-significant increases in agricultural educator personal teaching efficacy and outcome expectancy after completing a course on the science of floriculture. Carr et al. (2020) found agricultural educators reported using more interactive class activities for science than for technology, engineering, and mathematics, which indicates that higher efficacy is in play. Interestingly, Hamilton and Swortzel (2007) found that while agricultural educators' personal teaching efficacy towards science was high, a low but negative relationship existed with their actual ability to teach science integrated process skills.

Purpose and Objectives

The purpose of this study was to identify agricultural educators' efficacy towards the integration of science, technology, engineering, and mathematics (STEM) content into agricultural education. To achieve this purpose two objectives guided this study.

1. Determine Mississippi and Tennessee agricultural educators' personal teaching efficacy levels towards science, technology, engineering, and mathematics (STEM).
2. Determine the items that have the largest influence on a teacher's efficacy to teach individual STEM disciplines.

Methods and Procedures

The population for this study was in-service agricultural educators in Mississippi and Tennessee (*N* = 447). These states were purposefully selected because they displayed a wide variety of agricultural programs, educational cultures, and technological availability and were within the same geographic region. Participant contact information was provided by the Mississippi Department of Education and the Tennessee FFA Association. Approval to carry out this study was given by the Mississippi State University Institutional Review Board (IRB). All participants were contacted by email and asked to participate in the study.

Instrumentation

Respondents were asked to complete a portion of the Science, Technology, Engineering, Mathematics, and Elementary Teacher Efficacy and Attitudes toward STEM (T-STEM) Survey instrument originally developed by The Friday Institute for Educational Innovation at North Carolina State University (2012). The instrument was edited to reflect the needs of the study by removing all portions not pertaining to secondary-level educators' personal teaching efficacy. The instrument consisted of 11 statements pertaining to personal subject-specific teaching efficacy. Statements included "I am continually improving my [subject] teaching practices," and "I know the steps necessary to teach [subject] effectively." Respondents were asked to note their level of agreement or disagreement with each statement on a 5-point scale. This scale ranged from 1 = strongly disagree, to 5 = strongly agree (Unfried et al., 2014). The same procedure was followed for teachers of technology, engineering, and mathematics, resulting in an examination of teaching efficacy towards individual STEM components and not on STEM efficacy as an overarching construct. Although STEM is often viewed as one concept, the authors chose to represent each STEM area individually due to the domain specificity of teaching self-efficacy. Respondents completed the instrument once for each STEM discipline, with the appropriate name of the discipline inserted into statements where appropriate. As the instrument contained 11 items, participants were asked to complete 44 items in total.

The survey was pilot tested with 31 in-service agricultural educators from Alabama. Pilot test respondents were selected based on their similarity to the target population and were contacted via email. Based on feedback on face validity from the pilot study only one minor grammatical edit was made. Based on the pilot data a Cronbach's Alpha was calculated each section; science ($\alpha = 0.86$); technology ($\alpha = 0.70$), engineering ($\alpha = 0.82$) ; and mathematics ($\alpha = 0.84$). It was determined that the instrument was reliable (Nunnally, 1978).

Data Collection

Data collection occurred through the Qualtrics online survey platform. The (*N* = 447) agricultural educators in Mississippi and Tennessee were contacted through email and asked to complete the survey and followed Dillman's tailored design suggestions (2009). A link to the survey was also provided. An email reminder was sent one week after the initial survey release, followed by a second two weeks later. A total of three contacts were made with the population to elicit response.

Collected data were analyzed using IBM Statistical Package for Social Sciences (SPSS) Version 24. Item means and standard deviations as well as construct means and standard deviations for each of the four STEM subject areas were calculated. True limits for this questionnaire were 11-220, with 11-55 being the true limits per construct.

Ninety-one agricultural educators participated in the study, resulting in a 20% response rate. Of these 91 respondents, 79 provided demographic information: 32 teachers from Mississippi and 47 teachers from Tennessee. Based on Lindner et al.'s (2001) recommendation for handling non response error (Method

1) results were analyzed based on early versus late respondents. Results revealed that there were no significant differences between early and late respondents.

Results

Respondents

The average age of respondents was 41.26 years (*SD* = 12.01), with the youngest indicating they were 23 years of age and the oldest indicating they were 65. Forty-three respondents were male (54.43%) and 36 were female (45.57%). The majority of respondents indicated they were white (*f* = 76, 96.20%). Two were Black/African American (*f* = 2, 2.53%), and one selected they were ethnically "other" (*f* = 1, 1.27%).

Teaching career length varied from less than one year of experience (*f* = 5, 6.3%) to 42 years of experience (*f* = 1, 1.2%) with an average length of 14.14 years (*SD* = 9.30). Seventy-eight respondents possessed a bachelor's degree. Of those, 34 (43.59%) majored in agriculture fields outside of agricultural education, 36 (46.15%) majored in agricultural or extension education, four respondents (5.13%) did not report their major, and three earned their degree outside of the field of agriculture (3.8%). The one respondent without a bachelor's degree was alternatively certified and was working towards their bachelor's degree at the time of the study.

Objective One

Objective one determined Mississippi and Tennessee agricultural educators' personal teaching efficacy levels towards individual STEM subjects. Results showed that teachers had the highest teaching efficacy score relating to the field of science (*M* = 46.04, *SD* = 5.21), followed by the fields of technology (*M* = 41.06, *SD* = 5.80), mathematics (*M* = 37.95, *SD* = 7.49), and then engineering (*M* = 35.39, *SD* = 7.76). It is noted that engineering and mathematics had the highest measures of variability reflecting a high degree of irregularity in teachers' efficacy (Table 1).

Table 1

Agricultural Educators' Mean Personal Teaching Efficacy Towards Individual STEM Subjects

STEM Field	*M*	*SD*
Science	46.04	5.21
Technology	41.06	5.80
Mathematics	37.95	7.49
Engineering	35.39	7.76

Objective Two

Objective two determined the items that have the largest influence on a teacher's efficacy to teach individual STEM disciplines through the 11-item T-STEM instrument. Science demonstrated the highest reported efficacy levels (*M* = 46.04, *SD* = 5.21). The individual items with the highest means were "I am continually improving my science teaching practice," (*M* = 4.53, *SD* = 0.52), "I am confident that I can teach science effectively" (*M* = 4.36, *SD* = 0.64), and "I am confident that I can answer students' science questions" (*M* = 4.35, *SD* = 0.56). Items with the lowest means were "I would invite a colleague to evaluate my science teaching" (*M* = 3.98*,* *SD* = 0.81), and "I wonder if I have the necessary skills to teach science"

(*M* = 3.35, *SD* = 1.19). This last statement required reverse coding, as it was phrased in a negative manner (Table 2).

Table 2

Agricultural Educators' Personal Teaching Efficacy Towards Science

Item	*M*	*SD*
I am continually improving my science teaching practice.	4.53	.52
I am confident that I can teach science effectively.	4.36	.64
I am confident that I can answer students' science questions.	4.35	.56
When teaching science, I am confident enough to welcome student questions.	4.33	.59
I understand science concepts well enough to be effective in teaching it.	4.32	.63
I am confident that I can explain to students why science experiments work.	4.30	.64
When a student has difficulty understanding a science concept, I am confident that I know how to help the student understand it better.	4.26	.55
I know the steps necessary to teach science effectively.	4.26	.64
I know what to do to increase student interest in science.	4.00	.86
Given a chance, I would invite a colleague to evaluate my science teaching.	3.98	.81
I wonder if I have the necessary skills to teach science. *	3.35	1.19

Note. 1 = Strongly Disagree, 5 = Strongly Agree, * Reverse coded, n = 91

For technology (Table 3), the overall mean score for teaching efficacy in regard to technology was 41.06 (*SD* = 5.80). The statements with the highest level of agreement were "I am continually improving my technology teaching practice" (*M* = 4.11, *SD* = 0.62), "when I am teaching technology, I am confident enough to welcome student questions" (*M* = 4.02, *SD* = 0.64), and "I am confident that I can teach technology" (*M* = 3.85, *SD* = 0.77). Teachers felt the least confident about the statements "Given a chance, I would invite a colleague to evaluate my technology teaching" (*M* = 3.62, *SD* = 0.90), and "I wonder if I have the necessary skills to teach technology" (*M* = 3.02, *SD* = 1.08).

Table 3

Agricultural Educators' Personal Teaching Efficacy Towards Technology

Item	*M*	*SD*
I am continually improving my technology teaching practice.	4.11	.62
I am confident that I can teach technology effectively.	4.02	.64
I am confident that I can answer students' technology questions.	3.85	.77
When teaching technology, I am confident enough to welcome student questions.	3.79	.76
I understand technology concepts well enough to be effective in teaching it.	3.78	.72
I am confident that I can explain to students why technology experiments work.	3.76	.76
When a student has difficulty understanding a technology concept, I am confident that I know how to help the student understand it better.	3.73	.68
I know the steps necessary to teach technology effectively.	3.70	.70
I know what to do to increase student interest in technology.	3.69	.83
Given a chance, I would invite a colleague to evaluate my technology teaching.	3.62	.90
I wonder if I have the necessary skills to teach technology. *	3.02	1.08

Note. 1 = Strongly Disagree, 5 = Strongly Agree; * Reverse coded, n = 91

Mathematics (Table 4) had the third highest levels of personal teaching efficacy (*M* = 37.95, *SD* = 7.49). The statements with the highest mean were "When teaching mathematics, I am confident enough to welcome student questions" (*M* = 3.48, *SD* = 0.97), followed by "I am confident that I can explain to students why mathematics experiments work" (*M* = 3.38, *SD* = 0.90), and "I know what to do to increase student interest in mathematics" (*M* = 3.27, *SD* = 0.99). The statements with the lowest levels of confidence were "I know the steps necessary to teach mathematics effectively" (*M* = 3.07, *SD* = 0.92) and "I wonder if I have the necessary skills to teach mathematics" (*M* = 2.84, *SD* = 1.00).

Table 4

Agricultural Educators' Personal Teaching Efficacy Towards Mathematics

Item	*M*	*SD*
When teaching mathematics, I am confident enough to welcome student questions.	3.48	.87
I am confident that I can explain to students why mathematics experiments work.	3.38	.90
I know what to do to increase student interest in mathematics.	3.27	.99
I am confident that I can answer students' mathematics questions.	3.25	.95
When a student has difficulty understanding a mathematics concept, I am confident that I know how to help the student understand it better.	3.24	.87
I am confident that I can teach mathematics effectively.	3.24	.97
Given a chance, I would invite a colleague to evaluate my mathematics teaching.	3.24	1.04
I am continually improving my mathematics teaching practice.	3.19	.95
I understand mathematics concepts well enough to be effective in teaching it.	3.19	.96
I know the steps necessary to teach mathematics effectively.	3.07	.92
I wonder if I have the necessary skills to teach mathematics. *	2.84	1.00

Note. 1 = Strongly Disagree, 5 = Strongly Agree, * Reverse coded, n = 91

Engineering (Table 5) had the lowest level of teaching efficacy and highest standard deviation of the four STEM areas (*M* = 35.39, *SD* = 7.76). The statements with the highest mean scores were "When teaching engineering I am confident enough to welcome student questions" (*M* = 3.48, *SD* = 0.97), "I am confident that I can explain to students why engineering experiments work" (*M* = 3.38, *SD* = 0.90), and "I know what to do to increase student interest in engineering" (M = 3.27, SD = 0.99). The statements with the lowest means were "I know the steps necessary to teach engineering effectively" (*M* = 3.07, *SD* = 0.92), and "I wonder if I have the skill necessary to teach engineering" (*M* = 2.84, *SD* = 1.00).

Table 5

Agricultural Educators' Personal Efficacy Towards Engineering

Item	*M*	*SD*
When teaching engineering, I am confident enough to welcome student questions.	3.48	.97
I am confident that I can explain to students why engineering experiments work.	3.38	.90
I know what to do to increase student interest in engineering.	3.27	.99

I am confident that I can answer students' engineering questions.	3.25	.95
When a student has difficulty understanding an engineering concept, I am confident that I know how to help the student understand it better.	3.24	.87
I am confident that I can teach engineering effectively.	3.24	.97
Given a chance, I would invite a colleague to evaluate my engineering teaching.	3.24	1.04
I am continually improving my engineering teaching practice.	3.19	.95
I understand engineering concepts well enough to be effective in teaching it.	3.19	.96
I know the steps necessary to teach engineering effectively.	3.07	.92
I wonder if I have the necessary skills to teach engineering. *	2.84	1.00

Note. 1 = Strongly Disagree, 5 = Strongly Agree, * Reverse coded, n = 91

Conclusions and Recommendations

School Based Agricultural educators' overall personal teaching efficacy levels towards STEM subjects was high, especially with science and technology. Based on Bandura's (1994) suggestions that highly efficacious people are more likely to appraise their abilities positively, these results could indicate agricultural educators in Mississippi and Tennessee have backgrounds heavy in science and technology, but not in mathematics and engineering. This aligns with the degree plans of both major institutions certifying agricultural educators in Mississippi and Tennessee and supports the work of Bybee (2013) and Ring et al. (2017), who reported teachers approach STEM differently depending upon their educational background and subjects taught.

However, respondents reported feeling confident in their ability to teach STEM regardless of knowledge or experience. Teachers ranked the statement "I wonder if I have the skills necessary to teach __," the lowest for each STEM field. "I know the steps necessary to teach __ effectively" was also lowly ranked for all STEM areas. This reflects a highly efficacious attitude, as teachers who possess higher levels of efficacy are more likely to believe in their own abilities, take on greater challenges, and experiment with their teaching methods and materials (Tschannen-Moran & Woolfolk Hoy, 2001). Even if teachers were not familiar with the material, they did not doubt they possessed the skills to teach it effectively and to entertain students' STEM-related questions. Question-rich environments are characteristic of highly engaging and student-centered classrooms and highly efficacious teachers. (Tschannen-Moran & Hoy, 2001). However, this could be a function of the "Grin and Bear It – Silence" as described by Traini et al. (2020, p. 182). Traini et al. (2020) described new teachers as being silent or bordering on falsely optimistic about their weaknesses as educators. This could stretch to a silence or false outward optimism about abilities that seem to purvey agriculture teaching.

For science and technology, teachers reported they were continually improving their teaching practices and indicated a feeling of confidence in their understanding of and ability to teach science and technology. This would be expected considering Bandura (1986) and Tschannen-Moran and Woolfolk Hoy (2001) associated higher self-efficacy with an increased desire to improve oneself and one's abilities so that future goals might be achieved. Counter intuitively however, teachers were not particularly amenable to allowing a colleague to evaluate their teaching in science and technology, which seems paradoxical when considering their continuous self-improvement. Teachers seemed to be very clear and unified about their desire to improve, but reluctant to have anyone help them in that improvement. This again, could be related to the idea that agriculture teachers feel a sense of expectation and any lack of ability or knowledge could be seen poorly by peers/potential rivals (Clemons et al, 2021; Traini, et al, 2022).

Teachers on the whole felt as though they could handle students' questions well. When asked about engineering and math constructs, teachers indicated that they felt the most efficacious welcoming students' questions. Typically, this indicates a strong grasp on the knowledge or information that could be in the realm of questioning. But teachers indicated that was not the case. This was the area they had the least knowledge about. Teachers also felt less positive about their ability to help struggling students better understand science and technology material while at the same time reporting an ease with their ability to answer student's STEM based questions. A strong background in science would likely lead to teachers being exposed to deeper and more complex concepts, although they may feel that their ability to explain these concepts on a high school level is lacking. Results agree with Chumbley et al. (2019), who found agricultural educators felt less confident teaching topics that required deeper thinking and greater knowledge of STEM processes than classification and concrete knowledge. This discontinuity between teaching a topic and answering questions from students is troubling. We would suggest this might be a function of teachers, especially secondary teachers feeling comfortable turning the question back on the student as a means to obfuscate or distract from their lack of knowledge. This would be more of an indicator of teachers social-emotional capacity or knowledge of personal interaction and student management than ability to teach the subject, indicating more of an ability to understand the physical/cultural dynamics of a classroom than the information being taught (Bandura, 1994).

In light of the overall positive response to any efficacy questions that concerned interacting with students it was surprising that teachers were less confident about how to interest students in STEM subjects. This could indicate their lack of understanding of the subject matter, or a lack of understanding what students find to be "interesting" or "engaging" aspects of STEM. Such results could be related to teachers' lack of personal interest in STEM concepts and teachers' inability to see past what they themselves do not find appealing. This supports Bandura (1994), Tschannen-Moran and Woolfolk Hoy (2001), and Protheroe (2008), who wrote that highly efficacious teachers are better able to motivate and work with students regardless of their learning difficulties, behavior, or backgrounds. This also parallels the work of Festinger (1957) and could be an indicator of the teacher's cognitive dissonance toward STEM as a concept.

For engineering and mathematics, respondents felt most confident in their ability to increase student interest in those fields, assist students struggling with engineering and mathematics concepts, and felt as though they could explain to students why engineering and mathematics experiments worked. While these results do agree with Bandura's (1994) and Tschannen-Moran and Woolfolk-Hoy's (2001) ideas of self-efficacy in the classroom, they also point to areas of need identified by Carr et al. (2020). Carr et al. (2020) found agricultural educators used far fewer and less varied activities to teach engineering than they did for other STEM areas. They suggested that teachers are likely not aware of appropriate communities of practice for engineering or prefer to use only resources they comfortable with (Carr, 2020). The fact that respondents felt more efficacious in their ability to help a student having difficulties in mathematics and engineering than they did in science and technology could also indicate teachers do not realize the full extent of engineering and mathematics fields and are able to bring students up to their level of understanding more easily. Stripling and Roberts (2012) found preservice agricultural educators "were not proficient in solving agricultural mathematics problems" (p. 28) and most had not completed higher-level mathematics courses in either high school or college. This, combined with common perceptions of engineering and mathematics as difficult subjects, likely caused teachers to express lower levels of teaching self-efficacy regarding the integration of those subjects supporting the suggestions of a cognitive dissonance or bias (Festinger, 1957).

Results of this study indicate that teachers did not display high levels of efficacy in their ability to teach engineering. Engineering is often the least understood and least integrated field of all the STEM subjects (Stubbs & Myers, 2015; Yoon et al., 2012). Engineering as a field includes a number of specific branches such as chemical, civil, agricultural, environmental, audio, computer, and marine engineering (NACME, 2013). This variety may increase confusion about what engineering truly is and make it difficult for educators to connect agricultural concepts to engineering fields. Many engineering principles are already inherent to agricultural education classes, but it is possible that educators have not realized this, or do not feel confident relating agricultural topics into an engineering context. Engineering is also known for its heavy use of mathematics, which results indicate was similarly not an efficacious subject for agricultural educators.

The authors recommend teacher educators expose preservice teachers to a broad variety of STEM concepts early in their college careers. This should be both through traditional coursework and through courses specifically tailored to teach STEM education techniques. Both options have been shown to boost teacher efficacy towards STEM subjects (Mahler & Benor, 1984; McCall, 2017; Riggs, 1995). However, courses of study for agricultural education should not go far beyond the boundaries of what educators will be required to cover in their classrooms. Darling-Hammond (2000) found that increased course load in STEM subjects led to increased STEM teaching efficacy – up to a point. Once course material outpaced the needs of secondary education curricula, teacher efficacy fell. Thus, postsecondary teacher education pathways should include a sampling of courses covering all STEM disciplines, and not just greater emphasis on one or two. In order to determine which courses are necessary, teacher educators should correlate the material covered in STEM courses within teacher preparation pathways with the topics that must be covered according to state and national standards. This will help educators better prepare their students for teaching STEM subjects and make effective choices when developing curricula and selecting courses for student schedules. Such courses should also be tailored to help students more specifically address the material they will be required to teach; develop teaching methods and activities useful for explaining, demonstrating, and practicing this content; and lead students to participate in deeper thinking and greater contextual understanding about the topics they are covering. While this would vary from state to state, providing students with mastery experiences in these subjects at an appropriate level will likely improve efficacy overall (Bandura, 1986; Chumbley et al., 2019).

We also recommend that agricultural teacher educators offer in-service teachers with professional development opportunities to explore STEM topics – especially mathematics and engineering – in a safe environment. Respondents in this study were more likely to improve their science and technology teaching and less likely to do so for mathematics and engineering. This might be because they are unsure of how to explore these subjects or unaware of opportunities available to assist them in doing so. Professional development workshops have been shown to increase STEM teaching efficacy (Mahler & Benor, 1984; Riggs, 1995), and tailoring them directly to state teaching requirements while offering guided, hands-on experiences can provide educators with mastery experiences needed to build efficacy in the classroom (Bandura, 1986). For mathematics, these professional development courses should address ways that math is commonly used in agriculture, allow teachers time to practice the skills in question, and then discuss effective methods for teaching those skills to others. With regard to engineering, we should assist teachers in developing a deeper understanding of the field within agricultural mechanics and a more comprehensive understanding overall. When Carr et al. (2020) studied how in-service agricultural educators integrated STEM into their classrooms, they were much more specific and varied when discussing science, technology, and mathematics. Most who said they used engineering techniques did so only in agricultural mechanics and did not specify how or through what topics, projects, or experiences.

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