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Agricultural Educators' Personal Characteristics and Self-Efficacy Beliefs Regarding STEM Education

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Agricultural educators' personal characteristics and self-efficacy beliefs regarding STEM education

By

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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 Tennessee and Mississippi agricultural educators' personal teaching efficacy and outcome expectancy levels towards STEM subjects and identifies factors that may play a role in the development of STEM teaching efficacy. Analysis indicated that educators felt most confident in their ability to teach science, followed by technology, mathematics and then engineering. Factors that influenced STEM personal teaching efficacy included the number of postsecondary STEM courses taken, gender, and CASE course completion. Regarding outcome expectancy, teachers felt similarly across the four STEM fields. The one factor found to influence STEM outcome expectancy included the number of postsecondary STEM courses taken. Recommendations for future research include exploring agricultural educators' perceptions of engineering and its place in the agriculture industry,

recognizing how engineering is taught at both the secondary and postsecondary level, understanding the experience of minorities in STEM, and identifying ways in which agricultural educators use technology in their classrooms. Recommendations for practice include offering preservice agricultural educators more engineering and technology courses, specifically highlighting how STEM concepts are used in the modern agricultural industry, and improving agricultural educator outcome expectancy levels.

DEDICATION

This is dedicated to my friends and family, who stood by me and encouraged me throughout the journey. You were with me during good times and bad, and I was always glad to know that I had someone in my corner.

It is also dedicated to all the people who encouraged me to go to graduate school. Thank you for your help, advice, and inspiration along the way.

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CHAPTER I

INTRODUCTION

If the American agricultural industry is to continue feeding and clothing an ever-growing world, it is essential that the agriculturists of tomorrow continue developing their focus on skills related to science, technology, engineering, and mathematics (STEM). Even though agriculture is not always included in official lists of STEM disciplines (Koonce, Zhou, Anderson, Hening, & Conley, 2011), the two fields are, in reality, closely linked (Boone, 2013; National Council for Agricultural Education, 2012; Rada, 2015; Stubbs & Myers, 2015). Since the earliest days of agriculture, humans have (knowingly or unknowingly) utilized STEM principles to more efficiently produce food and fiber. Boone (2013) defined agriculture as "the original STEM," and noted that agricultural education has made use of "the scientific aspects of agriculture, the latest technological advances, engineering concepts needed to construct buildings and equipment, and math skills needed in day-to-day farming applications" since its formal inception in the 19th century (p. 2).

Over one hundred years later, modern-day students of agricultural education continue the tradition. Courses such as plant science, animal science, food science, agricultural mechanics and engineering, agricultural business and economics, landscaping, leadership, and more demonstrate STEM concepts in action. In 2009, the National Research Council (2009) even suggested that the ubiquitous STEM acronym be changed to STEAM (science, technology, engineering, agriculture, and mathematics) as a way of recognizing agriculture's fundamental role in the equation (Stubbs & Myers, 2015).

Overall, agricultural education and STEM share many of the same underlying values and subject matter (Stubbs & Myers, 2016). This is largely because both fields can trace their roots back to the ideas of the same educational theorist: John Dewey (Glancy & Moore, 2013; Knobloch, 2003.) First, both place emphasis on the learning process and in making meaning from learning instead of simple content mastery alone (Ejiwale, 2012; Phipps & Osborne, 1988; Stubbs & Myers, 2015). Two of agricultural education's three key components are classroom instruction and experiential learning (NAAE, 2018), and the National FFA Organization (2018b) even includes the phrase "learning to do, doing to learn," as a part of its motto (para. 3). On the STEM side, Ejiwale (2012) stressed the need to involve students in "motivational activities that integrate the curriculum" and that "promote hands-on and other related experiences" in the classroom (p. 91). Kelley and Knowles (2016) wrote that current STEM literature recommended teaching through "project, problem, and design-based approaches."

Second, both fields also place learning in context with other subjects, real-world needs, and student interests. The National Academy of Engineering (NAE) (2014) and National Research Council (NRC) (2014) state that approaching education in this way can make learning material "more relevant to students and ultimately increase their motivation and achievement" (p. 1). STEM education is broad in nature, and as such its integration into other subjects and the world at large must be made explicit (NAE &

NRC, 2014). It must “cut across subject-matter lines” and bring together “various aspects of the curriculum into meaningful association” while also serving as a reflection of the real world that students will one day face (Shoemaker, 1989, p. 5). Ejiwale (2012) wrote that STEM subjects should include information and activities “that would be needed to solve problems as they relate to their environments” (p. 92). One sample lesson plan provided by the National Academy of Engineers’ Link Engineering website (2016) asks students to construct and test their own water filtration devices. Before work begins, the teacher leads a discussion about the impact of contaminated water on the world, and how engineers and scientists are utilizing their knowledge to make our most valuable resource safe to drink. Students are also encouraged to make connections between human action and water quality, and between filter material and specific contaminants (NAE, 2016). In this way, a teacher can provide students with an interesting, hands-on activity that integrates several subjects into one lesson, and that is based on a real-world challenge that millions face every day.

STEM integration into agriculture is nothing new; rather the two have even been described as “inseparable” (Stubbs & Myers, 2016, p. 93). Agricultural education often serves as a context by itself (Israel, Myers, Lamm, & Galindo-Gonzales, 2012), with programs automatically connecting core content such as English, science, history, and math to their uses in the modern agricultural industry (Stubbs & Myers, 2016). One educator interviewed by Stubbs and Myers (2016) noted that he demonstrated algebra and chemistry by calculating fertilizer percentages, while another had his students explore agriculture’s effects on world history, ecology, and human development. A third used technology and animal science techniques to track, keep records, and improve the production of school livestock. Each of these lessons enhances standard content by placing it in a real-world context, and by combining it with other subjects in which students were enrolled.

Third, both agricultural education and STEM focus on improving students as human beings as well as scholars. In addition to classroom instruction and experiential learning, the third key concept of agricultural education is student leadership development (NAAE, 2018). This is largely accomplished through student participation in the National FFA Organization, the National Young Farmer Education Association, National Postsecondary Agricultural Student Organization and others (AAAE, 2018). These organizations offer students the opportunity to interact with others in similar fields, further develop their career knowledge and skills, and improve necessary leadership-based abilities such as communication, teamwork, and critical thinking.

While STEM education does not have as strong a focus on leadership through student organizations, it does place value on improving students' 21st century skills through the medium of education. Twenty-first century skills are usually defined as "the skills that today's students will need to be successful in this ever-changing world" (Defined STEM, 2018, para. 1). The most well-known 21st century skills "are the 4C's: communication, collaboration, critical thinking, and creativity," but others include "social and emotional intelligence, technological literacy, and problem-solving abilities" (Defined STEM, 2018, para 1).

With their many shared methods and goals, it is obvious that agricultural education and STEM share "a natural tie" with one another (The Council for Agricultural

Education, 2016). Both utilize similar theoretical backgrounds, teaching methods, and approaches for personal development to the same ends. By integrating the STEM subjects of science, technology, engineering, and mathematics into agricultural education, researchers and educators can assure that future agriculturists are properly equipped to face the challenges of tomorrow.

Statement of the Problem

STEM education is a key factor in readying tomorrow's workforce for the challenges they will one day face. Most key advancements in human history result from study in STEM fields (Carnevale et al., 2011), and so it is essential that the agriculturists – as well as the scientists, technicians, engineers, and mathematicians – of the future are given the education they need to continue the march of progress. Even students who do not choose STEM-related majors can benefit from the background knowledge, hands-on experiences, and leadership skills that STEM and agricultural education provide.

Since the 1990s, there have been numerous initiatives pushing for increased integration of STEM content across various educational levels (President's Council of Advisors on Science and Technology, 2012). However, implementation of these plans has proven to be more difficult than originally imagined. One of the largest challenges to the success of STEM education is a lack of teacher quality in STEM fields (Gonzales & Kuenzi, 2012). Many teachers are finding themselves unprepared to teach the new, more difficult curriculum expected from STEM fields (Granata, 2014; McKim, Lambert, Sorenson, & Valez, 2015; Seelman, 2003), and that others are unsure of how to interest students in STEM topics and careers (Seelman, 2003). In a science education manual from the U.S. National Institute of Health, Seelman (2003) stated that "few elementary teachers have even a rudimentary education in science and mathematics, and many junior and senior high school teachers of science and mathematics do not meet reasonable standards of preparation in those fields" (p. 1). A 2011 survey from the National Center for Educational Statistics found that approximately 30% of U.S. chemistry and physics teachers were not only untrained in STEM techniques, but also considered unqualified to teach their subject at all. Gonzales and Kuenzi (2012) stated that high school mathematics teachers are less likely to have majored in the specific subject that they taught, and 28% did not major in mathematics. Some teachers are also unaware of what different STEM disciplines entail. Engineering is by far the worst in this respect, as Hirsh, Rockland, and Bloom (2005) reported that educators often "do not know much about engineering or what engineers do" (p. 21).

If American agriculture is to improve its "productivity, efficiency, and effectiveness" while also "driving sustainable growth, scientific discovery, and innovation," it is essential that America's agricultural educators be able to produce "a sufficient supply of well-prepared agricultural scientists and professionals" (Doerfert, 2011, p. 18). Despite the natural connection that exists between agricultural education and STEM, this need has not yet been met. In order to better understand how STEM might better be integrated into agricultural education, it is important to explore how individual teachers themselves approach the task (Smith, Rayfield, & McKim, 2015). Integrating STEM requires teachers to make important decisions regarding subject matter, background context, instructional methods, and classroom environment.

Understanding how these choices are made can assist in identifying key factors that play into the success or failure of STEM integration.

This study examined these choices from a personal context based upon Albert Bandura's social cognitive theory (1986). Social cognitive theory posits that human learning is a cognitive and self-regulated process that is not solely controlled by either external forces or internal instincts, but rather by outwardly observing the actions of others and then inwardly reflecting upon them. Thus, the choices that we make are governed by the interaction of one's personal characteristics, past behavior, and social environment. (Bandura, 1986; McKim & Velez, 2016; Pajares, 2002). Although these three factors all play vital roles in human learning and decision-making processes, it is one's personal characteristics that shape the core of Bandura's theory (Pajares, 2002). From these personal characteristics emerges one's self-efficacy beliefs. Bandura (1986) defined self-efficacy as "people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performances" (p. 391).

Self-efficacy is involved with personal motivation, change, and accomplishment. If a person believes that a change in their actions, knowledge, or behavior can lead to a desired outcome, then they are more likely to be motivated and persevering in their efforts to make that change. Self-efficacy can affect a person's life in many ways, including their choices, goals, motivating factors, optimism, persistence, and response to stress and challenges (Bandura, 1986, 1994, 1997; McKim & Velez, 2016; Pajares, 2002). In the classroom, self-efficacy also impacts both teachers and their students in many ways. Teachers with high self-efficacy are more organized, resilient, and enthusiastic in their work, and are also shown to demonstrate more effective teaching behaviors and classroom management strategies overall. They are also less critical of student mistakes and more willing to work with students who have learning difficulties or behavior issues (Tschannen-Moran & Woolfolk Hoy, 2001). Teachers with high STEM self-efficacy, therefore, are more likely to not only envision themselves successfully integrating STEM into the classroom, but also exercise the appropriate actions and behaviors to make it a reality (Smith et al., 2015). Studying the effects of personal characteristics such as STEM background, age, gender, length of teaching career, and certification type on an agricultural educator's level of STEM self-efficacy is an important step to ensuring effective delivery of STEM content in agricultural education.

Purpose of the Study

The purpose of this study was to identify agricultural educators' self-efficacy levels regarding the integration of science, technology, engineering, and mathematics (STEM) content into agricultural education. In addition, this study also explored any connections that may exist between agricultural educator STEM self-efficacy and educator age, gender, years of teaching experience, certification type, and number of postsecondary-level STEM courses completed.

Research Objectives

This study utilized the following objectives so that its purpose could be successfully fulfilled:

1. Determine agricultural educators' levels of personal teaching self-efficacy regarding their ability to teach STEM content within the context of agricultural education.
2. Identify relationships that may exist between agricultural educators' personal teaching self-efficacy levels and their age, gender, ethnicity, certification type, teaching career length, STEM background, and professional development history
3. Determine agricultural educators' levels of teacher outcome expectancy beliefs regarding their ability to teach STEM content within the context of agricultural education.
4. Identify relationships that may exist between agricultural educators' outcome expectancy levels and their age, gender, ethnicity, certification type, teaching career length, STEM background, and professional development history.

Significance of the Study

With increasing demands being placed on the American agricultural industry every day, it is essential that American agricultural education programs embrace STEM content. In 2015, the USDA reported that more than a quarter of all new job openings in agriculture were directly related to STEM subjects, and that approximately 15,500 new STEM positions could be expected to open each year through 2020 (Goecker, Smith, Fernandez, Ali, & Theller, 2015). If agricultural educators are going to prepare students to fill these positions, it is essential that we understand the factors that underlie successful STEM integration into agricultural education. Personal factors and self-efficacy beliefs are known to have a strong influence on teacher effectiveness, behaviors, and judgments, which in turn affect student learning outcomes and attitudes (Zee & Koomen, 2016). Recognizing how agricultural educators feel about integrating STEM education and its components into their classrooms is a valuable first step in the process. Although some previous research has explored agricultural educator self-efficacy in regard to STEM, no study has yet examined its relationship to personal factors such as age, gender, years of teaching experience, certification type, and number of postsecondary-level STEM courses completed.

Operational Definitions

Agricultural education – educational content that "teaches students about agriculture, food and natural resources" while developing "a wide variety of skills including science, math, communications, leadership, management, and technology." Agricultural education is delivered through the three interconnected components of "classroom or laboratory instruction," "experiential learning," and "leadership education" (NAAE, 2018).

Agriscience education – "identifying and using concepts of biological, chemical, and physical science in the teaching of agriculture, and using agricultural examples to relate these concepts to the student" (Conroy & Walker, 1998, p. 12).

Engineering – "both a body of knowledge—about the design and creation of human-made products—and a process for solving problems" (National Academy of Sciences, 2014, p. 14).

Mathematics – "the study of patterns and relationships among quantities, numbers, and space" (National Academy of Sciences, 2014, p. 14).

National FFA Organization – "an intracurricular student organization for those interested in agriculture and leadership. It is one of the three components of agricultural education." (National FFA Organization, 2018).

Outcome Expectancy – teaching efficacy concerned with factors that cannot be controlled outright but that teachers believe they can influence (Angle & Moseley, 2010; Hoy, 2000). Factors include the value of education in a child's home, a student's psychological or physiological needs, and violence or substance abuse in the school community (Tschannen-Moran & Woolfolk Hoy, 2001). Also known as general teaching efficacy.

Personal Teaching Self Efficacy – Efficacy related "to a teacher's own feeling of confidence in regard to teaching abilities" (Protheroe, 2008, p. 43). It involves teachers expressing faith in their own capacity to "develop strategies for overcoming obstacles to student learning" (Tschannen-Moran & Woolfolk Hoy, 2001, p. 785).

Science – "the study of the natural world, including the laws of nature associated with physics, chemistry, and biology and the treatment or application of facts, principles, concepts, or conventions associated with these disciplines" (National Academy of Sciences, 2014, p. 14)

Self-efficacy – "people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performances" (Bandura, 1986, p. 391).

STEM – "teaching and learning in the fields of science, technology, engineering, and mathematics" that "typically includes educational activities across all grade levels— from pre-school to post-doctorate—in both formal (e.g., classrooms) and informal (e.g., afterschool programs) settings" (Gonzales & Kuenzi, 2012, p. 1).

Teacher self-efficacy – a teacher's "judgment of his or her capabilities to bring about desired outcomes of student engagement and learning" (Collie, Shapka, & Perry, 2012, p.2).

Technology – "the entire system of people and organizations, knowledge, processes, and devices that go into creating and operating technological artifacts, as well as the artifacts themselves" (National Academy of Sciences, 2014, p. 14).

Limitations

The following are limitations for this study:

1. The results cannot be generalized beyond the study due to the sample makeup.

2. Participants self-reported data for the study. Self-reported data can be subject to issues regarding honesty, accuracy, response bias, and completeness.

3. There is limited research concerning teacher self-efficacy for the integration of STEM content into agricultural education.

Assumptions

The following are assumptions made for this study:

1. Study participants completed the survey honestly and to the best of their ability.
2. Participants integrated STEM content into their agriculture classes in some manner.

CHAPTER II

REVIEW OF RELEVANT LITERATURE

This review of relevant literature will explore important aspects of agricultural education, STEM education, and Albert Bandura's Social Cognitive Theory. It will also examine the relationship between teacher self-efficacy regarding STEM education and teacher age, gender, years of experience, and number of postsecondary level STEM courses completed.

Historical Overview of Agriscience and Agricultural Education

Prior to 1862

If one is to understand the impact of STEM teaching self-efficacy and other factors on agricultural educators, it is best to begin by understanding the context in which American agricultural education exists and operates. Early American agricultural education can be said to have been meager at best and nonexistent at worst. Because agriculture was not recognized as a science until the mid-19th century (Barrick, 1989), early settlers often based their farming practices off old traditions and superstitions that had been brought from Europe. This lack of knowledge resulted in hard times for those in the New World, with many settlers woefully unprepared to face the challenges of famine, illness, and harsh winters.

One of the earliest forms of agricultural education in the United States began in the late 18th century with the creation of societies that focused on improving rural and agricultural affairs in the newly-fledged United States. The Philadelphia Society for the Promotion of Agriculture, founded on March 15, 1785, was the earliest of these societies and counted such luminaries as Benjamin Franklin and George Washington as members (Hillison, 2001). While most agricultural societies throughout the country differed somewhat in form and function, they all played valuable roles in improving American agriculture through education and experimentation. Some societies encouraged progress by fostering friendly competitions and offering prizes to those brave enough to implement and report upon novel practices. Others hosted meetings, lectures, and demonstrations during which agricultural news and topics were discussed and new advancements displayed. Most also published journals documenting members' exploits and sharing ways in which successes could be replicated (Hillison, 2001). From these societies also emerged the concept of the modern agricultural fair and livestock show (Lemmer, 1943), traditions that millions still enjoy today.

By the early 19th century, a call for increased access to education emerged on the behalf of America's working class. Until that time, a majority of Americans received only a rudimentary education in essential subjects such as reading and writing. Very few were privileged enough to have access to higher learning opportunities, and those that did often studied Classical subjects useful for little else than careers in the elite fields of medicine, politics, education, and law. America's vast population of farmers, laborers, and tradesmen had no need for such knowledge in their everyday lives, and it was highly unlikely they could even afford it should they find themselves wanting. Instead, visionaries such as Jonathan Baldwin Turner – a classically-trained educator living and teaching on the Illinois frontier – sought to create a new paradigm of education that brought relevant and affordable learning to all. Although it took many years of work, this dream was finally realized in 1862 with the passage of the Morrill Land Grant Act.

The Morrill Land Grant Act of 1862

Named for Justin Smith Morrill, a Congressman (and later Senator) from Vermont, the Morill Act established a system of federally-supported colleges meant to focus on teaching and research in the fields of agriculture, mechanics, and military science. Unlike other schools of the day, land grant colleges took a hands-on approach to education that often saw teachers working and learning right alongside their students. Although the schools faced many challenges in their first few decades of existence, they soon became important centers of scientific and technical advancement for rural America. In 1890, a second Morrill Act further funded the fledgling colleges and established Land Grant institutions for African-Americans in the segregated South. The 1994 Morrill Land Grant Act gave land grant status to several Native American colleges across much of the American West. In many ways, the Morrill Act can be considered one of the most important events in the development of agricultural education in the United States. Described as "the impetus to the development of agricultural education in its broader sense," (Camp & Crunkilton, 1985, p. 62), the Morill Land Grant Act of 1862 changed the face of higher education forever.

Unfortunately, the Morrill Act downplayed the importance of agricultural education at other levels. As the land grants rose to prominence, "it was widely assumed that they would meet the need for agricultural education," thus leaving younger students and those unable to attend college without recourse. In order to meet this emerging need, secondary schools across the nation began developing their own agricultural education programs (Phipps, et al., 2008, p. 24).

Early Secondary Agricultural Education

The first state-funded school with agriculture in its curriculum was the Gardiner Lyceum in Gardiner, Maine (Stevens, 1921; True, 1929; White, 1911). Founded in 1823, it provided students with the practical education they needed to become successful farmers, tradesmen, craftsmen, or schoolmasters (Stevens, 1921). Courses offered at the Gardiner Lyceum were often heavy in science and mathematics, and included such areas of study as farming, navigation, mathematics, natural philosophy, and chemistry (Berg, 2002; Stevens, 1921). The school also provided students with employment leads in various vocational fields so that they might find stable employment (Gazette, 1825). While the Gardiner Lyceum was unique for its time, it did not produce a particularly large impact on education; it closed in 1832 due to political wrangling and lack of funds (True, 1929).

Yet, secondary agricultural education continued to grow. Massachusetts encouraged agricultural education for youth through state legislation in 1862, and in 1881 the Storrs Agricultural School of Mansfield, Connecticut began providing boys as young as 15 with agricultural studies both in the classroom and on the farm (Phipps et al., 2008). The Hatch Act of 1887 also helped to encourage agricultural education at the secondary level (Talbert, Vaughn, & Croom, 2005). The primary intention of the Hatch Act was to establish outlying agricultural experiment stations that were linked to the land grant colleges (Phipps et al., 2008). It was through these stations that the land grants could continue their mission of research and education, but to a different audience. Many stations either played host to or developed close relationships with local agricultural schools (Hillison, 1996; Phipps et al., 2008). Rhode Island, Minnesota, Alabama, California, and Wisconsin were some of the earliest states to publicly fund these schools, and in 1891, Tennessee became the first state to require secondary agricultural education (National Research Council, 1988; Phipps et al., 2008). Much like at the earlier Gardiner Lyceum, the curriculum at these early agricultural high schools included a focus on mathematics, science, engineering, and hands-on laboratory and field work experience (National Research Council, 1988). By the dawn of the 20th century, approximately 400 high schools offered courses in agriculture or related sciences, a number that increased tenfold in a period of only 15 years (National Research Council, 1988, p. 56).

The influx of agricultural education students naturally created an increased need for teachers. Most early agricultural educators were originally employed as science teachers (National Research Council, 1988) and had little agricultural knowledge or background to call upon (Phipps et al., 2008). In 1902, the Association of American Agricultural Colleges and Experiment Stations recommended that agricultural educators possess a degree from an agricultural college (Phipps et al., 2008), and in 1907 the U.S. government passed the Nelson Amendment to the Morrill Act, which provided land grants with federal funds for training future educators (Herren & Hillison, 1996). By 1912, 40 agricultural colleges were establishing teacher training programs that included not only a focus on "the science and practice of agriculture," but also courses in pedagogy and educational psychology (Phipps et al., 2008, p. 24).

The Smith-Lever Act

The Smith-Lever Act of 1914 created the Cooperative Extension Service, which provided land grant-directed education and demonstration programs for adults and children not of college age (Phipps et al., 2008). Extension now serves as a third and vital portion of the land grant mission, but its creation also laid the groundwork for yet another act that has left its influence on American agricultural education for over a century (Hillison, 1996).

The Smith-Hughes Act

The Smith-Hughes Act of 1917 left an indelible mark on agricultural education in many ways. First, it provided federal funding to school-based agricultural education programs, and also allotted money for the training of teachers, supervisors, and administrators entering the field (Hillison, 1996). This funding helped improve the quality of agricultural education across the nation and ensured that teachers were provided with the knowledge, experience, and materials they needed to succeed (Hillison, 1996).

Second, the Smith-Hughes Act helped to formalize a hierarchy within agricultural education. This hierarchy further defined the roles of teachers, administrators, and supervisors, and created a system of state and local supervisors who oversaw teacher efforts and developed early techniques for evaluating teacher performance (Hillison, 1987). Perhaps less helpfully, the Smith-Hughes Act also created a rift in the agricultural education world. While both Extension and classroom-based agricultural education worked towards the same ends, political maneuvering placed them in completely separate domains.

Thus, Extension programs were left under the jurisdiction of the land grants, and agricultural education programs placed under that of state and local boards of education (Hillison, 1996). Finally, the Smith-Hughes Act changed the focus of agricultural education in the United States from scientific to vocational (Hillison, 1996). Before 1917, agricultural education was largely science-based. However, after the passage of the Smith-Hughes Act, it became oriented towards student vocational training and "de-emphasized academic instruction" (Hillison, 1996, p. 5). Even though agricultural education was still based on scientific principles, the brunt of instructional time was now directed towards preparing students for their future careers in the agricultural industry (National Research Council, 1988). Teachers now "sought to engage students in tasks that taught process and content" through "a mixture of classroom instruction, work experience, and entrepreneurship," and through activities that taught students to "make independent decisions and take initiative" (National Research Council, 1988, p. 56). Although the idea of learning by doing was not new to the field of agricultural education, the Smith-Hughes Act required students to take part in some kind of supervised or directed study that occurred largely outside of school hours (National Research Council, 1988).

The National FFA Organization

With school-based agricultural education on the rise, it became apparent that students might benefit from an organization that combined agricultural knowledge with leadership and personal development (National FFA Organization, 2018a). Walter S. Newman and Henry C. Groseclose, both agricultural educators from Virginia, began creating the backbone of the Future Farmers of America (now the National FFA Organization). Newman described the organization as providing boys with "a greater opportunity for self-expression and for the development of leadership," "confidence in their own ability," and "pride in the fact that they are farm boys" (National FFA Organization, 2018a, para. 2). Over the years, the National FFA Organization has become an integral part of American agricultural education, offering students the opportunity to develop "premier leadership, personal growth, and career success" (National FFA Organization, 2018b, para. 1) through classroom education, hands-on experience, and friendly competition.

The Mid-Twentieth Century

As time passed, the dichotomy of students either being college- or vocation-bound intensified, to the point where separate educational tracks were developed for each. This resulted in "science and academic skills" being largely considered as preparation for higher education, and therefore of less importance for those in agriculture or other vocational fields (National Research Council, 1988, p. 58).

The 1960s, 1970s, and early 1980s brought about a period of slow change for agricultural education. The Vocational Act of 1963 responded to adjusting societal and educational needs by redefining agricultural education and broadening its scope to include more than just production farming (National Research Council, 1988). Agriscience and agribusiness, two fields that still form an integral part of agricultural education today, made their debut into the curriculum around this time (Blassingame, 1999). However, these changes were not enough to ensure that agricultural education would remain relevant in the face of modernity. Much of what was taught still focused on traditional topics, and a great deal of the curriculum was written at the local level and thus varied widely from teacher to teacher or system to system (National Research Council, 1988). This decline in quality led to a drop in student enrollment across both agricultural education and career and technical education in general (National Research Council, 1988).

A Nation at Risk and the 1980s

In 1983, the Reagan administration published *A Nation at Risk: The Imperative for Educational Reform*, a report identifying, amongst other issues, the need for more science, technology, and math in America's public schools (The National Commission, 1983). Written as a response to the nation's supposed shortcomings on the global and economic stage, *A Nation at Risk* sought to prepare learners for the 21st century by fighting "a rising tide of mediocrity," (p. 9) that threatened America's "once unchallenged preeminence in commerce, industry, science, and technological innovation" (p. 9). The report drew attention to vital needs in the American educational system and led the charge for reform in the face of changing needs and times. Specific risk factors mentioned in the report included unprepared educators, decreased student performance on standardized tests, functional illiteracy, a lack of student higher-order skills, poor performance in comparison to international gains, and a decline of U.S. academic performance. (The National Commission, 1983, p. 11).

In the wake of *A Nation at Risk*, the National Research Council created the Committee on Agricultural Education in Secondary Schools to address challenges specific to the field. The committee examined issues including the overall purpose of agricultural education and its goals for the future, the need for providing updated and high-quality curriculum, and methods for increasing student enrollment (National Research Council, 1988). In their 1988 report, *Understanding Agriculture: New Directions for Education*, the Committee noted that "the focus of agricultural education must change" to better reflect "the reality within agriculture and of changes within society" (National Research Council, 1988, p. 4). Recommendations made included broadening the scope of agricultural education and the FFA, upgrading curriculum to meet emerging needs, integrating new technology, and reducing the heavy focus on vocational preparation (National Research Council, 1988). It did not take long for changes to occur. The 1984 Carl D. Perkins Vocational Act provided funds for "strengthening the academic foundations of vocational education courses by applying mathematics and science principles" (Phipps et al., 2008, p. 30), and some programs began offering agricultural science classes that provided students with a science credit (Dormody, 1993; Stubbs & Myers, 2015). In late 1988 the Future Farmers of America became the National FFA Organization, and the Agriscience Student Recognition program was introduced (National FFA Organization, 2018a). Ten years later, the National FFA Organization held the first National Agriscience Fair Career Development

Event (National FFA Organization Records, 2008). In 2001, the National FFA Organization recognized its first American Star in Agriscience, a prestigious award recognizing the utmost of student achievement in any form of agriculture-related science (National FFA Organization, 2018a). This award (alongside its sibling Star in Placement) took an important place in the FFA pantheon, allowing students to be honored for more than just the traditional achievements of Star Farmer or Star in Agribusiness for the first time.

Agricultural Education into the 21st Century

The 1990s and early 2000s also served as a period of change for agricultural education in other ways. Programs became much more technical in nature and continued a heavy emphasis on "integrating concepts from core academic subjects" (Phipps et al, 2008, p. 37). Federal legislation such as the Goals 2000: Educate America Act of 1994 and Elementary and Secondary Education Act of 2001 began endorsing standards-based education throughout the nation (Phipps et al, 2008). Under this system, standards acted as "concise, written descriptions of what students are expected to know and be able to do at specific stages of their education," (Great Schools Partnership, 2014, para. 1) and took much of the curricular planning decisions out of teachers' hands. Programs also became more specialized during this time period. A 2000 initiative from the U.S. Department of Education created 16 career clusters, one of which was named the Agriculture, Food, and Natural Resources Cluster (Phipps et al., 2008). This cluster offers courses that train students for specific career areas in agriculture such as "food scientist, environmental engineer, agriculture teacher, animal scientist, biochemist, and veterinary assistant"

(Phipps et al., 2008, p. 37). Unlike in the past, modern agricultural education has also begun to place great focus on preparing students for postsecondary education (National Council for Agricultural Education, 2015).

Understanding the history and founding principles of agricultural education is an important factor in helping shape it for the future. As the world grows and changes, agricultural educators must look back upon the historical record to identify the guiding values that still stand true. The integration of STEM into agricultural education is still an emerging 21st century concept, but it is one for which history has long since paved the way.

Agricultural Education Demographics

Although the demographic makeup of American agricultural educators is changing, it is still largely "dominated by white males" (Myers & Dyer, 2004, p. 49). In 2018, the American Association for Agricultural Education (AAAE) published *Status of the U.S. Supply and Demand for Teachers of Agricultural Education, 2014-2016*, which collected information about current and future agricultural educators (Lawver, Foster, & Smith, 2018). This report found that around 90% of teacher education program completers from 2013-2016 were white, while 1% were African American, 5% were Hispanic, and 3% were of other ethnic backgrounds (Lawver et al., 2018). However, current trends show an approximate 50/50 split between male and female program completers. Eighty-eight percent of agricultural educators currently in the field are white, with around 64% being white and male. The authors of the report indicate a severe need for minority representation in agricultural education and call for “major efforts” towards recruiting and preparing minority teachers to be made (Lawver et al., 2018, p. 43).

Historical Overview of STEM Education

Early STEM Education

Before the 19th century, most students entering STEM-related fields were taught through apprenticeships instead of through a formal, classroom-based education (Reynolds, 1992). The rapidly-growing nation, however, needed more STEM students than apprenticeships could provide. By the 1820s, schools such as the aforementioned Gardner Lyceum began offering students courses in practical subjects necessary for everyday life. Institutions of higher learning also capitalized on the trend, with the University of Virginia, the College of William and Mary, and the University of Alabama requiring minimal instruction in engineering, mechanics, and mathematics as early as the mid-1830s (Reynolds, 1992). The following years saw similar programs develop in colleges and universities throughout the south. Some STEM-related programs did emerge from northern schools, but their implementation was not as rapid nor as widespread. The growth of early STEM education during the early-to-mid 1800s helped lead to the creation of the Bachelor of Science degree, which swapped traditional subjects such as Latin and logic for science, modern languages, and civil engineering (Reynolds, 1992).

STEM and the Morrill Land Grant Act

Like agricultural education, public STEM education in the United States got its start with the passage of the Morrill Act in 1862. Although agriculture was the main impetus behind the bill, universities accepting the land grant status also had to offer courses in engineering, mechanics, and military science (White, 2014). Perhaps ironically, many of these other subject areas soon overshadowed their agricultural brethren in prestige and student enrollment numbers. Not only were these programs better prepared and more well-equipped than agricultural ones, an expanding country dependent upon new developments like the railroad and the telegraph put scientists and engineers in high demand (Reynolds, 1992).

Early Secondary STEM Efforts

The first specialized STEM high schools opened in early 20th Century New York, and largely provided students with technical skills and educations heavy in science and mathematics (Thomas & Williams, 2010). In 1917, the Smith-Hughes Act aided early efforts at STEM education by providing funds to not just agriculture programs, but also those that instructed students in industry and the trades (Alexander, Salmon, & Alexander, 2015).

World War II also had a great effect on the growth of STEM education in the United States. For the first time, academia, the military, the government, and "a highly skilled STEM workforce" worked together to further the war effort in Europe and Asia and provide "economic and military advances like never before seen" (Gonzales & Kuenzi, 2012, p.1; White, 2014). Advancements in technology, weaponry, medicine, manufacturing, transportation, and communication all emerged from this time period and showcased the power of STEM ingenuity. Atomic missiles, radar, synthetic rubber, penicillin, batteries, plastics, and modern airplanes are just a few of the World War II-era developments that still impact life today (National World War II Museum, 2012). The National Science Foundation, created in 1950 with the intention of honoring and continuing the work of scientists, engineers, and mathematicians from World War II, is also an important link between STEM of the mid-20th century and STEM of today (White, 2014). The National Science Foundation has long been a supporter of STEM education in the United States and has become one of the largest sources of federal funding for research, development, and training in STEM areas (Gonzales & Kuenzi, 2012).

Sputnik and the Space Race

Great changes were made to public education in the fall of 1957 as a result of the launch of Sputnik I, a tiny beach-ball sized satellite belonging to the USSR (Powell, 2007). Following the end of World War II, the United States experienced a wave of unmatched power and prosperity on a global scale. However, escalating tensions brought on by the Cold War created a need for constant technological improvement on both sides. Sputnik came largely as a surprise to the United States and acted as a powerful “focusing event” that drew the nation’s attention to its place in the world and the state of its public schools (Powell, 2007, para. 4). America no longer viewed itself at the forefront of scientific advancement and academic achievement as it once had, a predicament blamed mostly upon a lack of science in school curricula (Powell, 2007). The very next year

Congress passed the National Defense Education Act, which began efforts to improve science-, math-, and technology-based education throughout the nation. Schools were tasked to no longer "emphasize information, terms, and applied aspects of content," but rather, "the structures and procedures of science and mathematics disciplines" (Bybee, 1997, para. 3). This educational landscape continued throughout the following decades, ushering in a time of great technological achievement and change. In 1958, the Space Act led to the creation of the National Aeronautics and Space Administration (NASA), which was meant to oversee the improvement and expansion of the United States' space program through the use of scientific, engineering, and mathematical principles (White, 2014). While NASA certainly did achieve this goal – even putting men on the moon in 1969 – it also provided funding and materials for STEM-related educational initiatives in the country (White, 2014). Other notable advancements such as the personal computer, cellular phone, space shuttle, and artificial heart, improved life and made new developments possible (Marick Group, 2018).

STEM in the Late Twentieth Century

Much as it had for agricultural education, the Reagan administration's landmark *A Nation at Risk: The Imperative for Educational Reform* – colloquially referred to as "the paper Sputnik" – advocated for more STEM subjects integrated into general education (Bracey, 2006, p. 543; The National Commission, 1983). By the 1990s, educational councils and organizations such as the National Science Education Standards and the National Council of Teachers of Mathematics created new guidelines for teachers to better prepare students for STEM subjects (Marick Group, 2018). This decade was also the first time that STEM subjects were gathered together under one acronym. Originally dubbed SMET by the National Science Foundation (and later changed to STEM in 2001), the term was used to refer to content areas that fell under or applied the broad categories of science, technology, engineering, and mathematics (Bybee, 2010; National Research Council, 2011). Since then the term has been widely used to describe a wide range of disciplines that involve one or more of the four areas.

STEM in the Twenty-First Century

In 2000, the report *Before it's too Late: A Report to the Nation from the National Commission on Mathematics and Science Teaching for the 21st Century* examined the United States' mathematics and science education and made recommendations for improvement. The report focused on teacher quality and discussed methods for improving training, recruitment, retention, and professional development for mathematics and science educators (Glenn, 2000). In 2007, the National Academy of Sciences published *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*. This report brought forward issues with STEM education in the nation and recognized a need to increase the number of students entering STEM fields (Marick Group, 2018; National Academy of Sciences, 2007).

The future of STEM education continued to be an important theme through the Obama administration. In 2009, the Educate to Innovate initiative sought to improve student performance in mathematics and science by increasing funding for STEM education and preparing 100,000 STEM teachers (Marick Group, 2018). The next year, the administration also held the first annual White House Science Fair with the purpose of “celebrating the winners of a broad range of science, technology, engineering, and math (STEM) competitions” (Office of the Press Secretary, 2010). Several students who won their divisions of the National FFA Organization’s Agriscience Fair were invited to participate in the White House Science Fair for several years in a row (National FFA Organization, 2016).

In 2016, the United States Department of Education published *STEM 2026: A Vision for Innovation in STEM Education.* This report makes further suggestions for improving STEM education throughout the country by supporting STEM educators, building strong STEM networks and communities of practice, creating innovative learning spaces and methods, promoting diversity in STEM fields, and building critical thinking and problem-solving skills through both challenge and play. The report also discussed inequities in STEM education access based on socioeconomic status, the role of early childhood STEM education, the role of STEM representation in the media, and the need to make STEM education a cohesive part of the overall educational experience (USDE, 2016)

STEM Education Demographics

Specific information on the demographics of STEM educators in the United States is sparse. Most of the focus is placed upon STEM student, graduate, and non-education related workforce demographics instead. However, the data that are available can be used to better illustrate the status of STEM educators in the country. According to the 2000 Schools and Staffing Survey (SASS), there were 1.4 million public secondary school educators, 13.7% of whom named mathematics as their main area of teaching and

11.4% of whom named science as their main area of teaching (Kuenzi, 2008). Results from the 2011 SASS found that the number of secondary school teachers had increased to over 1.5 million, with 14.7% focusing on math and 11.9% focusing on science (National Science Board, 2016). The United States Bureau of Labor Statistics (2017b) reported that there were 247,400 STEM-related postsecondary educators in May of 2015, a number that was expected to increase through the year 2024. The National Science Foundation (2014; 2017) noted that women scientists and engineers were more likely than men to become educators or work in educational institutions. This effect held true across every racial and ethnic group, with most male scientists and engineers choosing to enter the business sector (NSF, 2017).

In 2014, the National Science Foundation reported that women comprised 28% of all science and engineering workers, a statistic that has risen from 23% in 1993. Men outnumber women in every STEM field except psychology, although parity has almost been reached in the fields of biological, agricultural, and life sciences. The greatest disparity lies in the field of engineering, which was only 13% female in 2010 and 9% in 1993. The number of women in computer science more than doubled between 1993 and 2010, with women comprising approximately 25% of the workforce (NSF, 2014).

By far, whites continue to make up the vast majority of STEM employees in the United States. The National Science Foundation (2014) reported that in 2010 nearly 70% of employees in science and engineering fields were white, a statistic that had decreased from 84% in 1993. Asians make up the second largest ethnic group in STEM fields, followed by Hispanics, African-Americans, American Indians/Alaska Natives, and Native Hawaiians/Pacific Islanders.

Agricultural Education and STEM

When considering their histories, values, subject matter, and goals, agricultural education and STEM education have a great deal in common (Stubbs & Myers, 2016). In fact, the two areas can be quite complimentary when taught together. Scherer, McKim, Wang, DiBenedetto, and Robinson (2017) consider STEM subjects to play an important role in agricultural career success, and Stubbs and Myers (2016) speak of a "close match" between the two, and note that "agricultural education may be particularly well-suited to addressing STEM achievement" (p. 88). Budke (1991) notes that agricultural education courses can act as "a marvelous vehicle for teaching genetics, photosynthesis, nutrition, pollution control, water quality, reproduction, and food processing where real live examples can become part of the classroom experimentation and observation" (p.4).

Wilson and Curry (2011) reviewed numerous studies indicating that the integration of academic subjects into agriculture – with a specific focus on science – has been favorably received within the educational community at large. Agricultural educators, preservice teachers, school principals, science teachers, parents, and guidance counselors all expressed positive opinions of integration, especially in regard to the "real world context" that agriculture offers (p. 140). Teachers also largely support using integrated agriscience courses as an opportunity for students to earn science credit (Wilson & Curry, 2011). Many agricultural educators also recommend that preservice teachers receive instruction in using curriculum that highlights STEM concepts and practices.

Whent and Leising (1988) found agricultural students achieving "slightly higher" test scores than biology students and noted that agricultural students were keeping pace with their general science peers (p. 14). Enderlin and Osbourne (1992) saw that students in an integrated science and agriculture course demonstrated better knowledge of both agricultural and biological science concepts than those in a traditional horticulture course. Connors and Elliot (1995) found that high school seniors enrolled in agriscience courses "performed as well as" seniors who did not take agriscience, and Chiasson and Burnett (2001) reported that Louisiana agriscience students "had significantly higher overall scores than non-agriscience students" on the science portion of state tests (p. 74). Ricketts, Duncan, and Peake (2006) observed 78% of agriscience students passing state science examinations on their first attempt, which was higher than the state average of 68%. The study also identified a small yet positive correlation between a student's level of science achievement and number of agriscience courses completed (Ricketts, Duncan, & Peake, 2006). In a study by Conroy and Walker (2000), students who completed aquaculture courses self-reported improvement in both mathematics and science classes as a result of their agricultural education experiences. Parr, Edwards, and Leising (2006) found that a math-enhanced agricultural technology course significantly affected student performance on college-level mathematics placement exams. Young, Edwards, and Leising (2009) reported that enhancing mathematics content in agricultural power and technology courses did not diminish student learning gains in technology. Very little research has examined the integration of engineering into agricultural education, although it does have many applications in the field (Stubbs & Myers, 2015).

Swafford (2018) researched how postsecondary agricultural education faculty viewed STEM implementation. Swafford (2018) discovered that over 90% of those surveyed felt that undergraduates should receive instruction on emphasizing STEM content and utilizing experimental methods in the classroom. Interestingly, Swafford (2018) found that the land grant status of one's university (either land grant or non-land grant), as well as the appointment focus of faculty members (either STEM or non-STEM) significantly affected attitudes towards STEM integration in agricultural education curricula. Those employed at land grant universities showed overall higher levels of agreement towards STEM integration statements, as did those who were appointed to a STEM-focused position.

Swafford (2018) also examined the STEM-related educational behaviors of agricultural education faculty. Over 80% of participants indicated that they modeled inquiry-based teaching methods in their own classes and taught preservice teachers specific techniques for integrating STEM (Swafford, 2018). Less than half of participants indicated they maintained partnerships with those in STEM industries or used an "action plan" to guide STEM implementation into their agricultural education programs (Swafford, 2018, p. 322).

Barriers to STEM Integration in Agricultural Education

Despite the benefits of STEM integration into agricultural education, there are still many barriers that exist. Wilson and Curry (2012) cite that the actual integration effort can sometimes be a daunting task, and many agricultural educators find themselves in need of "encouragement and assistance to adopt integrated curriculum into their classrooms" (p. 140). Balschweid, Thompson, and Cole (2000) found that preservice agricultural educators were hesitant to integrate science material due to the time commitment involved in doing so. Myers and Washburn (2008) noted that a lack of time, support, materials, funding, and previous experience were all significant barriers as well. Poor teacher quality and lack of proper training are also barriers to STEM integration (Gonzales & Kuenzi, 2012), with many teachers realizing they are unprepared to teach more rigorous material and unsure about how to make new content relevant to student needs and interests (Granata, 2014; McKim, Lambert, Sorenson, & Valez, 2015; Seelman, 2003). Stubbs and Myers (2016) noted that some secondary teachers even fear too much integration of STEM content, feeling that it might decrease students' interests in agriculture and damage positive student/teacher relationships.

Coley, Warner, Stair, Flowers, and Croom (2015) identified agricultural teachers' lack of ability and support as barriers to the integration of technology in the classroom and recommended that preservice teachers practice using technology during university training and microteaching sessions. They also suggested that current teachers develop a "technology bank" from which both resources and ideas might be shared (p. 47). Some teachers of STEM content do not even possess the appropriate qualifications to teach their subject at all (Gonzales & Kuenzi, 2012).

Hamilton and Swortzel (2007) noted that while there are increased opportunities for students to learn science in secondary agriculture courses, "there is a concern about not only the quality of such courses, but also with the preparation of agriculture teachers teaching such courses (p. 2). The amount of STEM content to which students should be exposed during their university careers is one such concern. While a vast majority of postsecondary agricultural educators do believe that STEM is an important part of the curriculum, many are averse to increasing the number of STEM courses that students are required to complete (Swafford, 2018). Stubbs and Myers (2016) recommended that postsecondary agricultural teacher education programs attempt to find a careful balance between STEM-focused and pedagogy-focused courses.

Conversely, underexposure to STEM knowledge is also an issue. A study by Thoron and Myers (2009) revealed that a "lack of understanding of science content is the biggest barrier to integrating science in the agriculture education curriculum" (p. 536). Only 45% of surveyed preservice agricultural educators felt prepared to integrate physical science concepts into their classroom, and 58% were comfortable with integrating biological science material (Thoron & Myers, 2009).

Seelman (2003) wrote that many STEM educators were not given the opportunity to keep up with modern technology. Coley et al. (2015) studied technology usage by Tennessee agriculture teachers and found that over one half "did not have access to new educational technologies," and that "many teachers had limited access to various technologies" overall (p. 46). Barriers against the integration of technology included high costs and a lack of time for planning and preparing new lessons (Coley, et al., 2015). Smith et al. (2015) note that, with the exception of biotechnology, "minimal research has been conducted related to integration of technology in agriculture courses" (p. 184).

In a case study of STEM integration across three agricultural education programs Stubbs and Myers (2015) found that engineering concepts were primarily utilized in agricultural mechanics classes, although they were sometimes incorporated into other classes as well. When examining the textbooks used by the three programs, Stubbs and Myers (2015) realized that "engineering knowledge, skills, and careers were not consistently integrated" (p. 196). In addition, two of the three teachers that were interviewed displayed a "muddled" understanding of engineering concepts that paled in comparison to their perceptions of the other STEM fields. Smith et al. (2015) found that agricultural educators felt least confident in their ability to integrate engineering into their classes, and that they also viewed it as the least important of the four STEM disciplines.

Conroy, Trumbull, and Johnson (1999) noted that agricultural education was an excellent context through which students could learn mathematical skills, and agreed with Shinn et al. (2003) that improving student mathematical ability was an important role for agricultural educators. However, McKim et al. (2015) found that many Oregon agriculture teachers felt they had not received "adequate professional training" in new mathematics and English standards (p. 140). Stripling and Roberts (2013b) stated that "preservice agricultural educators were not prepared to effectively teach mathematical concepts" (p. 25), agreeing with previous work by Miller and Gliem (1996). Stripling and Roberts (2012) also found that University of Florida preservice agricultural educators "were not proficient in solving agricultural mathematics problems," and that only 16.7% had taken an advanced-level math course in college (p. 117).

Breaking the Barriers to STEM Integration in Agricultural Education

Although agricultural education curriculum is designed to give preservice agricultural educators a broad overview of general knowledge, agricultural content, and professional/educational content, recently programs have been changing to meet new needs (Torres, Kitchel, & Ball, 2010). Most agricultural teacher education programs require preservice students to complete general education courses in science and mathematics, as well as courses like soil science, animal nutrition, mechanics, and landscaping that allow scientific and mathematical principles to be applied directly in an agricultural context (Torres et al., 2010). Most programs also require students to complete technology courses that cover a wide range of needs and uses. Some are specifically agriculture- and career-focused, while others familiarize future teachers with the educational technology they will one day use in the classroom (Torres et al., 2010). Though engineering is usually not addressed as its own component, many engineering principles such as problem-solving, design, construction, and experimentation are covered in other courses (U.S. Bureau of Labor Statistics, 2017a).

Some universities with agricultural education programs are beginning to offer graduate-level classes that address STEM integration specifically (Virginia Tech, 2017). Virginia Tech's course, *STEM Integration in Agricultural Education*, gives students the opportunity to explore the purpose and components of STEM, as well their connection to agricultural education. The course also discusses inquiry-based instruction, problem-based learning, models for STEM education, methods for teaching qualitative skills, and STEM activities that can be utilized in agricultural education classrooms (Virginia Tech, 2017). The University of Florida has the Ag-STEM Lab, which was created to "discover ways to improve student learning of STEM concepts in agricultural and life sciences through collaborative research in teaching and learning in formal and informal settings" (University of Florida, 2018, para. 1). The Ag-STEM Lab offers educators research, advice, and lesson plans for better integrating STEM subjects into the classroom.

The Curriculum for Agricultural Science Education (CASE) is another method through which agricultural educators are preparing themselves to teach STEM-related content. Developed by the Council for Agricultural Education and managed by the National Association of Agricultural Educators, CASE was formed in response to calls for agricultural education reform. CASE material integrates science and mathematics into agriculture through “a structured sequence of courses” (CASE Pathways, 2018, para. 1), and offers teachers lesson plans, training, and community support in several agriculture-related courses across four pathways of study (CASE Pathways, 2018). These pathways include Plant Science, Animal Science, Agricultural Engineering, and Natural Resources (CASE Pathways, 2018). CASE lessons are designed to enhance student learning opportunities by providing standards-aligned content with opportunities for active participation via laboratory experiments, research projects, and group activities (CASE Pathways, 2018).

Social Cognitive Theory

When teachers integrate STEM content into agricultural education, they make many important decisions regarding content background, curriculum, context, teaching methods, teaching techniques, and classroom management. Understanding how and why these decisions are made can assist in improving efforts for STEM integration.

This study will examine these choices from a personal context based upon Albert Bandura’s social cognitive theory (Bandura, 1986). Social cognitive theory states that human learning and development is a cognitive process governed not by a single external or internal force, but rather by a mix of one’s past behavior, social environments, and personal characteristics. These three factors are closely linked, and they all interact with one another in what has been termed a “triadic reciprocality” (Figure 1; Bandura, 1986; Pajares, 2002).

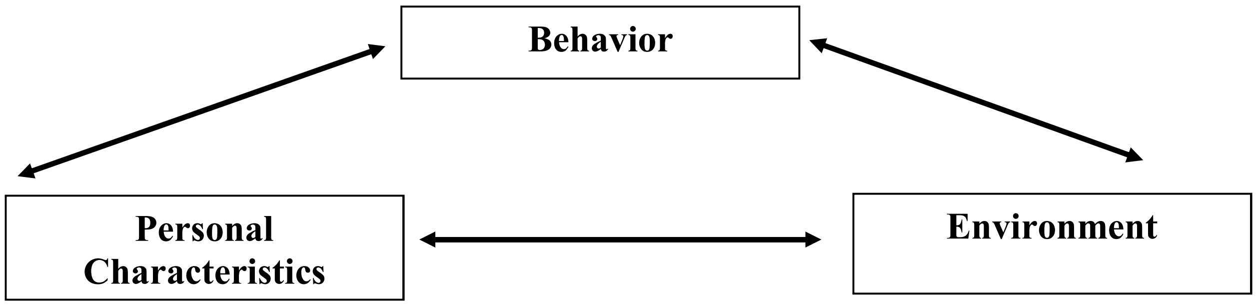

Figure 1 Social Cognitive Theory

(Bandura, 1986; Pajares, 2002)

The first factor in Bandura's model of Social Cognitive Theory is personal characteristics. In this context, personal characteristics "include mental and emotional factors such as goals and anxieties," "metacognitive knowledge," and "self-efficacy" (Snowman, McCown, & Biehler, 2009, p. 276). Metacognitive knowledge involves a functional understanding of "one's own cognitive processes," which includes analyzing, planning, and monitoring one's own tendencies and abilities to maximize achievement while learning takes place (Snowman et al., 2009, p. 276). Self-efficacy is essentially one's beliefs in one's own ability to achieve specific goals or carry out specific tasks. In the classroom, personal characteristics might influence how teachers respond to students' (or even their own) emotions, how confident they feel in their ability to teach certain subjects, or how they are able to use gathered knowledge to make effective decisions for the future (Snowman et al., 2009).

The second factor of Social Cognitive Theory is a person's behavior. This includes not only how a person acts in various situations, but also their ability to recognize that behavior, reflect upon its impact, and make changes accordingly. While self-efficacy is considered to be a personal characteristic in Bandura's model, the behavioral factor affects how self-efficacy is developed, how emotions are managed, and how failure is learned from and overcome (Snowman et al., 2009). A teacher's behaviors in the classroom include the teaching methods and techniques employed, as well as their response to the situations and demands that arise in the classroom every day (Snowman et al., 2009).

The third factor in Bandura's model is "an individual's social and physical environment" (Snowman et al., 2009, p. 276). According to Bandura, environments include not only a person's surroundings and social circle, but also "the nature of the task" at hand, how rewards are given and consequences enforced, the quality of explanations and directions, the effectiveness of models, and the influence of others upon both physical and mental states (Snowman et al., 2009, p. 276). In educational settings, environments can involve the physical classroom itself, a school or community's culture, classroom management strategies, school leadership, and relationships that develop amongst teachers, students, parents, and administrators.

Self-Efficacy

Learning occurs when we outwardly observe the actions of others, reflect upon them internally, and decide to regulate our behavior in the most optimal way (Bandura, 1986; McKim & Velez, 2016; Pajares, 2002). In other words, humans are capable of making change through their own actions and are actively engaged in their own development. Because a great deal of learning is internal, it is one's personal characteristics that form the foundations of Bandura's theory (Pajares, 2002). Self-efficacy can be considered a personal characteristic. Bandura (1986) defined self-efficacy as "people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performances" (p. 391). Stated more simply, self-efficacy is one's confidence in their ability to make choices and secure desired outcomes. Self-efficacy can affect one's actions in a variety of ways, and can have effects on a person's choices, goals, motivations, outlook, persistence, and response to challenges (Bandura, 1986, 1994, 1997; McKim & Velez, 2016; Pajares, 2002). It should not be confused with self-esteem, which is "concerned with judgments of self-worth," rather than with one's beliefs in their ability to shape outcomes (Bandura, 1997, p. 11). Bandura (1997) noted that the two concepts are not identical, as a person could lack skill in something but still like themselves no less, or conversely perform a task well but still dislike themselves.

Effects of Self-Efficacy

Self-efficacy is known to affect human functioning in four areas. The first of these involves cognitive functions such as goal-setting, self-appraisal, resilience, and expectations. A person with high self-efficacy is more likely to appraise themselves and their skills in a positive light and will therefore decide that they are capable of taking on more difficult challenges. In addition, they are better able to imagine possible positive outcomes and success scenarios that can serve as driving forces or guiding objectives.

Where those with low self-efficacy would focus only on what has gone (or could go) wrong, someone with high self-efficacy could visualize desired results and work towards them faithfully. Self-efficacious people are also known to be more committed and persistent in achieving lofty challenges they set for themselves, even when beset with distractions and failures. Bandura (1994) stated that ignoring self-doubt and remaining task-oriented during difficult times certainly required “a strong sense of efficacy,” and that those who succumbed would become “erratic in their analytic thinking”, and experience “lowered aspirations” and poor performance quality (p. 4).

The second of the four areas influenced by self-efficacy is motivation. People with high self-efficacy often believe that failures are due to lack of effort, instead of lack of skill or other outside factors. Thus, they see failure as something that can be actively dealt with and overcome through hard work and perseverance, instead of something outside the realm of their control. A highly self-efficacious person also finds motivation in their ability to envision desirable outcomes and seek satisfaction by making them reality. According to Bandura (1994), “explicit, challenging goals enhance and sustain motivation,” and experiencing “discontent with substandard performances” only serves as a call to redouble one’s efforts on the path to self-satisfaction (p. 5).

Affective processes make up the third area of human functioning affected by self-efficacy. Affective processes involve a person’s ability to cope with and manage stressful factors and situations. Low-self efficacy usually manifests in “high anxiety arousal,” magnification of threats, over-worrying, and the idea that one’s environment is “fraught with danger,” at every turn (Bandura, 1994, p. 5). Those who experience these symptoms often find themselves unable to take risks or control the emergence of disturbing thoughts. Whether self-imposed or not, an inability to control the stressors in one's environment can lead to both mental and physical health issues such as depression, anxiety, and susceptibility to infection (Bandura, 1994). High self-efficacy is related to more positive mental and physical health, as well as openness to experience and control over one's life and affairs.

The final area of human functioning affected by self-efficacy is in the selection processes that people undertake. Because self-efficacy is intertwined with the concept of choice, it can therefore have a large effect on one's life, occupation, personal growth, and abilities. A person with high self-efficacy will "readily undertake challenging activities and select situations they judge themselves capable of handling," which greatly broadens the range of life outcomes and possibilities to which they can seriously aspire (Bandura, 1994, p. 7). This, in turn, increases one's interest and motivation to achieve in the selected areas, which leads to better educational and mental preparation and eventually greater success. As a person moves through this journey, they also come into contact with people, ideas, and competencies that shape their progression and worldview. Such growth occurs throughout one's life.

Sources of Self-Efficacy

Bandura (1994) stated that self-efficacy can be developed through four main sources: mastery experiences, vicarious experiences, social persuasion, and emotional states. Mastery experiences are by far the most effective way of building one's sense of self-efficacy. A mastery experience is an experience in which a person successfully overcomes obstacles to achieve an objective or goal. According to Bandura (1994), "successes build a robust belief in one's personal efficacy," while "failures undermine it, especially if failures occur before a sense of efficacy is firmly established" (p. 2). However, early success alone is not enough to ensure that self-efficacy is developed. Too many early successes cause people to "expect quick results" and become "easily discouraged by failure" when challenges arise (Bandura, 1994, p. 2). Instead, setbacks can be useful for convincing learners that they have the ability to succeed in spite of obstacles, and that perseverance through difficulty will help them become stronger and more capable overall.

The second source of self-efficacy is through vicarious experiences provided by models (Bandura, 1994). A person has a vicarious experience when they observe a model exhibiting a specific behavior or completing a specific task. The observer then uses the information gathered via observation as a baseline against which they compare their own perceived knowledge and skills. Vicarious experiences are most effective as builders of self-efficacy when the model is both successful in their task and similar to the learner, as this "raises observers' beliefs that they too possess the capabilities to master comparable activities" (Bandura, 1994, p. 3). Conversely, watching a model fail at a task despite giving great effort will cause an observer to lower their estimation of their own capabilities. However, a model's influence decreases as differences between model and observer grow. If observers determine that a model is not much like themselves, neither the model's successes nor failures will result in lasting self-efficacy change. Vicarious experiences also require that the model be proficient in the knowledge they are expressing or the behavior they are displaying. Observers gauge a model's level of proficiency by taking the model's knowledge and actions into account. The more competent that a model is perceived to be, the more efficacious the observer will feel, and the more positive and persevering they will become.

The third source of self-efficacy is social persuasion (Bandura, 1994). Social persuasion involves a person being verbally told that they have the ability to succeed. Hearing such encouragement makes people more likely to "mobilize greater effort and sustain it," and can serve as a boost for overcoming self-doubt, "personal deficiencies," and other obstacles to success (Bandura, 1994, p. 3). Social persuasion can often be a double-edged sword, however, as it can easily serve as means for decreasing self-efficacy too. Those who are told they do not have what it takes will likely avoid a challenging undertaking all together or may give up easily when problems occur. Insincere or unrealistic social persuasion can also harm a person's self-efficacy, as they are often "quickly disconfirmed by disappointing results" that may become negative mastery experiences. Thus, social persuasion works most effectively when it is given honestly and objectively, and when it occurs in situations structured to bring success and limit failure.

The fourth source of self-efficacy involves a person using physiological indicators such as "somatic and emotional states" to make judgments regarding self-efficacy (Bandura, 1994, p. 3). This occurs when people interpret their reactions and moods as indicators of performance quality. For example, someone feeling stress after completing a task may think that their performance was poor or negatively received, whereas someone with less stress will think better of their abilities and outcomes. Physical signs such as pain, illness, or fatigue can also carry this connotation, as can one's mood. Someone attempting a task in a negative mood will likely have lower self-efficacy than someone attempting it while in a positive one. Therefore, one can improve one's own self-efficacy by learning to recognize, manage, and correctly interpret emotions and physiological states. Those modeling tasks or behaviors can also assist in the effort by reducing opportunities for stress and by teaching appropriate emotional skills.

Teacher Self-Efficacy

Teacher self-efficacy is a form of self-efficacy that is specific to the education field. The concept was originally studied in the mid-1960s when the Rand Corporation examined the relationship between teacher characteristics and student learning gains (Tschannen-Moran & Woolfolk Hoy, 2001). The Rand Corporation's work conceived teacher self-efficacy as "the extent to which teachers believed that they could control the reinforcement of their actions" and if such control lay within the teacher's realm of influence (Tschannen-Moran & Woolfolk Hoy, 2001). Tschannen-Moran, Woolfolk Hoy, and Hoy (1998) described teacher self-efficacy as a teacher's "belief in his or her capability to organize and execute courses of action required to successfully accomplish a specific task (i.e., student performance) in a particular context" (p. 233).

Teacher self-efficacy can be divided into two categories: outcome expectancy (also called general teaching efficacy) and personal teaching efficacy (Tschannen-Moran & Woolfolk Hoy, 2001). Outcome expectancy is related to factors that teachers know they cannot control outright but believe they can influence (Angle & Moseley, 2010; Hoy, 2000). Such factors include the value of education in a child's home, a student's psychological or physiological needs, and violence or substance abuse in the school community (Tschannen-Moran & Woolfolk Hoy, 2001). Personal teaching efficacy "relates to a teacher's own feeling of confidence in regard to teaching abilities"

(Protheroe, 2008, p. 43), and involves teachers expressing faith in their own capacity to "develop strategies for overcoming obstacles to student learning" (Tschannen-Moran & Woolfolk Hoy, 2001, p. 785).

Bandura (1994) stated that "the task of creating learning environments conducive to development of cognitive skills rests heavily on the talents and self-efficacy of teachers" (p. 11). In other words, a teacher's level of efficacy holds a powerful influence on many of the factors that affect student performance and learning. Studies have shown that a teacher's self-efficacy is closely related to classroom performance, student motivation, and student achievement (Tschannen-Moran et al., 1998). Teachers with high self-efficacy are more organized, resilient, and enthusiastic in their work, and are shown to demonstrate more effective teaching behaviors and classroom management strategies overall (Protheroe, 2008; Tschannen-Moran & Woolfolk Hoy, 2001). This includes being less critical of student mistakes and being more willing to work with students who have learning difficulties or behavior issues (Protheroe, 2008; Tschannen-Moran & Woolfolk Hoy, 2001). They are also better at motivating students, facilitating general cognitive development, and building "a positive atmosphere for development that promotes academic attainments" regardless of students' backgrounds (Bandura, 1994, p. 11).

In contrast, teachers with lower teaching self-efficacy display less motivation, persistence, and general teaching ability than their more efficacious peers. They are less open to new or innovative ideas, and less willing to experiment with different teaching methods and techniques. (Protheroe, 2008; Tschannen-Moran & Woolfolk Hoy, 2001). This includes focusing mainly on teacher-directed instructional approaches and avoiding those that are more student-centered, such as inquiry-based learning (Powell-Moman &

Brown-Schild, 2011). Their classroom management skills are also weaker, and they may "favor a custodial orientation that relies heavily on negative sanctions to get students to study" (Bandura, 1994, p. 11). Finally, low teacher self-efficacy is also related to decreased career commitment and job satisfaction, as well as increased risk of teacher burnout (Blackburn & Robinson, 2008; Evers, Brouwers, & Tomic, 2002; Skaalvik & Skaalvik, 2010).

Teacher Self-Efficacy and Agricultural Education

Teacher efficacy is both subject- and situation-specific, meaning that a teacher could feel more confident teaching certain subjects or working with certain students (Tschannen-Moran et al., 1998). Therefore, it is a worthwhile endeavor to examine the history of efficacy research within agricultural education. One of the first studies involving agricultural educator self-efficacy was conducted by Rodriguez (1997). This study examined the self-efficacy levels of preservice and beginning agricultural educators in Ohio. Rodriguez (1997) found that preservice and beginning teachers had higher personal teaching efficacy than outcome expectancy, and that teachers in their second year had the lowest levels of efficacy overall. This was confirmed by Swan, Wolf, and Cano (2011), but contrasted by Blackburn and Robinson (2008), who found that teachers with 3 to 4 years of experience had the lowest efficacy.

In the first published study on agricultural educator teacher self-efficacy, Knobloch (2001) looked at the effects of peer teaching on preservice agricultural education students. While peer teaching did increase teacher self-efficacy, the benefits disappeared after students completed early field experiences. In 2002, Knobloch and

Whittington followed up these early studies by exploring the effects of school principal behaviors on the collective efficacy of several preservice and beginning agricultural educators. They continued their study into the topic in 2003, examining teacher self-efficacy differences between those who were highly committed to their careers and those who were not (Knobloch & Whittington, 2003a). The study found that the highly committed teachers had no changes in self-efficacy after ten weeks of teaching, while their less-committed counterparts saw a decrease. Knobloch and Whittington (2003b) also identified that student teachers had the highest levels of efficacy, which contrasted with first year teachers who had the lowest. Swan (2005) found no connection between learning style and efficacy and found that some variance in career intent was indeed linked to teachers' self-efficacy beliefs.

Positive experiences during teacher preparation and student teaching were both found to be significant predictors of agricultural educators' teacher self-efficacy (Knobloch, 2006; Whittington, McConnell, & Knobloch, 2006; Wolf, 2008), while the number of classes that a teacher prepared for was found to be a negative predictor (Whittington, McConnell, & Knobloch, 2006). Roberts, Harlin, and Ricketts (2006) and Harlin, Roberts, Briers, Mowen, and Edgar (2007) both observed the efficacy levels of student teachers who completed a 4-week training. Efficacy was high immediately after the training, but it fell during the middle of student teaching, only to rise again at its successful conclusion. Stripling, Ricketts, Roberts, and Harlin (2008) collected efficacy data from student teachers at three points in time (before a teaching methods course, after the teaching methods course, and after student teaching), and found that efficacy levels increased at each.

Rocca and Washburn (2006) and Duncan and Ricketts (2006) studied differences in efficacy between alternatively certified and traditionally certified agricultural educators. Both studies found similar efficacy levels between the two groups regarding teaching and learning, although Duncan and Ricketts (2006) noted that traditionally certified teachers were more efficacious in certain areas such as FFA and program management.

Teacher Self-Efficacy and STEM Education

Like with agricultural education, research into STEM teacher efficacy is relatively new. However, research into its separate components – specifically science and mathematics – is more common. Factors that influence science teaching efficacy include specific subject matter (Tschannen-Moran et al., 1998), gender, grade level(s) taught, teacher perceptions of administrative support, and the number of professional development sessions completed (Margot, 2017). Methods for improving science teaching efficacy include attending professional development workshops (Mahler & Benor, 1984; Riggs, 1995) and increasing the number of science courses completed at the university level (Rubeck & Enoch, 1991). Courses meant to specifically instruct teachers in science education techniques can also boost teacher self-efficacy (McCall, 2017). Darling-Hammond (2000) does warn, however, that increased science courses for educators are only effective up to a point, as subject expertise eventually outpaces the needs of most scientific curricula. Science teaching efficacy has a direct effect on the teaching methods that are used, as science teachers with lower efficacy levels were found to provide fewer cooperative learning opportunities and more "text-based approaches" instead of those that were “hands-on, activity based” (Riggs, 1995; Tschannen-Moran et al., 1998, p. 216).

Regarding science integration into agriculture, Hamilton and Swortzel (2007) found that Mississippi agriculture teachers believed themselves to possess a high level of teacher efficacy for science. However, a low but negative relationship was discovered between science teaching efficacy and teachers’ abilities to teach science integrated process skills. Burris, McLaughlin, McCulloch, Brashears, and Fraze (2010) found that fifth year agricultural educators had slightly higher efficacy levels for teaching animal science, plant and soil science, and environmental science than did first year agricultural educators. Ulmer, Velez, Lambert, Thompson, Burris, and Witt (2013) studied the science teaching efficacy of agricultural educators who had completed a Curriculum for Agricultural Science Education (CASE) training institute in 2010. Participants demonstrated immediate gains in both personal science teaching efficacy and science teaching outcome expectancy. Nine months later the same teachers showed similar levels of efficacy but decreased outcome expectancy, which indicated that CASE institutes have the potential to leave lasting effects on teacher self-efficacy.

Technology-based teacher self-efficacy is also impacted by several factors that include teacher age and attitudes, perspectives of technology, school access to technology, cost, and training or education (Murphrey, Miller, & Roberts, 2009; Redmann, Kotrlik, & Douglas, 2003; Watson, 2006). A few studies have examined technological teacher self-efficacy in agricultural education. Burris, McLaughlin, McCulloch, Brashears, and Fraze (2010) found that fifth year agricultural educators had higher teaching self-efficacy levels in an agricultural technology and mechanics course than did agricultural educators in their first year. Stewart, Antonenko, Robinson, and Mwavita (2013) examined levels of technology integration, teacher self-efficacy, and content knowledge for both preservice and in-service agricultural educators. Results showed no significant differences in efficacy levels, but suggested that in-service teachers viewed technology as a tool for increasing engagement and facilitating educational gains, while preservice educators tended to use it for classroom management purposes.

Engineering teaching efficacy has “rarely been explored in the setting of K-12 engineering education” (Yoon, Evans, & Strobel, 2012, p. 3). Most educators are not exposed to engineering concepts during the course of their teacher education, and as such the field and its “content, materials, and teaching styles” are often quite unfamiliar (Yoon et al., p. 3). Hammack and Ivey (2017) found that elementary school teachers had low levels of engineering teacher self-efficacy, and that gender, grade level, ethnicity, and Title I school status were all important factors in its development. Hirsch, Kimmel, Rockland, and Bloom (2005) attested that teacher workshops on engineering principles and their integration into the classroom has a beneficial effect on attendees’ views of engineering fields.

In agricultural education, engineering is often the least consistently integrated of the four STEM subject areas (Stubbs & Myers, 2015). Stubbs and Myers (2015) identified agricultural educators covering some engineering content in their courses, although a few participants’ perceptions of engineering were described as “muddled compared to their perceptions of science, technology, and mathematics” (p. 198). Smith et al. (2015) found that agricultural educators were least confident in their ability to integrate engineering out of the four STEM areas, and that female agricultural educators were less confident than male teachers. Individuals' perceptions of instructional method effectiveness also impacted teacher efficacy towards engineering content (Smith et al., 2015).

Mathematics teaching efficacy, is affected by determinants such as age (Stripling & Roberts, 2013b), gender, (Stripling & Roberts, 2013b), mathematical knowledge (Isiksal-Bostan, 2016; Hilby, Stripling, & Stephens, 2014), anxiety towards mathematics (Gresham, 2009; Hilby et al., 2014), past experience with mathematics (Hilby et al., 2014; Stripling & Roberts, 2012) and professional development in mathematical subjects (Zambo & Zambo, 2008). Like with science teaching ability, increased numbers of university-level mathematics courses lead to increased teaching ability, at least up to a certain threshold level where subject matter specifics bypass the needs of the curriculum being taught (Darling-Hammond, 2000).

Integration of mathematics into agricultural education has been described as "limited" (Hilby et al., 2014, p. 115). Stripling and Roberts (2013b) found that preservice agricultural educators with the highest levels of mathematical teaching efficacy had completed the most mathematics courses in college although their overall mathematics ability was lower. Those who earned high grades in their most recent mathematics course also had higher mathematics and mathematics teaching self-efficacy scores. Elapsed time since a student's last mathematics course also effected efficacy levels. As time increased, so too did participants' mathematics teaching self-efficacy scores. Once 10 semesters had passed, however, efficacy scores were seen to fall.

Stripling and Roberts (2013a) also examined the effects of a math-enhanced teaching methods course for preservice agricultural educators. Results revealed that participants' mathematics ability increased but mathematics teaching self-efficacy decreased. Haynes and Stripling (2014) reported that the majority of Wyoming agricultural educators were "moderately efficacious" in their mathematics teaching self-efficacy and recommended that mathematical professional development be tailored to teachers' individual efficacy levels (p. 57). Teachers with moderate levels of mathematics teaching self-efficacy were said to be "more concerned with procedural elements or tasks" related to teaching mathematics, and thus would benefit from assistance in "locating and selecting mathematics reference material, and designing lesson plans that use agriculture as a context for teaching mathematics" (p. 58). Teachers with higher levels of mathematics teaching self-efficacy are "more concerned with improving pedagogical content knowledge" and can benefit from professional development that focused on "teaching specific mathematics concepts," "collaborating with math teachers," and "motivating students to learn mathematics in the agriculture and natural resources curricula" (p. 58)

Summary

Agricultural education and STEM education both have rich histories that have helped the United States to grow and progress throughout the years. Both also have complimentary philosophies that involve teaching students more than just information, but also how that information can be applied in the everyday world. Combining agricultural education and STEM – an initiative that is supported on both sides of the aisle – helps to create educational experiences that better prepare students not only for standardized tests, but also for life.

Teacher self-efficacy, or a teacher's "belief in his or her capability to organize and execute courses of action required to successfully accomplish a specific task (i.e., student performance) in a particular context" (Tschannen-Moran, Woolfolk Hoy, and Hoy, 1998, p. 233) is an important indicator of teacher performance. Teachers with high self-efficacy show better levels of job satisfaction, resilience, effective teaching skills, and classroom management than their less efficacious peers. Teacher self-efficacy is subject-specific and can be improved through various means including increased educational and professional development opportunities, familiarity with the subject matter, and positive mastery experiences.

Previous studies have examined agricultural educators' general self-efficacy beliefs as well as their beliefs in science and math. Studies have also examined STEM educators' self-efficacy beliefs in their respective subject areas. However, no studies have examined agricultural educators' self-efficacy beliefs in regard to the four STEM areas of science, technology, engineering, and mathematics.

CHAPTER III

METHODS AND PROCEDURES

Introduction

This chapter describes the materials, methods, and procedures used to conduct this study. This includes descriptions of the research purpose and objectives, research design, study population, instrument, variables, and data collection procedures.

Purpose of the Study

The purpose of this study was to identify agricultural educators' self-efficacy levels regarding the integration of science, technology, engineering, and mathematics (STEM) content into agricultural education. In addition, this study also explored any connections that may exist between agricultural educator STEM self-efficacy and educator age, gender, years of teaching experience, certification type, and number of postsecondary-level STEM courses completed.

Research Objectives

This study utilized the following objectives:

1. Determine agricultural educators' levels of personal teaching self-efficacy regarding their ability to teach STEM content within the context of agricultural education.

2. Identify relationships that may exist between agricultural educators' personal teaching self-efficacy levels and their age, gender, ethnicity, certification type, teaching career length, STEM background, and professional development history.
3. Determine agricultural educators' levels of outcome expectancy beliefs regarding their ability to teach STEM content within the context of agricultural education.
4. Identify relationships that may exist between agricultural educators' outcome expectancy levels and their age, gender, ethnicity, certification type, teaching career length, STEM background, and professional development history.

Research Design

This study utilized a descriptive correlational cross-sectional research design. The descriptive part of the study was used to identify various characteristics of secondary agricultural educators in Tennessee and Mississippi. These characteristics include teachers' self-efficacy towards STEM content, outcome expectancy beliefs towards STEM content, age, gender, years of teaching experience, and number of postsecondary-level STEM courses completed. The correlational part of the study identified if relationships existed between agricultural educators' STEM self-efficacy, STEM outcome expectancy, and other characteristics. This study did not attempt to determine if a causal relationship existed between variables.

Advantages of this design include its ability to compare and identify relationships amongst many variables at once and provide insight into a phenomenon at a single point in time (Sedgewick, 2014). In this study, current conditions regarding agricultural educators' self-efficacy beliefs towards STEM and personal characteristics will be considered. Disadvantages of this design include the fact that causal relationships cannot be determined amongst variables and that gathered information does not describe changes over a period of time (Sedgewick, 2014).

Study Population

The study population consisted of secondary agricultural education teachers in Mississippi and Tennessee. These states were selected due to location and ease of obtaining participant contact information. Participant contact information was provided by the Mississippi FFA Association and the Tennessee Department of Education. Contact information indicated that there were 143 agricultural educators in Mississippi and 334 in Tennessee, which provided a total population size of 447. All 447 teachers were contacted via email and asked to participate in the study. Only data collected from respondents was used for statistical analysis.

Variables

Dependent Variables

There were two dependent variables measured in the study. The first dependent variable was agricultural educators' personal teaching efficacy in their ability to teach the four STEM subject areas of science, technology, engineering, and mathematics within the context of agricultural education. The second dependent variable being measured was agricultural educators' outcome expectancy beliefs regarding STEM content.

Independent Variables

There were seven independent variables considered in this study. These variables examined possible factors affecting agricultural educators' personal teaching efficacy and outcome expectancy towards the STEM subjects of science, technology, engineering, and mathematics. These variables were teacher age, teacher gender, years of teaching experience overall and in agricultural education, teacher CASE attendance, STEM professional development attendance, and number of postsecondary STEM courses completed.

Instrument

This study used the Teacher Efficacy and Attitudes Toward STEM (T-STEM) Survey instrument to collect data. Permission was given by the creators of the T-STEM instrument for the instrument to be used in this study (Appendix C). The T-STEM instrument was developed by researchers at The Friday Institute for Educational Innovation at North Carolina State University (2012). Overall, there were five versions of the T-STEM instrument developed: one each for teachers of the four STEM areas (science, technology, engineering, and mathematics), and one for elementary school teachers (Unfried, Faber, Townsend, & Corn, 2014). This study makes use of only the first four versions, as they provide deeper insight into teacher efficacy regarding specific STEM areas. Although there were four different surveys, they were designed to be "parallel" to one another, with only "subject specific identifiers" changed to address the STEM area in question. Thus, the four surveys were very similar to one another in format overall.

The four T-STEM surveys used in this study contained seven constructs each. This study, however, used only two of the constructs: Personal Teaching Efficacy and Beliefs (PTEBS) and Teacher Outcome Expectancy Beliefs (TOES). These constructs were selected because they best met the objectives of the study.

The first construct measured was Personal Teaching Efficacy and Beliefs (PTEBS), which was described as a teacher's "self-efficacy and confidence related to teaching the specific STEM subject" (Unfried et al., 2014, p. 5). This construct was measured on measured on a 5-point Likert-type scale ranging from "1 = strongly disagree" to "5 = strongly agree (Unfried et al., 2014, p. 6). Cronbach's Alpha was reported as 0.92 for the science-targeted survey, and as 0.94 for the mathematics-targeted survey (Unfried et al., 2014, p. 7). Due to small sample sizes, the researchers were "not able to calculate reliability levels or factor analysis" for all surveys or constructs, and in this case the reliability was not reported for the technology- and engineering-targeted instruments (Unfried et al., 2014, p. 6).

The second construct measured was Teaching Outcome Expectancy Beliefs (TOES), or the "degree to which the respondent believes, in general, student-learning in the specific STEM subject can be impacted by the actions of teachers" (Unfried et al., 2014, p. 5). This construct was measured on a 5-point Likert-type scale ranging from "1 = strongly disagree" to "5 = strongly agree (Unfried et al., 2014, p. 6). Cronbach's Alpha was reported as 0.84 for the science-themed instrument, and 0.87 for mathematics (Unfried et al., 2014, p. 7). Like the first construct, low sample sizes made it impossible to report on the reliability of the technology or engineering instruments.

These two constructs were originally developed from the Science Teaching Efficacy Beliefs Instrument (STEBI), (Riggs and Enochs, 1990). (Unfried et al., 2014). Items on the original instrument were updated for modern educational needs, edited for clarity and ease of understanding, and altered to “use student growth language instead of student achievement language” where necessary (Unfried et al., 2014, p. 5).

For the purposes of this study, the instrument was edited to include questions that gather information on participant characteristics. These questions asked participants to identify their age, gender, ethnic background, CASE attendance history, and educational background, including the type of teaching license possessed. Participants were also asked to identify educational courses in science, technology, engineering, and mathematical fields that they had completed at the postsecondary level.

Pilot Test

Prior to actual data collection, the survey instrument was pilot tested with a group of 31 agricultural educators from Alabama. Pilot test participants were selected based on their willingness to assist with in the pilot test phase and were contacted via email. These participants were given a link to the survey and were asked to complete it while looking for errors in grammar, spelling, formatting, and overall survey flow. Overall response to the survey was positive, and only one edit was recommended. This edit involved reformatting the response spaces available on question 27. This question asked participants to list their degrees and majors, as well as the institution that granted each. Response spaces were edited to clarify instructions and ensure that participants provided all three pieces of information.

The pilot test was also used to evaluate the reliability and validity of the T-STEM instrument for use in this study. Cronbach's Alpha was .86 for the science section of the instrument, .70 for the technology section, .82 for the engineering section, and .84 for the mathematics section. These alpha levels were lower than those reported by Unfried et al. (2014), but this is likely because the total number of survey items was reduced for the purposes of this study. However, the alpha levels of each section do meet Nunnally's (1978) threshold of .70, which is suggested as a baseline for early research in social science areas.

Data Collection

This study was approved by the Mississippi State University Institutional Review Board (IRB) before data collection began (Appendix B). Overall, data collection was largely carried out through digital means. Possible participants were contacted by email and asked to complete the survey online. Participant emails were provided by the Tennessee and Mississippi Departments of Education. An email reminding participants of the study was sent one week after the initial survey release, followed by a second two weeks later. This schedule follows Salant and Dillman's (1994) recommended survey distribution procedures.

All emails contained a short letter to the recipient describing the survey's purpose and thanking the recipient for their time and consideration. The emails also included a link to the survey instrument, which was administered via the online survey website Qualtrics.

Data Analysis

Collected data were analyzed using the IBM Statistical Package for Social Sciences (SPSS) Version 24. Data were analyzed for relationships that exist between STEM teaching efficacy and outcome expectancy and other factors such as age, gender, length of teaching career, CASE attendance, and number of courses completed in STEM areas. In order to minimize bias, results were also analyzed based on the date of collection and compared using a standard t-test with an alpha level of 0.05. Results of this test revealed that there were no significant differences between early and late responders.

Both the personal teaching efficacy and outcome expectancy portions of the instrument were scored on a summated scale. The personal teaching efficacy portion consisted of 11 items that were all scored with a Likert-type scale ranging from 1 = "strongly disagree" and 5 = "strongly agree." This made the lowest possible efficacy score 11 and the highest possible score 55. The outcome expectancy portion consisted of 9 items that were scored with an identical Likert-type scale. This resulted in the lowest possible efficacy score being 9 and the highest being 45.

Missing Data

Twelve respondents completed the personal teaching efficacy portion of the instrument, but did not complete the outcome expectancy section. This is likely due to survey fatigue, as the instrument was relatively long and all 12 responses stopped at the same point in the survey. These 12 responses were included in the analysis of objectives one and two (which analyzed personal teaching efficacy towards STEM), but not in objectives three and four (which analyzed outcome expectancy).

CHAPTER IV

RESULTS AND FINDINGS

Purpose of the Study and Research Objectives

The purpose of this study was to identify agricultural educators' self-efficacy levels regarding the integration of science, technology, engineering, and mathematics (STEM) content into agricultural education. In addition, this study also explored any connections that may exist between agricultural educator STEM self-efficacy and educator age, gender, years of teaching experience, certification type, professional development history, and number of postsecondary-level STEM courses completed.

This study utilized the following objectives:

1. Determine agricultural educators' levels of personal teaching self-efficacy regarding their ability to teach STEM content within the context of agricultural education

2. Identify relationships that may exist between agricultural educators' personal teaching self-efficacy levels and their age, gender, ethnicity, certification type, teaching career length, STEM background, and professional development history
3. Determine agricultural educators' levels of teacher outcome expectancy beliefs regarding their ability to teach STEM content within the context of agricultural education

4. Identify relationships that may exist between agricultural educators' outcome expectancy levels and their age, gender, ethnicity, certification type, teaching career length, STEM background, and professional development history

Participant Characteristics

In order to identify factors that play a role in shaping teachers' personal teaching efficacy and outcome expectancy towards STEM subjects, several specific characteristics were selected for investigation. These factors were chosen because they have already been shown to play a role in impacting teacher efficacy levels. The characteristics examined in this study included teacher age, gender, ethnicity, certification type, teaching career length, STEM background, and professional development history.

State, Age, Gender, and Ethnic Background

In total, 91 agricultural educators participated in the study, resulting in a 20% response rate. Seventy-nine participants completed the entire instrument for the study, for a 17.7% total completion rate. Twelve respondents completed only the general teaching efficacy portion of the instrument and did not provide data on their STEM-related outcome expectancy levels.

Of the 79 respondents who provided demographic information, there were 32 Mississippi teachers and 47 Tennessee teachers. The average age of participants was 41.26 years (*SD* = 12.01), with the youngest participants indicating they were 23 years old and the oldest indicating they were 65 years old. Forty-three participants were male

(54.43%), and 36 were female (45.57%). Regarding ethnic background, 76 respondents were White/Caucasian (96.20%), 2 were Black/African-American (2.53%), and 1 selected "other," (1.27%). Table 1 displays agricultural educators' demographic information.

Table 1 Agricultural educators' state, gender, and ethnic background (n = 79)

	f	%
State		
Mississippi	32	40.50
Tennessee	48	59.50
Gender		
Male	43	54.43
Female	36	45.57
Ethnic Background		
Black/African American	2	2.53
Asian American/Pacific Islander	0	0
Hispanic/Latino	0	0
Native American/Alaska Native	0	0
White/Caucasian	76	96.20
Other	1	1.27

Teaching Career

Career length varied from less than 1 year of experience (f = 5, 6.3%) to 42 years (f = 1, 1.2%) of experience, with a mean of 14.14 years (SD = 9.30). Like total teaching career length, agricultural education career length ranged from 1 year of experience (*f* = 5, 6.8%) to 42 years of experience (*f* = 1, 1.3%). The average length of participants' careers in agricultural education was 12.44 years (SD = 9.17). Fifty-four participants (68.35%) earned their teaching certifications through traditional means with a student teaching internship. Twenty-five participants (31.65%) received their certifications through an alternative route that did not include a student teaching internship. Table 2 shows agricultural educators' certification types.

Table 2 Agricultural educators' certification types (*n* = 79)

	f	%
Certification Type		
Traditional	54	68.35
Alternative	25	31.65

Education

Fifteen respondents (18.98%) had associate's degrees, 8 of which were in areas directly related to agriculture. Majors included pre-veterinary medicine (*f* = 2, 13.33%), agriscience technology (*f* = 1, 6.67%), agricultural resource management (*f* = 1, 6.67%), agricultural science (*f* = 1, 6.67%), agricultural mechanics (*f* = 1, 6.67%), animal science (*f* = 1, 6.67%), and general agriculture (*f* = 1, 6.67%). Two respondents earned their associate's in STEM-related areas (13.33%), and one earned their associate's in education (6.67%). The other four respondents earned their degrees in fields outside of agriculture, STEM, or education (26.65%)

Itawamba Community College (20.00%) and Jones County Junior College (20.00%) were the most commonly attended institution for associate's degrees, with three participants selecting each. One participant each (6.67%) attended Northeast Mississippi Community College, Delta State Community College, Hinds Community College and East Central Community College. For Tennessee, one participant each (6.67%) attended Walters State Community College and Middle Tennessee State University for their associate's degrees. Three participants (20.00%) earned associate's degrees from institutions outside of Mississippi or Tennessee. Table 3 contains a list of agricultural educators' associate's degrees by major and the institutions that granted those degrees.

Table 3 Agricultural educators' associate's degrees and granting institutions (n = 79)

	f	%
Major		
Pre-veterinary medicine	2	13.33
Agriscience technology	1	6.67
Agricultural resource management	1	6.67
Agricultural science	1	6.67
Agricultural mechanics	1	6.67
Animal science	1	6.67
General agriculture	1	6.67
STEM fields	2	13.33
Education	1	6.67
Other	4	26.65
Institution		
Itawamba Community College	3	20.00
Jones County Junior College	3	20.00
Northeast Mississippi Community College	1	6.67
Delta State Community College	1	6.67
Hinds Community College	1	6.67
East Central Community College	1	6.67
Walters State Community College	1	6.67
Middle Tennessee State University	1	6.67
Other	3	20.00

Seventy-eight respondents (98.73%) reported that they had earned a bachelor's degree, with 36 (46.15%) indicating their major was in an area directly related to agricultural and/or extension education. Other reported majors included animal, dairy, and poultry science ($f = 15$, 19.23%); agricultural science ($f = 10$, 12.82%), and agricultural business and economics ($f = 5$, 6.41%). Forestry, horticulture, agronomy, and landscape architecture each had only one respondent who reported it as their major (5.13%). Two participants majored in biology (2.57%), one majored in English (1.28%), one in human resources (1.28%), and four (5.13%) did not report their specific major.

Sixty-nine respondents (87.34%) reported the institution that granted their bachelor's degree. Mississippi State University was the most commonly attended institution, with 20 participants receiving their bachelor's degrees from there (28.99%). This was followed by the University of Tennessee ($f = 12$, 17.39%), the University of Tennessee at Martin ($f = 9$, 13.04%), Middle Tennessee State University ($f = 9$, 13.04%), Tennessee Technological University ($f = 6$, 8.70%), and Tennessee State University ($f =$ 1, 1.45%). One respondent received their degree from the University of Mississippi (1.45%). Eleven respondents (15.94%) received their bachelor's degrees from universities that were outside Tennessee or Mississippi. Table 4 shows educators' major areas for bachelor's degrees, as well as the institutions that granted the degrees.

Table 4 Agricultural educators' bachelor's degrees and granting institutions (n = 79)

	f	%
Major		
Agricultural and/or extension education	36	46.15
Animal, dairy, and/or poultry science	15	19.23
Agricultural science	10	12.82
Agricultural business/economics	5	6.41
Forestry/horticulture/landscaping/agronomy	4	5.13
Biology	2	2.57
English	1	1.28
Human resources	1	1.28
Institution		
Mississippi State University	20	28.99
University of Tennessee	12	17.39
University of Tennessee at Martin	9	13.04
Middle Tennessee State University	9	13.04
Tennessee Technological University	6	8.70
Tennessee State University	1	1.45
University of Mississippi	1	1.45
Other	11	15.94

Forty-two respondents (53.16%) identified themselves as having earned a master's degree. Of these 42 respondents, half earned degrees in agricultural and extension education (f = 21, 50.00%), 6 were in administration and supervision (14.29%), 4 were in educational leadership (9.53%), 3 were in education (7.14%), and 2 were in agricultural science (4.76%). The fields of biology, curriculum and instruction, forest products, teaching and learning, special education, and secondary education were all named by one respondent each (2.38%).

Forty respondents identified the institution where they received their master's degrees. Mississippi State University was the most attended institution (*f* = 9, 22.50%), followed by the University of Tennessee (*f* = 5, 12.50%) and Middle Tennessee State University (*f* = 5, 12.50%), Tennessee State University (*f* = 4, 10.00%), Tennessee Technological University (*f* = 2, 5.00%), and Union University (*f* = 2, 5.00%). The University of Tennessee at Martin and Lipscomb University had one graduate each (2.50%), and the University of Mississippi also had one graduate (2.50%). The remaining respondents (*f* = 10, 25.00%) indicated that they received their master's degrees from institutions in other states. Table 5 shows the majors and degree-granting institutions for agricultural educators' master's degrees.

Table 5 Agricultural educators' master's degrees and granting institutions (n = 79)

	n	%
Major		
Agricultural and/or extension education	21	50.00
Administration and supervision	6	14.29
Educational leadership	4	9.53
Education	3	7.14
Agricultural science	2	4.76
Biology	1	2.38
Curriculum and instruction	1	2.38
Forest products	1	2.38
Teaching and learning	1	2.38
Special education	1	2.38
Secondary education		
Institution		
Mississippi State University	9	22.50
University of Tennessee	5	12.50
Middle Tennessee State University	5	12.50
Tennessee State University	4	10.00
Tennessee Technological University	2	5.00
Union University	2	5.00
University of Tennessee at Martin	1	2.50
Lipscomb University	1	2.50
University of Mississippi	1	2.50
Other	10	25.00

Twelve respondents indicated they had earned an education specialist degree, with only 4 of those 12 identifying a major area of study. The 4 major areas identified were agricultural education, curriculum and instruction, administration and supervision, and school reform. The most commonly attended institutions were Tennessee Technological University ($f = 3$, 25.00%), Union University ($f = 2$, 16.67%), and a joint program between the University of Tennessee and Middle Tennessee State University ($f = 2$, 16.67%). One graduate attended Mississippi State University (8.33%), and another attended the University of Mississippi (8.33%). The remaining respondents received their educational specialist degrees from out of state institutions ($f = 3$, 25.00%). No participants indicated that they had earned a doctoral degree. Table 6 contains a list of the major areas in which participants earned education specialist degrees, as well as the institutions which granted those degrees.

Table 6 Agricultural educators' education specialist degrees and granting institutions (*n* = 79)

	n	%
Major		
Agricultural education	1	8.33
Curriculum and instruction	1	8.33
Administration and supervision	1	8.33
School reform	1	8.33
Other/not specified	8	66.68
Institution		
Tennessee Technological University	3	25.00
Union University	2	16.67
University of Tennessee/Middle Tennessee State University	2	16.67
Mississippi State University	1	8.3
University of Mississippi	1	8.3
Other	3	25.00

STEM Background

Participants also reported the STEM-related courses they had completed at the undergraduate or graduate level. A basic course list was created from a list of National Science Foundation approved STEM fields of study (National Science Foundation, 2012) and edited for length and redundancy. Participants were allowed to select courses they had completed from the list, and also to suggest other courses that they felt were relevant but not included. Data on participants' postsecondary STEM backgrounds were self-reported, and thus may be subject to error regarding accuracy or views of what constitutes STEM education.

Science

In the area of science, plant science/botany was the most commonly selected course, with 74 respondents (93.6%) indicating they had completed such a course either at the undergraduate or graduate level. Biology (f = 72, 91.1%) was the second most selected course, followed by animal science, chemistry, and soil science which each had 68 selections (86.1%). Forty participants had completed a genetics course (50.6%), 39 had completed anatomy and physiology (49.3%), 36 had completed an entomology course (45.5%), and 34 had completed environmental science (43.0%). Physical science and microbiology were each selected by 25 participants (31.6%) each, and science education, organic chemistry, and food science were each selected by 24 (30.3%). Less commonly selected courses included physics (f = 21, 26.5%), geology (f = 10, 12.6%), and astronomy (f = 2, 2.5%). Other science courses identified included biochemistry, horticulture, nutrition, animal nutrition, analytical chemistry, crop science, ichthyology, weed science, and viticulture.

Technology

In the area of technology, 54 participants (68.3%) indicated they had completed at least one agricultural mechanics class and 32 (40.5%) had completed an educational technology course. Twenty (25.3%) had experience in computer programming, 15

(18.9%) had finished a course in technology education, 13 (16.4%) in information technology, 9 (11.3%) in web design, 5 (6.3%) in electronics, and 1 (1.2%) in medical technology. Participants also mentioned that they had completed courses in internal combustion engines, computer applications, computer service technology, Microsoft Excel, and welding.

Engineering

In the area of engineering, 61 participants (77.2%) had completed at least one course in agricultural engineering and 13 (16.4%) in environmental engineering. Seven (8.8%) had completed a computer engineering course. Engineering education and mechanical engineering both had six respondents indicate their completion of a course (7.5%). Chemical engineering and electrical engineering both had 3 respondents (3.7%), and biomedical and civil engineering were each selected by only 1 respondent (1.2%). No respondents had completed courses in aerospace/aeronautical engineering, architectural engineering, or automotive engineering.

Mathematics

In the area of mathematics, 70 respondents (88.6%) indicated their completion of a college algebra course, followed by 49 (62.0%) who had completed an economics course. Thirty-five (44.3%) had completed a statistics course and 18 (22.7%) each had enrolled in accounting and trigonometry. Calculus had 16 completers (20.2%) and finance and geometry had 14 apiece (17.7%). Six had taken a course in mathematics education (7.5%), and only one had completed differential equations (1.2%). Other courses that participants indicated were agricultural economics, farm business management, business mathematics, and finite or discrete mathematics.

Professional Development

Curriculum for Agricultural Science Education (CASE)

Eleven participants indicated that they had completed at least one Curriculum for Agricultural Science Education (CASE) course (12.1%). Sixty-eight (86.1%) stated that they had not completed any CASE courses. Agriculture, Food, and Natural Resources (AFNR) was the most commonly completed CASE course, with 10 participants indicating they had attended (90.9%). Four participants had completed Principles of Agricultural Science – Animal (36.3%). Principles of Agricultural Science – Plant, Agricultural Power and Technology, and Natural Resources and Ecology both had 2 completers each (18.1%). The Animal and Plant Biotechnology, Mechanical Systems in Agriculture, and Environmental Science courses all had 1 participant each (9.1%). No participants had completed Food Science or Agricultural Research Development.

Three respondents identified themselves as being certified to teach CASE courses either as a Lead Teacher or Master Teacher (27.2%), 7 indicated they were not certified (63.6%), and did not respond (9.1%). Three were certified to teach Agriculture, Food, and Natural Resources, 1 was certified to teach Principles of Agricultural Science – Plant, and 1 was certified to teach Natural Resources and Ecology.

Other Professional Development

Participants were asked to describe any STEM-related workshops, training, or professional development that they had attended in the past year. Forty participants (31%) provided responses. The most commonly attended STEM professional development sessions were those offered at state level conferences. Seven respondents attended STEM workshops at the Tennessee Association of Agricultural Educators (TAAE) conference, and 3 attended workshops at the Tennessee Department of Education's Institute for Career and Technical Educators. In Mississippi, 1 respondent identified the Mississippi Association of Vocational Agriculture Teachers (MAVAT) conference as a source of STEM training, and 1 identified the Mississippi Association for Career and Technical Educators conference.

Four participants had attended CASE institutes within the past year, 3 had attended Agriculture in the Classroom workshops from the American Farm Bureau Federation, and 2 had attended Briggs and Stratton mechanics workshops. Two participants also attended workshops from the Institute of Agricultural Educators that allowed them to teach dual credit plant science courses. Two also attended an Exploring Computer Science workshop. One attended a workshop at the National Association of Agricultural Educators (NAAE) conference, and another respondent attended a workshop on women in STEM offered by the National Science Foundation (NSF). Three respondents indicated their attendance at other STEM-related professional development events, but did not specify the exact workshop or program that was attended. Twelve respondents stated they had not been able to attend STEM-based professional development, with 3 noting that funding was not available despite their interest. One

Mississippi respondent felt that there were not enough STEM-focused professional development opportunities open to agricultural educators.

Research Objective One

Participants in the study completed an online survey instrument that measured their levels of teaching efficacy related to STEM (science, technology, engineering, and mathematics) content. Research objective one, which concerned itself with teachers' personal teaching self-efficacy, was addressed by the first part of the instrument. Personal teaching efficacy relates to a teacher's level of confidence in their ability to facilitate student learning and overcome obstacles that obstruct the learning process.

The personal teaching efficacy portion of the instrument presented participants with 11 statements such as "I am continually improving my ___ teaching practices," and "I know the steps necessary to teach ___ effectively." Participants were asked to replace the blank in each statement with the name of one of the STEM disciplines (science, technology, engineering, or mathematics) and then note their level of agreement or disagreement with the statement. Agreement was measured on a 5-point Likert-type scale that included 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree. Once participants had finished the 11 statements for the first STEM discipline (science, for example), they were asked to complete the process again for the other three.

This portion of the instrument was scored on a summated scale with the highest possible value being 55 and the lowest possible value being 11. Participant responses were coded and analyzed with IBM Statistical Package for Social Sciences (SPSS) Version 24. The following table displays the overall mean scores for each area of the instrument. The field of science had the highest mean score (*M* =46.04, *SD* =5.21), followed by technology (*M* = 41.06, *SD* = 5.80), mathematics (*M* = 37.95, *SD* = 7.49), and then engineering (*M* = 35.39, *SD* = 7.76). Table 7 shows the mean scores for teacher's personal teaching efficacy levels towards the four

Table 7 Agricultural educators' mean personal teaching efficacy towards STEM subjects

STEM Field	*n*	*M*	*SD*
Science	91	46.04	5.21
Technology	91	41.06	5.80
Engineering	91	35.39	7.76
Mathematics	91	37.95	7.49

Personal Teaching Efficacy towards Science

Out of the four STEM disciplines, science had the highest reported levels of efficacy with an overall mean score of 46.04 (*SD* = 5.21). The statements with the highest means were "I am continually improving my science teaching practice" (*M* = 4.53, *SD* = .52), "I am confident that I can teach science effectively," (*M* = 4.36, *SD* = .64), and "I am confident that I can answer students' science questions" (*M* = 4.35, *SD* = .56). These statements were followed by "When teaching science, I am confident enough to welcome student questions" (*M* = 4.33, *SD* = .59), "I understand science concepts well enough to be effective in teaching it" (*M* = 4.32, *SD* = .63), "I am confident that I can explain to students why science experiments work" (*M* = 4.30, *SD* = .64), "When a student has difficulty understanding a science concept, I am confident that I know how to help the student" (*M* = 4.26, *SD* = .55), and "I know the steps necessary to teach science effectively" (*M* = 4.26, *SD* = .64). The statements with the lowest means were "I know what to do to increase student interest in science" (*M* = 4.00, *SD* = .86), "Given a chance, I would invite a colleague to evaluate my science teaching" (*M* = 3.98, *SD* = .81), and "I wonder if I have the necessary skills to teach science" (*M* = 3.35, *SD* = 1.19.). Table 8 shows agricultural educators' personal teaching efficacy towards science.

Table 8 Agricultural educators' personal teaching efficacy towards science

Item	*n*	*M*	*SD*
I am continually improving my science teaching practice.	91	4.53	.52
I know the steps necessary to teach science effectively.	91	4.26	.64
I am confident that I can explain to students why science experiments work.	91	4.30	.64
I am confident that I can teach science effectively.	91	4.36	.64
I wonder if I have the necessary skills to teach science.	91	3.35*	1.19*
I understand science concepts well enough to be effective in teaching it.	91	4.32	.63
Given a chance, I would invite a colleague to evaluate my science teaching.	91	3.98	.81
I am confident that I can answer students' science questions.	91	4.35	.56
When a student has difficulty understanding a science concept, I am confident that I know how to help the student understand it better.	91	4.26	.55
When teaching science, I am confident enough to welcome student questions.	91	4.33	.59
I know what to do to increase student interest in science.	91	4.00	.86

Note. 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree
* Reverse coded

Personal Teaching Efficacy towards Technology

Technology had the second highest reported levels of efficacy with an overall mean score of 41.06 (*SD* = 5.80). The three statements with the highest means were "I am continually improving my technology teaching practice" (*M* = 4.11, *SD* = .62), "When teaching technology, I am confident enough to welcome student questions" (*M* = 4.02, *SD* = .64), and "I am confident I can teach technology effectively" (*M* = 3.85, *SD* = .77).

These statements were followed by “I understand technology concepts well enough to be effective in teaching it” (*M* = 3.79, *SD* = .76), “I am confident that I can explain to students why technology experiments work” (*M* = 3.78, *SD* = .72), “I am confident that I can answer students’ technology questions” (*M* = 3.76, *SD* = .76),” and “When a student has difficulty understanding a technology concept, I am confident that I know how to help the student understand it better” (*M* = 3.73, *SD* = .68). The three statements with the lowest means were “I know what to do to increase student interest in technology” (*M* = 3.69, *SD* = .68), “Given a chance, I would invite a colleague to evaluate my technology teaching” (*M* = 3.62, *SD* = .90), and “I wonder if I have the necessary skills to teach technology” (*M* = 3.02, *SD* = 1.08). Table 9 shows agricultural educators’ personal teaching efficacy levels towards technology.

Table 9 Agricultural educators' personal teaching efficacy towards technology

Item	*n*	*M*	*SD*
I am continually improving my technology teaching practice.	91	4.11	.62
I know the steps necessary to teach technology effectively.	91	3.70	.70
I am confident that I can explain to students why technology experiments work.	91	3.78	.72
I am confident that I can teach technology effectively.	91	3.85	.77
I wonder if I have the necessary skills to teach technology.	91	3.02*	1.08*
I understand technology concepts well enough to be effective in teaching it.	91	3.79	.76
Given a chance, I would invite a colleague to evaluate my technology teaching.	91	3.62	.90
I am confident that I can answer students' technology questions.	91	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.	91	3.73	.68
When teaching technology, I am confident enough to welcome student questions.	91	4.02	.64
I know what to do to increase student interest in technology.	91	3.69	.83

Note. 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree
* Reverse coded

Personal Teaching Efficacy towards Engineering

Engineering was the STEM area that received the lowest efficacy levels. The overall mean score was 35.39 (*SD* = 7.76). The statements with the highest means were "When teaching engineering, I am confident enough to welcome student questions" (*M* = 3.48, *SD* = .97), "I am confident that I can explain to students why engineering experiments work" (*M* = 3.38, *SD* = .90), and "I know what to do to increase student interest in engineering" (*M* = 3.27, *SD* = .99). These were followed by "I am confident that I can answer students' engineering questions" (*M* = 3.25, *SD* = .95), "When a student has difficulty understanding an engineering concept, I am confident that I know how to help the student understand it better" (*M* = 3.24, *SD* = .87), "I am confident that I can teach engineering effectively" (*M* = 3.24, *SD* = .97), "I am continually improving my engineering teaching practice" (*M* = 3.19, *SD* = .95), and "I understand engineering concepts well enough to be effective in teaching it" (*M* = 3.19, *SD* = .96). The two statements with the lowest means were "I know the steps necessary to teach engineering effectively" (*M* = 3.07, *SD* = .92) and "I wonder if I have the skills necessary to teach engineering" (*M* = 2.84, *SD* = 1.00). Table 10 displays agricultural educators' personal teaching efficacy levels towards engineering.

Table 10 Agricultural educators' personal teaching efficacy towards engineering

Item	*n*	*M*	*SD*
I am continually improving my engineering teaching practice.	91	3.19	.95
I know the steps necessary to teach engineering effectively.	91	3.07	.92
I am confident that I can explain to students why engineering experiments work.	91	3.38	.90
I am confident that I can teach engineering effectively.	91	3.24	.97
I wonder if I have the necessary skills to teach engineering.	91	2.84*	1.00*
I understand engineering concepts well enough to be effective in teaching it.	91	3.19	.96
Given a chance, I would invite a colleague to evaluate my engineering teaching.	91	3.24	1.04
I am confident that I can answer students' engineering questions.	91	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.	91	3.24	.87
When teaching engineering, I am confident enough to welcome student questions.	91	3.48	.97
I know what to do to increase student interest in engineering.	91	3.27	.99

Note. 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree
* Reverse coded

Personal Teaching Efficacy towards Mathematics

With an overall mean score of 37.95 (*SD* = 7.49), the area of mathematics showed the second lowest level of personal teaching efficacy. The statements with the highest means were "When teaching mathematics, I am confident enough to welcome student questions" (*M* = 3.48, *SD* = .97), "I am confident that I can explain to students why mathematics experiments work" (*M* = 3.38, *SD* = .90), and "I know what to do to increase student interest in mathematics" (*M* = 3.27, *SD* = .99). These statements were followed by "I am confident that I can answer students' mathematics questions" (*M* = 3.25, *SD* = .95), "When a student has difficulty understanding mathematics concept, I am confident that I know how to help the student understand it better" (*M* = 3.24, *SD* = .87), "I am confident that I can teach mathematics effectively" (*M* = 3.24, *SD* = .97), "Given a chance, I would invite a colleague to evaluate my mathematics teaching" (*M* = 3.24, *SD* = 1.04), "I am continually improving my mathematics teaching practice" (*M* = 3.19, *SD* = .95), and "I understand mathematics concepts well enough to be effective in teaching it (*M* = 3.19, *SD* = .96). The statements with the lowest means were "I know the steps necessary to teach mathematics effectively" (*M* = 3.07, *SD* = .92) and, "I wonder if I have the necessary skills to teach mathematics" (*M* = 2.84, *SD* = 1.00). Table 11 displays agricultural educators' personal teaching efficacy levels towards mathematics.

Table 11 Agricultural educators' personal teaching efficacy towards mathematics

Item	*n*	*M*	*SD*
I am continually improving my mathematics teaching practice.	91	3.19	.95
I know the steps necessary to teach mathematics effectively.	91	3.07	.92
I am confident that I can explain to students why mathematics experiments work.	91	3.38	.90
I am confident that I can teach mathematics effectively.	91	3.24	.97
I wonder if I have the necessary skills to teach mathematics.	91	2.84*	1.00*
I understand mathematics concepts well enough to be effective in teaching it.	91	3.19	.96
Given a chance, I would invite a colleague to evaluate my mathematics teaching.	91	3.24	1.04
I am confident that I can answer students' mathematics questions.	91	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.	91	3.24	.87
When teaching mathematics, I am confident enough to welcome student questions.	91	3.48	.87
I know what to do to increase student interest in mathematics.	91	3.27	.99

Note. 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree
* Reverse coded

Research Objective Two

Research objective two was addressed by the third part of the survey instrument. This part contained 18 questions that asked participants about personal characteristics including age, gender, ethnicity, certification type, teaching career length, STEM background, and professional development history. Answers to these questions were analyzed against participants' general teaching efficacy scores to determine if relationships existed between STEM general teaching self-efficacy and any personal characteristics.

Age

Science

A bivariate correlation was performed to determine if a relationship existed between participant age (M = 41.26, SD = 12.00) and STEM personal teaching efficacy in science (M = 46.04, SD = 5.21). Results found no significant relationship between the two variables, indicating that participants' science teaching efficacy was not affected by age (r = -.09, p = .42). Table 12 illustrates the relationship that existed between participants' personal teaching efficacy towards science and age.

Technology

A bivariate correlation between participants' age (M = 41.26, SD = 12.00) and personal teaching efficacy towards technology (M = 41.06, SD = 5.80) was performed to determine of the relationship between the two variables was significant. Results indicated that there were no significant relationship between participant age and teaching efficacy (r = -.07, p = .54). Table 12 illustrates the relationship that existed between participants' personal teaching efficacy towards technology and age.

Engineering

A bivariate correlation was performed to determine if a relationship existed between participant age (*M* = 41.26, *SD* = 12.00) and personal teaching efficacy in the field of engineering (*M* = 35.39, *SD* = 7.76). There were no significant relationship identified between the two variables ($r = .12$, $p = .27$). Table 12 illustrates the relationship that existed between participants' personal teaching efficacy towards engineering and age.

Mathematics

A bivariate correlation was performed to analyze the relationship between participant age (*M* = 41.26, *SD* = 12.00) and mathematics personal teaching efficacy (*M* = 37.95, *SD* = 7.49). Results revealed that no significant relationships existed (r = .15, $p = .17$). Table 12 illustrates the relationships that existed between participants' personal teaching efficacy towards mathematics and age.

Table 12 Bivariate correlation coefficients between agricultural educators' age and efficacy towards STEM subjects

Variables	1	2	3	4	5
1. Age	-				
2. Science	-.09	-			
3. Technology	-.07	.56**	-		
4. Engineering	.12	.13	.40**	-	
5. Mathematics	.15	.23*	.16*	.49**	-

* p < .05, ** p < .001

Gender

Science

An independent samples t-test was performed to identify differences in personal teaching efficacy towards science based on gender. The results indicated that there were no significant difference between men's (*M* = 45.92, *SD* =4.41) and women's (*M* = 46.38, *SD* = 6.26) science teaching efficacy scores ($t(76) = -.37$, p = .70). Table 13 shows the difference male and female between agricultural educators' personal teaching efficacy towards STEM.

Table 13 Comparison between agricultural educators' personal teaching efficacy towards science and gender

Group	*n*	*M*	*SD*	*t*	*df*	*p*
Males	43	45.92	4.41	-.37	76	.70
Females	36	46.38	6.62			

Technology

An independent samples t-test was used to identify if differences existed in participants' personal teaching efficacy towards technology. Results showed no significant difference between men's (*M* = 41.16, *SD* = 5.74) and women's (*M* = 40.63, *SD* = 6.12) scores ($t(76) = .39$, $p = .69$). Table 14 shows the results of this t-test comparing technology-related personal teaching efficacy by gender.

Table 14 Comparison between agricultural educators' personal teaching efficacy towards technology and gender

Group	*n*	*M*	*SD*	*t*	*df*	*p*
Males	43	41.16	5.74	.39	76	.69
Females	36	40.63	6.12			

Engineering

An independent samples t-test revealed that there was a significant difference between men's and women's personal teaching efficacy scores in the field of engineering. Men (*M* =38.47, *SD* = 6.84) had significantly higher scores than women (*M* = 33.61, *SD* = 7.23) ($t(76) = 3.04$, $p = .003$). Table 15 shows the comparison between men's and women's personal teaching efficacy towards engineering.

Table 15 Comparison between agricultural educators' personal teaching efficacy towards engineering and gender

Group	*n*	*M*	*SD*	*t*	*df*	*p*
Males	43	38.47	6.84	3.04	76	.003
Females	36	33.61	7.23			

Mathematics

An independent samples t-test found a significant difference between men's and women's personal teaching efficacy scores regarding mathematics. Men (*M* = 39.71, *SD* = 7.00) had significantly higher personal teaching efficacy scores towards mathematics than did women (*M* = 36.44, *SD* = 7.46) (*t*(76) = 1.99, *p* = .05). Table 16 shows the results of this t-test in detail.

Table 16 Comparison between agricultural educators' personal teaching efficacy towards mathematics and gender

Group	*n*	*M*	*SD*	*t*	*df*	*p*
Males	43	39.71	7.00	1.99	76	.05
Females	36	36.44	7.46			

Ethnic Background

Science

A one-way analysis of variance (ANOVA) was performed to determine if participants' ethnic background had an effect on their personal teaching efficacy towards science. The single participant who identified themselves as being of an "other" ethnicity had the highest mean score (*M* = 54.00), followed by those identifying themselves as "African-American/Black" (*M* = 49.50, *SD* = .70), and then those identifying themselves as "White/Caucasian" (*M* = 45.86, *SD* = 5.32). Because there were no participants who identified as Hispanic/Latino, Asian American/Pacific Islander, or Native American/Alaska Native, these ethnic groups were not included in the analysis. Results indicated that there were no significant differences in science personal teaching efficacy based on ethnicity (*F*(2,76) = 1.60, *p* = .20). Table 17 shows the means and standard deviations for each group and Table 18 shows the ANOVA results in detail.

Table 17 Agricultural educators' mean personal teaching efficacy scores towards science by ethnic background

Group	*n*	*M*	*SD*
African-American/Black	2	49.50	.70
White/Caucasian	76	45.86	5.32
Other	1	54.00	-
Total	79	46.06	5.32

Table 18 Analysis of variance of agricultural educators' personal teaching efficacy towards science by ethnic background

	SS	*df*	*MS*	*F*	*p*
Between Groups	89.49	2	44.75	1.60	.20
Within Groups	2123.18	76	27.93		
Total	2212.68	78			

Technology

A one-way analysis of variance (ANOVA) was performed to determine if ethnicity effected personal teaching efficacy towards technology. The participant identifying themselves as of an "other" ethnic group had the highest mean score (*M* = 45.00), followed by those identifying themselves as "African-American/Black" (*M* =44.00, *SD* = 2.82), and then by those identifying as "White/Caucasian" (*M* = 40.77, *SD* = 5.91). Because there were no participants who identified as Hispanic/Latino, Asian American/Pacific Islander, or Native American/Alaska Native, these ethnic groups were not included in the analysis. The results showed that no significant differences existed in participants' technology teaching efficacy when compared by ethnic background,

($F(2,76) = .53$, $p = .58$). Table 19 shows the means and standard deviations for each group and Table 20 shows the ANOVA results in detail.

Table 19 Agricultural educators' mean personal teaching efficacy scores towards technology by ethnic background

Group	*n*	*M*	*SD*
African-American/Black	2	44.00	2.82
White/Caucasian	76	40.77	5.91
Other	1	45.00	-
Total	79	40.91	5.85

Table 20 Analysis of variance of agricultural educators' personal teaching efficacy towards technology by ethnic background

	SS	*df*	*MS*	*F*	*p*
Between Groups	37.18	2	18.59	.53	.58
Within Groups	2635.19	76	34.67		
Total	2212.68	78			

Engineering

A one-way analysis of variance (ANOVA) was performed to identify differences in participants' engineering efficacy scores based on ethnicity. Those who described themselves as "White/Caucasian" had the highest mean score ($M = 36.42$, $SD = 7.45$), followed by those who described themselves as "African-American/Black" ($M = 34.00$, $SD = 2.28$). The individual who described themselves as "other" had the lowest mean score (*M* =30.00). Because there were no participants who identified as Hispanic/Latino, Asian American/Pacific Islander, or Native American/Alaska Native, these ethnic groups were not included in the analysis. Results determined that ethnic background did not significantly affect the engineering efficacy scores of participating agricultural educators, ($F(2,76) = .46$, $p = .62$). Table 21 shows the means and standard deviations for each group and Table 22 shows the ANOVA results in detail.

Table 21 Agricultural educators' mean personal teaching efficacy scores towards engineering by ethnic background

Group	*n*	*M*	*SD*
African-American/Black	2	34.00	2.82
White/Caucasian	76	36.42	7.45
Other	1	30.00	-
Total	79	36.27	7.36

Table 22 Analysis of variance of agricultural educators' personal teaching efficacy towards technology by ethnic background

	SS	*df*	*MS*	*F*	*p*
Between Groups	51.34	2	25.67	.46	.62
Within Groups	4174.52	76	54.92		
Total	4225.87	78			

Mathematics

A one-way analysis of variance (ANOVA) was used to identify the impact of ethnic background on participants' personal teaching efficacy scores towards mathematics. Participants describing themselves as "White/Caucasian" had the highest mean score (M = 38.31, SD = 7.43), followed by those describing themselves as "African-American/Black" (M = 37.00, SD = 1.41). The individual who described themselves as "other" had the lowest mean score (M = 33.00). Because there were no participants who identified as Hispanic/Latino, Asian American/Pacific Islander, or Native American/Alaska Native, these ethnic groups were not included in the analysis. Results determined that there were no significant differences between means, indicating that ethic background did not affect participants' teaching self-efficacy in relation to mathematics ($F(2, 76) = .28$, $p = .75$). Table 23 shows the mean scores and standard deviations for each group and Table 24 shows the ANOVA results in detail.

Table 23 Agricultural educators' mean personal teaching efficacy scores towards engineering by ethnic background

Group	*n*	*M*	*SD*
African-American/Black	2	37.00	1.41
White/Caucasian	76	38.31	7.43
Other	1	33.00	-
Total	79	36.27	7.36

Table 24 Analysis of variance of agricultural educators' personal teaching efficacy towards technology by ethnic background

	SS	*df*	*MS*	*F*	*p*
Between Groups	30.92	2	15.46	.28	.75
Within Groups	4144.42	76	54.53		
Total	41.75.34	78			

Certification Type

Science

An independent samples t-test was performed to identify if teaching certification type affected science teaching self-efficacy. Teachers with traditional certification (M = 46.46, SD = 5.24) had slightly higher mean scores than did alternatively certified teachers (M = 45.20, SD = 5.69). However, there was no significant difference between the two groups' mean scores ($t(77)$ = .98, p = .33). This indicates that teaching certification type did not influence agricultural educators' science teaching self-efficacy. Table 25 shows the t-test results in greater detail.

Table 25 Comparison between agricultural educators' personal teaching efficacy towards science and certification type

Group	*n*	*M*	*SD*	*t*	*df*	*p*
Traditionally certified	54	46.46	5.24	.98	77	.43
Alternatively certified	25	45.20	5.69			

Technology

An independent samples t-test was performed to determine if technology teaching self-efficacy was impacted by certification type. Results indicated that teachers with traditional certification (M = 41.51, SD = 5.94) had slightly higher means scores in for technology than did traditionally certified teachers (M = 39.60, SD = 5.53). However, there were no significant differences between the two groups' mean scores ($t(77) = 1.36$, $p = .17$), indicating that teaching certification type did not influence agricultural educators' technology-based teaching self-efficacy. Table 26 shows the t-test results in greater detail.

Table 26 Comparison between agricultural educators' personal teaching efficacy towards technology and certification type

Group	*n*	*M*	*SD*	*t*	*df*	*p*
Traditionally certified	54	41.51	5.53	1.36	77	.17
Alternatively certified	25	39.60	5.94			

Engineering

An independent samples t-test was used to examine the relationship between teacher certification type and personal teaching efficacy in engineering. Results indicated that traditionally certified (M = 36.29, SD = 7.29) and alternatively certified (M = 36.24, SD = 7.65) teachers felt similar levels of efficacy towards the subject of engineering. Overall there were no significant differences between the two groups' mean scores ($t(77) = -.01$, $p = .98$). Table 27 shows the t-test results in greater detail.

Table 27 Comparison between agricultural educators' personal teaching efficacy towards engineering and certification type

Group	*n*	*M*	*SD*	*t*	*df*	*p*
Traditionally certified	54	36.29	7.29	.03	77	.97
Alternatively certified	25	36.24	7.65			

Mathematics

An independent samples t-test was used to identify the effect of teacher certification type on personal teaching efficacy in mathematics. Results indicated that traditionally certified teachers (*M* = 37.81, *SD* = 8.10) had lower mean scores for mathematics than alternatively certified (*M* = 39.08, *SD* = 5.27) teachers. Overall there were no significant differences between the two groups' mean scores ($t(77) = -.71$, $p = .41$). Table 28 shows the t-test results in greater detail.

Table 28 Comparison between agricultural educators' personal teaching efficacy towards mathematics and certification type

Group	*n*	*M*	*SD*	*t*	*df*	*p*
Traditionally certified	54	37.81	8.10	-.71	77	.41
Alternatively certified	25	39.08	5.27			

Teaching Career Length

Science

A bivariate correlation was used to examine the relationship between teaching career length and science teaching efficacy. Results indicated that length of participants' total teaching careers was not significantly correlated with science teaching efficacy scores (r = -.01, p = .92). Length of participants' agricultural education teaching careers was also not significantly correlated with science teaching efficacy (r = -.11, p = .33). Table 29 shows the relationship that existed between participants' total teaching career length and personal teaching efficacy towards STEM subjects. Table 30 shows the relationship that existed between participants' agricultural education career length and their personal teaching efficacy towards STEM.

Technology

A bivariate correlation was performed to identify the relationship between teaching career length and personal teaching efficacy towards technology. Results indicated that length of participants' total teaching careers was not significantly correlated with technology teaching efficacy (r = .01, p = .94). Length of participants' agricultural education teaching careers was also not significantly correlated with science teaching efficacy (r = -.01, p = .92). Table 29 shows the relationship that existed between participants' total teaching career length and personal teaching efficacy towards STEM subjects. Table 30 shows the relationship that existed between participants' agricultural education career length and their personal teaching efficacy towards STEM.

Engineering

A bivariate correlation was used to examine the relationship between teaching career length and engineering-related personal teaching efficacy. Results indicated that length of participants' total teaching careers was not significantly correlated with engineering teaching efficacy (r = .10, p = .38). Length of participants' agricultural education teaching careers was also not significantly correlated with engineering teaching efficacy (r = .17, p = .12). Table 29 shows the relationship that existed between participants' total teaching career length and personal teaching efficacy towards STEM subjects. Table 30 shows the relationship that existed between participants' agricultural education career length and their personal teaching efficacy towards STEM.

Mathematics

A bivariate correlation was used to examine the relationship between teaching career length and engineering-related personal teaching efficacy. Results indicated that length of participants' total teaching careers was not significantly correlated with mathematics teaching efficacy (r = .09, p = .38). Length of participants' agricultural education teaching careers was also not significantly correlated with mathematics teaching efficacy (r = .08, p = .47). Table 29 shows the relationship that existed between participants' total teaching career length and personal teaching efficacy towards STEM subjects. Table 30 shows the relationship that existed between participants' agricultural education career length and their personal teaching efficacy towards STEM.

Table 29 Correlation coefficients between the length of agricultural educators' teaching careers and personal teaching efficacy towards STEM subjects

Variables	1	2	3	4	5
1. Career length	-				
2. Science	-.01	-			
3. Technology	.01	.56**	-		
4. Engineering	.10	.13	.40**	-	
5. Mathematics	.09	.23*	.16*	.49**	-

* $p < .05$, ** $p < .001$

Table 30 Correlation coefficients between the length of agricultural educators' teaching careers in agriculture and personal teaching efficacy towards STEM subjects

Variables	1	2	3	4	5
1. Ag. Ed. career length	-				
2. Science	-.11	-			
3. Technology	-.01	.56**	-		
4. Engineering	.17	.13	.40**	-	
5. Mathematics	.08	.23*	.16	.49**	-

* $p < .05$, ** $p < .001$

Postsecondary STEM Background

Science

A bivariate correlation was used to examine the relationship between the number of postsecondary science courses completed by participants and participants' STEM personal teaching efficacy scores. Participants reported completing a total of 699 postsecondary science courses. A significant, positive correlation of intermediate strength was found between the number of science courses completed and science personal teaching efficacy ($r = .30$, $p = .006$). Nonsignificant, positive, and weak correlations were identified between science course load and technology ($r = .19$, $p = .08$), engineering ($r = .21$, $p = .06$), and mathematics ($r = .20$, $p = .07$) personal teaching efficacy scores. The following table (Table 31) shows the relationships that existed between participants' outcome expectancy towards science and the number of science courses completed.

Table 31 Correlation coefficients between number of science courses completed and personal teaching efficacy towards STEM subjects

Variables	1	2	3	4	5
1. Science courses completed	-				
2. Science	.30*	-			
3. Technology	.19	.56**	-		
4. Engineering	.21	.13	.40**	-	
5. Mathematics	.20	.23*	.16*	.49**	-

* p < .05, ** p < .001

Technology

A bivariate correlation was used to examine the relationship between the number of postsecondary technology courses completed by participants and participants' STEM personal teaching efficacy scores. Participants reported attending a total of 161 postsecondary technology courses. A nonsignificant, positive correlation was found between the two variables (r = .19, p = .11). A significant, positive, and weak correlation was identified between the number of postsecondary technology courses completed by participants and participants' engineering efficacy scores (r = .25, p = .04). Nonsignificant, positive, and weak correlations were identified between technology course load and science (r = .11, p = .35), technology (r = .19, p = .11), and mathematics (r = .20, p = .30) personal teaching efficacy scores. The following table (Table 32) shows the relationships that existed between participants' personal teaching efficacy towards technology and the number of technology courses completed.

Table 32 Correlation coefficients between number of technology courses completed and personal teaching efficacy towards STEM subjects

Variables	1	2	3	4	5
1. Tech. courses completed	-				
2. Science	.11	-			
3. Technology	.19	.56**	-		
4. Engineering	.25*	.13	.40**	-	
5. Mathematics	.12	.23*	.16*	.49*	-

p < .05, ** p < .001*

Engineering

A bivariate correlation was used to examine the relationship between the number of postsecondary engineering courses completed by participants and participants' STEM personal teaching efficacy scores. Participants reported completing a total of 101 postsecondary engineering courses. A significant, positive correlation of intermediate strength was found between the two variables ($r = .41$, $p = .001$). Nonsignificant, positive, and weak correlations were identified between engineering course load and science ($r = .12$, $p = .35$), technology ($r = .10$, $p = .42$), and mathematics ($r = .18$, $p = .15$) personal teaching efficacy scores. The following table (Table 33) shows the relationships that existed between participants' personal teaching efficacy towards engineering and the number of engineering courses completed.

Table 33 Correlation coefficients between number of engineering courses completed and personal teaching efficacy towards STEM subjects

Variables	1	2	3	4	5
1. Engr. courses completed	-				
2. Science	.12	-			
3. Technology	.10	.56**	-		
4. Engineering	.41**	.13	.40**	-	
5. Mathematics	.18	.23*	.16*	.49*	-

p < .05, ** p < .001*

Mathematics

A bivariate correlation was used to examine the relationship between the number of postsecondary mathematics courses completed by participants and participants' STEM personal teaching efficacy scores. Participants reported completing a total of 252 postsecondary mathematics classes. A significant, positive correlation of intermediate strength was found between the two variables ($r = .31$, $p = .005$). Nonsignificant, positive, and weak correlations were identified between mathematics course load and science ($r = .19$, $p = .08$), technology ($r = .73$, $p = .06$), and engineering ($r = .11$, $p = .33$) personal teaching efficacy scores. The following table (Table 34) shows the relationships that existed between participants' personal teaching efficacy towards mathematics and the number of mathematics courses completed.

Table 34 Correlation coefficients between number of mathematics courses completed and personal teaching efficacy towards STEM subjects

Variables	1	2	3	4	5
1.Math courses completed	-				
2. Science	.19	-			
3. Technology	.03	.56**	-		
4. Engineering	.11	.13	.40**	-	
5. Mathematics	.31**	.23*	.16*	.49*	-

* p < .05, ** p < .001

Professional Development – CASE

Science

An independent samples t-test was utilized to determine if completion of Curriculum for Agricultural Science Education (CASE) courses significantly affected participants' personal teaching efficacy scores in the field of science. Overall, 11 participants had completed at least one CASE course (*M* = 48.18, *SD* = 5.13) and 68 indicated that they had not taken any CASE courses (*M* = 45.72, *SD* = 5.31). Results indicated that CASE attendance did not significantly affect participants' science teaching efficacy scores ($t(76) = -1.47$, $p = .15$). Table 35 shows the results of the t-test in detail.

Table 35 Comparison between agricultural educators' personal teaching efficacy towards science and CASE course completion

Group	*n*	*M*	*SD*	*t*	*df*	*p*
Attended CASE	11	48.18	5.13	-1.47	76	.15
Did not attend CASE	68	45.72	5.31			

Technology

An independent samples t-test was utilized to determine if completion of Curriculum for Agricultural Science Education (CASE) courses significantly affected participants' personal teaching efficacy scores towards technology. Eleven participants indicated their completion of at least one CASE course (*M* = 44.63, *SD* = 3.10) and 68 indicated that they had not completed any CASE courses (*M* = 40.30, *SD* = 5.98). Results indicated that CASE attendance did significantly affect participants' technology teaching efficacy scores (*t*(76) = -2.33, *p* = .02). Table 36 shows the results of the t-test in detail.

Table 36 Comparison between agricultural educators' personal teaching efficacy towards technology and CASE course completion

Group	*n*	*M*	*SD*	*t*	*df*	*P*
Attended CASE	11	44.63	3.10	-2.33	76	.02
Did not attend CASE	68	40.30	5.98			

Engineering

An independent samples t-test was utilized to determine if completion of Curriculum for Agricultural Science Education (CASE) courses significantly affected participants' personal teaching efficacy scores in the field of engineering. Overall, 11 participants had completed at least one CASE course (*M* = 38.72, *SD* = 5.69) and 67 indicated that they had not taken any CASE courses (*M* = 35.88, *SD* = 7.55). Results indicated that CASE attendance did not significantly affect participants' engineering teaching efficacy scores (*t*(76) = -1.19, *p* = .23). Table 37 shows the results of the t-test in detail.

Table 37 Comparison between agricultural educators' personal teaching efficacy towards engineering and CASE course completion

Group	*n*	*M*	*SD*	*T*	*df*	*P*
Attended CASE	11	38.72	4.88	-1.19	76	.23
Did not attend CASE	68	35.88	7.55			

Mathematics

An independent samples t-test was utilized to determine if completion of Curriculum for Agricultural Science Education (CASE) courses affected participants' personal teaching efficacy scores in the field of mathematics. Overall, 11 participants had completed at least one CASE course (M = 38.45, SD = 5.83) and 67 indicated that they had not taken any CASE courses (M = 38.17, SD = 7.56). Results indicated that CASE attendance did not significantly affect participants' mathematics teaching efficacy scores (t(76) = -1.19, p = .90). Table 38 shows the results of the t-test in detail.

Table 38 Comparison between agricultural educators' personal teaching efficacy towards mathematics and CASE course completion

Group	n	M	SD	t	df	p
Attended CASE	11	38.45	5.83	-.11	76	.90
Did not attend CASE	68	38.17	7.56			

Professional Development – Other

Science

A bivariate correlation was used to examine the relationship between the number of STEM-related professional development opportunities completed by participants and participants' science teaching personal efficacy scores. A nonsignificant correlation was found between the two variables (r = .26, p = .19). Table 39 shows the relationships that existed between participants' personal teaching efficacy towards science and the number of professional development opportunities attended.

Technology

A bivariate correlation was used to examine the relationship between the number of STEM-related professional development opportunities completed by participants and participants' technology teaching efficacy scores. A nonsignificant yet positive correlation was found between the two variables (r = -.07, p = .72). Table 39 shows the relationships that existed between participants' personal teaching efficacy towards technology and the number of professional development opportunities attended.

Engineering

A bivariate correlation was used to examine the relationship between the number of STEM-related professional development opportunities completed by participants and participants' engineering teaching efficacy scores. A nonsignificant correlation was found between the two variables (r = .19, p = .34). Table 39 shows the relationships that existed between participants' personal teaching efficacy towards engineering and the number of professional development opportunities attended.

Mathematics

A bivariate correlation was used to examine the relationship between the number of STEM-related professional development opportunities completed by participants and participants' mathematics teaching efficacy scores. A nonsignificant correlation was found between the two variables (r = .32, p = .11). Table 39 shows the relationships that existed between participants' personal teaching efficacy towards mathematics and the number of professional development opportunities attended.

Table 39 Correlation coefficients between number of professional development courses completed and personal teaching efficacy towards STEM subjects

Variables	1	2	3	4	5
1. PD Completed	-				
2. Science	.26	-			
3. Technology	-.07	.56**	-		
4. Engineering	.19	.13	.40**	-	
5. Mathematics	.32	.23*	.16*	.49*	-

* p < .005, ** p < .001

Other Identified Correlations

While examining relationships between age and personal teaching efficacy, other correlations of note were identified. A significant, positive correlation of intermediate strength was identified between participants' science and technology personal teaching efficacy scores (r = .56, p < .001). A significant, positive, and weak correlation was found between participants' science and mathematics efficacy scores (r = .23, p = 03). A significant, positive correlation of intermediate strength existed between participants' technology and engineering personal teaching efficacy scores (r = .40, p < .001). There was also a significant, positive, weak correlation found between technology and mathematics efficacy scores (r = .16, p =.04), and a significant, positive correlation of intermediate strength between engineering and mathematics scores (r = .49, p < .001). Table 40 shows the relationships that existed between agricultural educators' science, technology, engineering, and mathematics personal teaching efficacy scores.

Table 40 Correlation coefficients between agricultural educators' science, technology, engineering, and mathematics personal teaching efficacy scores

Variables	1	2	3	4
1. Science	-			
2. Technology	.56**	-		
3. Engineering	.13	.40**	-	
4. Mathematics	.23*	.16*	.49**	-

* p < .05, ** p < .001

Research Objective Three

Participants in the study completed an online survey instrument that measured their levels of teaching efficacy related to STEM (science, technology, engineering, and mathematics). Research objective three, which concerned itself with teachers' outcome expectancy (also known as outcome expectancy) beliefs, was addressed by the second part of the instrument. Outcome expectancy or general teaching efficacy involves a teacher's beliefs in their ability to influence factors that are difficult or impossible to control outright. Examples of such factors include students' backgrounds and views of education, school and community culture, and students' physical and psychological needs. This section of the instrument contained 9 statements in total, to which participants would indicate their level of agreement on a 5-point Likert-type scale. Possible responses on the scale included 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree.

Statements in this section of the instrument included “when a student does better than usual in ___,” “it is often because the teacher exerted a little extra effort,” and “the inadequacy of a student’s ___ background can be overcome by good teaching.” Participants were asked to replace the blank in each statement with the name of one of the four STEM disciplines (science, technology, engineering, and mathematics) before indicating their agreement. Once all 9 statements had been addressed for one discipline, participants were asked to complete the process again for the other three.

This portion of the instrument was scored on a summated scale with the highest possible value being 45 and the lowest possible value being 9. Participant responses were coded and analyzed with IBM Statistical Package for Social Sciences (SPSS) Version 24. The field of science had the highest outcome expectancy score (M = 32.56, SD = 3.38), followed by mathematics (M = 32.34, SD = 3.29), engineering (M = 32.22, SD = 3.40), and then technology (M = 32.20, SD = 3.34). Table 41 displays agricultural educators’ mean outcome expectancy scores towards science, technology, engineering, and mathematics.

Table 41 Agricultural educators' mean outcome expectancy scores towards STEM subjects

STEM Field	*n*	*M*	*SD*
Science	79	32.56	3.38
Technology	79	32.20	3.34
Engineering	79	32.22	3.40
Mathematics	79	32.34	3.29

Outcome Expectancy towards Science

The overall mean score for science was 32.56 (*SD* = 3.38). The three statements with the highest means were "When a low achieving child progresses more than expected in science, it is usually due to extra attention given by the teacher" (*M* = 3.91, *SD* = .70), "If parents comment that their child is showing more interest in science at school, it is probably due to the performance of the child's teacher" (*M* = 3.87, *SD* = .72), and "The inadequacy of a student's science background can be overcome by good teaching" (*M* = 3.85, *SD* = .86). These statements were followed by "When a student does better than usual in science, it is often because the student exerted a little extra effort" (*M* = 3.81, *SD* = .81), "When a student's learning in science is greater than expected, it is most often due to the teacher having found a more effective approach" (*M* = 3.78, *SD* = .84), and "The teacher is generally responsible for students' learning in science" (*M* = 3.75, *SD* = .92). The statements with the lowest mean scores were "Students' learning in science is directly related to the teacher's effectiveness in teaching that subject" (*M* = 3.39, *SD* =

.96), “If students’ learning in science is less than expected, it is most likely due to ineffective teaching” (*M* = 3.18, *SD* = 1.02), and “Minimal student learning in science can generally be attributed to their teachers” (*M* = 3.03, *SD* = .86). Agricultural educators’ mean outcome expectancy scores towards science are displayed in Table 42.

Table 42 Agricultural educators’ mean outcome expectancy scores towards science

Item	*n*	*M*	*SD*
When a student does better than usual in science, it is often because the teacher exerted a little extra effort.	79	3.81	.81
The inadequacy of a student’s science background can be overcome by good teaching.	79	3.85	.86
When a student’s learning in science is greater than expected, it is most often due to the teacher having found a more effective teaching approach.	79	3.78	.84
The teacher is generally responsible for students’ learning in science.	79	3.75	.92
If students’ learning in science is less than expected, it is most likely due to ineffective teaching.	79	3.18*	1.02*
Students’ learning in science is directly related to the teacher’s effectiveness in teaching that subject.	79	3.39	.96
When a low achieving child progresses more than expected in science, it is usually due to extra attention given by the teacher.	79	3.91	.70
If parents comment that their child is showing more interest in science at school, it is probably due to the performance of the child’s teacher.	79	3.87	.72
Minimal student learning in science can generally be attributed to their teachers.	79	3.03*	.86*

Note. 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree
* Reverse coded

Outcome Expectancy towards Technology

The overall mean score towards technology was 32.20 (*SD* = 3.34). The statements with the highest means were "When a low achieving child progresses more than expected in technology, it is usually due to extra attention given by the teacher" (*M* = 3.90, *SD* = .69), "The inadequacy of a student's technology background can be overcome by good teaching," (*M* = 3.85, *SD* = .84), and "If parents comment that their child is showing more interest in technology at school, it is probably due to the performance of the child's teacher" (*M* = 3.81, *SD* = .69). These were followed by "When a student does better than usual in technology, it is often because the teacher exerted a little extra effort" (*M* = 3.77, *SD* = .80), "When a student's learning in technology is greater than expected, it is most often due to the teacher having found a more effective teaching approach" (*M* = 3.77, *SD* = .80), and "The teacher is generally responsible for students' learning in technology" (*M* = 3.56, *SD* = .95). The statements with the lowest means were "Students' learning in technology is directly related to the teacher's effectiveness in teaching that subject" (*M* = 3.35, *SD* = 1.05), "If students' learning in technology is less than expected, it is most likely due to ineffective teaching" (*M* = 3.18, *SD* = 1.02), and "Minimal student learning in technology can generally be attributed to their teachers" (*M* = 3.01, *SD* = .88). Table 43 contains agricultural educators' outcome expectancy scores towards technology.

Table 43 Agricultural educators' outcome expectancy scores towards technology

Item	*n*	*M*	*SD*
When a student does better than usual in technology, it is often because the teacher exerted a little extra effort.	79	3.77	.80
The inadequacy of a student's technology background can be overcome by good teaching.	79	3.85	.84
When a student's learning in technology is greater than expected, it is most often due to the teacher having found a more effective teaching approach.	79	3.77	.80
The teacher is generally responsible for students' learning in technology.	79	3.56	.95
If students' learning in technology is less than expected, it is most likely due to ineffective teaching.	79	3.18*	1.02*
Students' learning in technology is directly related to the teacher's effectiveness in teaching that subject.	79	3.35	1.05
When a low achieving child progresses more than expected in technology, it is usually due to extra attention given by the teacher.	79	3.90	.69
If parents comment that their child is showing more interest in technology at school, it is probably due to the performance of the child's teacher.	79	3.81	.69
Minimal student learning in technology can generally be attributed to their teachers.	79	3.01*	.88*

Note. 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree
* Reverse coded

Outcome Expectancy towards Engineering

The overall mean score for engineering was 32.22 (*SD* = 3.40). The statements with the highest means were "When a low achieving child progresses more than expected in engineering, it is usually due to extra attention given by the teacher" (*M* = 3.90, *SD* = .70), "If parents comment that their child is showing more interest in engineering at school, it is probably due to the performance of the child's teacher" (*M* = 3.82, *SD* =.73), and "The inadequacy of a student's engineering background can be overcome by good teaching" (*M* = 3.81, *SD* = .90). These were followed by "When a student does better than usual engineering, it is because the teacher exerted a little extra effort" (*M* = 3.76, *SD* = .82), "When a student's learning in engineering is greater than expected, it is most often due to the teacher having found a more effective teaching approach" (*M* = 3.75, *SD* = .80), and "The teacher is generally responsible for students' learning in engineering" (*M* = 3.63, *SD* = .90). The statements that had the lowest means were "Students' learning in engineering is directly related to the teacher's effectiveness in teaching that subject" (*M* = 3.37, *SD* = 1.00), "If students' learning in engineering is less than expected, it is most likely due to ineffective teaching" (*M* = 3.18, *SD* = 1.01), and "Minimal student learning in engineering can generally be attributed to their teachers" (*M* = 3.01, *SD* = .89). Table 44 shows agricultural educators' outcome expectancy scores towards engineering.

Table 44 Agricultural educators' outcome expectancy scores towards engineering

Item	*n*	*M*	*SD*
When a student does better than usual in engineering, it is often because the teacher exerted a little extra effort.	79	3.76	.82
The inadequacy of a student's engineering background can be overcome by good teaching.	79	3.81	.90
When a student's learning in engineering is greater than expected, it is most often due to the teacher having found a more effective teaching approach.	79	3.75	.80
The teacher is generally responsible for students' learning in engineering.	79	3.63	.90
If students' learning in engineering is less than expected, it is most likely due to ineffective teaching.	79	3.18*	1.01*
Students' learning in engineering is directly related to the teacher's effectiveness in teaching that subject.	79	3.37	1.00
When a low achieving child progresses more than expected in engineering, it is usually due to extra attention given by the teacher.	79	3.90	.70
If parents comment that their child is showing more interest in engineering at school, it is probably due to the performance of the child's teacher.	79	3.82	.73
Minimal student learning in engineering can generally be attributed to their teachers.	79	3.01*	.89*

Note. 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree

Outcome Expectancy towards Mathematics

The overall mean score for mathematics was 32.34 (*SD* = 3.29). The statements with the highest means were "When a low achieving child progresses more than expected in mathematics, it is usually due to extra attention given by the teacher" (*M* = 3.94, *SD* = .72), "If parents comment that their child is showing more interest in mathematics at school, it is probably due to the performance of the child's teacher" (*M* = 3.89, *SD* = .75), and “When a student does better than usual in mathematics, it is often because the teacher exerted a little extra effort” (*M* = 3.78, *SD* = .79). This were followed by “When a student’s learning in mathematics is greater than expected, it is most often due to the teacher having found a more effective teaching approach” (*M* = 3.77, *SD* = .84), “The inadequacy of a student’s mathematics background can be overcome by good teaching” (*M* = 3.71, *SD* = .90), and “The teacher is generally responsible for students’ learning in mathematics” (*M* = 3.66, *SD* = .91). The statements with the lowest means were “Students’ learning in mathematics is directly related to the teacher’s effectiveness in teaching that subject” (*M* = 3.38, *SD* = .96), “If students’ learning in mathematics is less than expected, it is most likely due to ineffective teaching” (*M* = 3.19, *SD* = .97), and “Minimal student learning in mathematics can generally be attributed to their teachers” (*M* = 3.03, *SD* = .90). Table 45 displays agricultural educators’ outcome expectancy scores towards mathematics.

Table 45 Agricultural educators' outcome expectancy scores towards mathematics

Item	*n*	*M*	*SD*
When a student does better than usual in mathematics, it is often because the teacher exerted a little extra effort.	79	3.78	.79
The inadequacy of a student's mathematics background can be overcome by good teaching.	79	3.71	.90
When a student's learning in mathematics is greater than expected, it is most often due to the teacher having found a more effective teaching approach.	79	3.77	.84
The teacher is generally responsible for students' learning in mathematics.	79	3.66	.91
If students' learning in mathematics is less than expected, it is most likely due to ineffective teaching.	79	3.19*	.97*
Students' learning in mathematics is directly related to the teacher's effectiveness in teaching that subject.	79	3.38	.96
When a low achieving child progresses more than expected in mathematics, it is usually due to extra attention given by the teacher.	79	3.94	.72
If parents comment that their child is showing more interest in mathematics at school, it is probably due to the performance of the child's teacher.	79	3.89	.75
Minimal student learning in mathematics can generally be attributed to their teachers.	79	3.03*	.90*

Note. 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree
* Reverse coded

Research Objective Four

Research Objective Four was addressed by the third part of the survey instrument. This part contained 18 questions that asked participants about personal characteristics including age, gender, educational background, STEM background, and years of teaching experience. Answers to these questions were analyzed against participants' outcome expectancy scores to determine if relationships existed between STEM outcome expectancy and any personal characteristics.

Age

Science

A bivariate correlation was performed to determine if a relationship existed between participant age (*M* = 41.26, *SD* = 12.00) and STEM outcome expectancy towards the field of science (*M* = 32.56, *SD* = 3.38). Results found no significant relationships between the two variables, indicating that participants' science teaching efficacy was not affected by age (*r* = .10, *p* = .38). Table 46 illustrates the relationship that existed between participants' outcome expectancy towards science and age.

Technology

A bivariate correlation between participants' ages (*M* = 41.26, *SD* = 12.00) and outcome expectancy towards technology was performed to identify if a significant relationship existed between participant age and outcome expectancy towards technology (*M* = 32.20, *SD* = 3.34). Results indicated that there were no significant relationships between participant age and outcome expectancy (*r* = .07, *p* = .53). Table 46 illustrates the relationship that existed between participants' outcome expectancy towards technology and age.

Engineering

A bivariate correlation was performed to identify the relationship between participant age (*M* = 41.26, *SD* = 12.00) and outcome expectancy in the field of engineering (*M* = 32.22, *SD* = 3.40). There was no significant relationship between the two variables (*r* = .11, *p* = .30). Table 46 illustrates the relationship that existed between participants' outcome expectancy towards engineering and age.

Mathematics

A bivariate correlation was performed to analyze the relationship between participant age (*M* =27.81, *SD* = 7.60) and mathematics outcome expectancy (*M* = 32.34, *SD* = 3.29). Results revealed that no significant relationship existed (*r* = .06, *p* = .60). Table 46 illustrates the relationship that existed between participants' outcome expectancy towards mathematics and age.

Table 46 Correlation coefficients between agricultural educators' age and outcome expectancy towards STEM subjects

Variables	1	2	3	4	5
1. Age	-				
2. Science	.10	-			
3. Technology	.07	.92**	-		
4. Engineering	.11	.95**	.95**	-	
5. Mathematics	.06	.96**	.93*	.96**	-

* p < .05, ** p < .001

Gender

Science

An independent samples t-test was performed to identify if differences existed in outcome expectancy towards science based on gender. The results indicated that there were no significant difference between men's (M = 32.67, SD = 3.09) and women's (M = 32.44, SD = 3.74) science teaching efficacy scores ($t(76) = -.29$, $p = .76$). The t-test results are displayed in detail in Table 47.

Table 47 Comparison between agricultural educators' outcome expectancy towards science and gender

Group	*n*	*M*	*SD*	*t*	*df*	*p*
Males	43	32.67	3.09	.29	76	.76
Females	36	32.44	3.74			

Technology

An independent samples t-test was used to identify if differences existed in participants' outcome expectancy towards technology. Results showed no significant difference between men's (M = 32.37, SD = 2.92) and women's (M = 32.00, SD = 3.84) scores ($t(76) = .49$, $p = .62$). The t-test results are displayed in detail in Table 48.

Table 48 Comparison between agricultural educators' outcome expectancy towards technology and gender

Group	*n*	*M*	*SD*	*t*	*df*	*p*
Males	43	32.37	2.92	.49	76	.62
Females	36	32.00	3.84			

Engineering

An independent samples t-test was performed to identify if a difference existed between men's and women's outcome expectancy scores regarding the subject of engineering. Men's scores (*M* = 32.39, *SD* = 3.07) were not significantly different from women's scores (*M* = 32.02, *SD* = 3.79) (*t*(76) = .47, *p* = .63). The t-test results are displayed in detail in Table 49.

Table 49 Comparison between agricultural educators' outcome expectancy towards engineering and gender

Group	*n*	*M*	*SD*	*t*	*df*	*p*
Males	43	32.39	3.07	-.47	76	.63
Females	36	32.02	3.79			

Mathematics

An independent samples t-test was performed to identify if a difference existed between men's and women's outcome expectancy scores regarding the subject of mathematics. Men's (*M* = 32.55, *SD* = 3.01) and women's scores (*M* = 32.08, *SD* = 3.63) were not statistically different ($t(76) = .63$, $p = .52$). The t-test results are displayed in detail in Table 50.

Table 50 Comparison between agricultural educators' outcome expectancy towards mathematics and gender

Group	*n*	*M*	*SD*	*t*	*df*	*p*
Males	43	32.55	3.01	.63	76	.52
Females	36	32.08	3.63			

Ethnic Background

Science

A one-way analysis of variance (ANOVA) was performed to determine if participants' ethnic background had an effect on their outcome expectancy towards science. The individual identifying themselves as "other" had the highest mean score ($M = 33.00$), followed by those identifying themselves as "Caucasian/White" ($M = 32.63$, $SD = 3.38$), and by those identifying themselves as "African-American/Black" ($M = 30.00$, $SD = 4.24$). Results indicated that there was no significant difference in science outcome expectancy based on ethnicity ($F(2,76) = .59$, $p = .55$). Table 51 shows the mean outcome expectancy scores for each ethnicity and Table 52 shows the ANOVA results in greater detail.

Table 51 Agricultural educators' mean outcome expectancy scores towards science by ethnic background

Group	*n*	*M*	*SD*
African-American/Black	2	30.00	4.24
White/Caucasian	76	32.63	3.38
Other	1	33.00	-
Total	79	32.56	3.38

Table 52 Comparison of agricultural educators' outcome expectancy towards science by ethnic background

	SS	*df*	*MS*	*F*	*p*
Between Groups	13.68	2	6.84	.59	.55
Within Groups	879.68	76	11.57		
Total	893.36	78			

Technology

A one-way analysis of variance (ANOVA) was performed to determine if participants' ethnic background had an effect on their outcome expectancy towards technology. The individual identifying themselves as "other" had the highest mean score (*M* = 33.00), followed by those identifying themselves as "Caucasian/White" (*M* = 32.25, *SD* = 3.35), and then by those identifying themselves as "African-American/Black" (*M* = 30.00, *SD* = 4.24). Results indicated that there was no significant difference in science outcome expectancy based on ethnicity ($F(2,76) = .46$, $p = .63$). Table 53 shows the mean outcome expectancy scores for each ethnicity and Table 54 shows the ANOVA results in greater detail.

Table 53 Agricultural educators' outcome expectancy towards technology by ethnic background

Group	*n*	*M*	*SD*
African-American/Black	2	30.00	4.24
White/Caucasian	76	32.25	3.35
Other	1	33.00	-
Total	79	32.22	3.40

Table 54 Comparison of agricultural educators' outcome expectancy towards technology by ethnic background

	SS	*df*	*MS*	*F*	*p*
Between Groups	10.50	2	5.25	.46	.63
Within Groups	860.25	76	11.31		
Total	870.75	78			

Engineering

A one-way analysis of variance (ANOVA) was performed to determine if participants' ethnic background had an effect on their outcome expectancy towards engineering. The individual identifying themselves as "other" had the highest mean score (M = 33.00), followed by those identifying themselves as "White/Caucasian" (M = 32.27, SD = 3.41), and then by those identifying themselves as "African-American/Black" (M = 30.00, SD = 4.24). Results indicated that there was no significant difference in science outcome expectancy based on ethnicity ($F(2,76)$ = .45, p = .63). Table 55 shows the mean outcome expectancy scores for each ethnicity and Table 56 shows the ANOVA results in greater detail.

Table 55 Agricultural educators' outcome expectancy towards engineering by ethnic background

Group	*n*	*M*	*SD*
African-American/Black	2	30.00	4.24
White/Caucasian	76	32.27	
Other	1	33.00	-
Total	79	32.22	3.40

Table 56 Comparison of agricultural educators' outcome expectancy towards engineering by ethnic background

	SS	*df*	*MS*	*F*	*p*
Between Groups	10.70	2	5.35	.45	.63
Within Groups	885.19	76	11.00		
Total	905.89	78			

Mathematics

A one-way analysis of variance (ANOVA) was performed to determine if participants' ethnic background had an effect on their outcome expectancy towards mathematics. The individual identifying themselves as "other" had the highest mean score (M = 33.00), followed by those identifying themselves as "White/Caucasian" (M = 32.39, SD = 3.30), and then by those identifying themselves as "African-American/Black" (M = 30.00, SD = 4.24). Results indicated that there was no significant difference in science outcome expectancy based on ethnicity ($F(2,76) = .52$, $p = .59$). Table 57 shows the mean outcome expectancy scores for each ethnicity and Table 58 shows the ANOVA results in greater detail.

Table 57 Agricultural educators' outcome expectancy towards mathematics by ethnic background

Group	*n*	*M*	*SD*
African-American/Black	2	30.00	4.24
White/Caucasian	76	32.39	3.30
Other	1	33.00	-
Total	79	32.34	3.29

Table 58 Comparison of agricultural educators' outcome expectancy towards mathematics by ethnic background

	SS	*df*	*MS*	*F*	*p*
Between Groups	11.61	2	5.80	.52	.59
Within Groups	836.15	76	11.00		
Total	847.77	78			

Certification Type

Science

An independent samples t-test was performed to identify if teaching certification type affected science teaching outcome expectancy. There was no significant difference between the scores of traditionally certified (*M* = 32.37, *SD* = 3.29) and alternatively certified teachers (*M* = 33.00, *SD* = 3.60) ($t(77) = -.76$, $p = .44$). Table 59 displays the t-test results.

Table 59 Comparison between agricultural educators' outcome expectancy towards science and certification type

Group	*n*	*M*	*SD*	*t*	*df*	*p*
Traditionally certified	54	32.37	3.29	-.76	77	.44
Alternatively certified	25	33.00	3.60			

Technology

An independent samples t-test was performed to determine if technology teaching outcome expectancy was impacted by certification type. No significant difference was identified between the scores of traditionally certified teachers (M = 32.18, SD = 2.94) and alternatively certified teachers (M = 32.24, SD = 4.14) ($t(77) = -.06$, $p = .94$). Table 60 displays the t-test results.

Table 60 Comparison between agricultural educators' outcome expectancy towards technology and certification type

Group	*n*	*M*	*SD*	*t*	*df*	*p*
Traditionally certified	54	32.18	2.94	-.06	77	.94
Alternatively certified	25	32.24	4.14			

Engineering

An independent samples t-test was used to examine the relationship between teacher certification type and outcome expectancy in engineering. Results indicated that both traditionally certified (M = 32.16, SD = 3.21) and alternatively certified (M = 32.36, *SD* = 3.85) teachers felt similar levels of efficacy towards the subject of engineering. Overall there was no significant difference between the two groups mean scores ($t(77) = -.23$, $p = .81$). Table 61 displays the t-test results.

Table 61 Comparison between agricultural educators' outcome expectancy towards engineering and certification type

Group	*n*	*M*	*SD*	*t*	*df*	*p*
Traditionally certified	54	32.16	3.21	-.23	77	.81
Alternatively certified	25	32.36	3.85			

Mathematics

An independent samples t-test was used to identify the effect of teacher certification type on mathematics teaching outcome expectancy. No significant difference existed between the responses of traditionally certified ($M = 32.24$, $SD = 3.23$) and alternatively certified teachers ($M = 32.56$, $SD = 3.47$) ($t(77) = -.39$, $p = .69$). Table 62 displays the t-test results.

Table 62 Comparison between agricultural educators' outcome expectancy towards mathematics and certification type

Group	*n*	*M*	*SD*	*t*	*df*	*p*
Traditionally certified	55	32.24	3.23	-.39	77	.69
Alternatively certified	25	32.56	3.47			

Teaching Career Length

Science

A bivariate correlation was used to examine the relationship between teaching career length and science teaching outcome expectancy. Results indicated that length of participants' total teaching careers was not significantly correlated with science teaching outcome expectancy (r = .08, p = .45). Length of participants' agricultural education teaching careers was also not significantly correlated with science teaching outcome expectancy (r = .05, p = .62). Table 63 shows the relationship between agricultural educators' total teaching career length and their outcome expectancy towards STEM subjects. Table 64 shows the relationship between agricultural educators' agricultural education career length and their outcome expectancy towards STEM.

Technology

A bivariate correlation was performed to identify if a relationship existed between teaching career length and outcome expectancy towards technology. Results indicated that length of participants' total teaching careers was not significantly correlated with technology teaching outcome expectancy (r = .08, p = .45). Length of participants' agricultural education teaching careers was also not significantly correlated with technology teaching outcome expectancy (r = .08, p = .43). Table 58 illustrates the relationships that existed between participants' outcome expectancy towards technology and total teaching career length. Table 63 shows the relationship between agricultural educators' total teaching career length and their outcome expectancy towards STEM subjects. Table 64 shows the relationship between agricultural educators' agricultural education career length and their outcome expectancy towards STEM.

Engineering

A bivariate correlation was used to examine the relationship between teaching career length and engineering-related outcome expectancy. Results indicated that length of participants' total teaching careers was not significantly correlated with engineering outcome expectancy (r = .10, p = .34). Length of participants' agricultural education teaching careers was also not significantly correlated with engineering outcome expectancy (r = .09, p = .40). Table 63 shows the relationship between agricultural educators' total teaching career length and their outcome expectancy towards STEM subjects. Table 64 shows the relationship between agricultural educators' agricultural education career length and their outcome expectancy towards STEM.

Mathematics

A bivariate correlation was used to find if a relationship existed between teaching career length and mathematics-related outcome expectancy. Results indicated that length of participants' total teaching careers was not significantly correlated with mathematics teaching outcome expectancy (r = .05, p = .63). Length of participants' agricultural education teaching careers was also not significantly correlated with mathematics teaching outcome expectancy (r = .04, p = .70). Table 63 shows the relationship between agricultural educators' total teaching career length and their outcome expectancy towards

STEM subjects. Table 64 shows the relationship between agricultural educators' agricultural education career length and their outcome expectancy towards STEM.

Table 63 Correlation coefficients between the length of agricultural educators' teaching careers and efficacy towards STEM subjects

Variables	1	2	3	4	5
1. Career length	-				
2. Science	.08	-			
3. Technology	.08	.92**	-		
4. Engineering	.10	.95**	.95**	-	
5. Mathematics	.05	.96**	.93**	.96**	-

* $p < .05$, ** $p < .001$

Table 64 Correlation coefficients between the length of agricultural educators' teaching career in agriculture and outcome expectancy towards STEM subjects

Variables	1	2	3	4	5
1. Ag. Ed. career length	-				
2. Science	.05	-			
3. Technology	.08	.92**	-		
4. Engineering	.09	.95**	.95**	-	
5. Mathematics	.04	.96**	.93**	.96**	-

* $p < .05$, ** $p < .001$

Postsecondary STEM Background

Science

A bivariate correlation was used to examine the relationship between the number of postsecondary science courses completed by participants and participants' STEM teaching outcome expectancy scores. Nonsignificant, positive, and weak correlations were identified between science course load and science (r = .09, p = .42), technology (r = .03, p = .78), engineering (r = .06, p = .57), and mathematics (r = .07, p = .52) outcome expectancy scores. Table 65 displays the correlation between the number of science courses completed and agricultural educators' outcome expectancy towards STEM subjects.

Table 65 Correlation coefficients between number of science courses completed and outcome expectancy towards STEM subjects

Variables	1	2	3	4	5
1. Science courses completed	-				
2. Science	.09	-			
3. Technology	.03	.92**	-		
4. Engineering	.06	.95**	.95**	-	
5. Mathematics	.07	.96**	.93**	.96**	-

* p < .05, ** p < .001

Technology

A bivariate correlation was used to examine the relationship between the number of postsecondary technology courses completed by participants and participants' STEM teaching outcome expectancy scores. Nonsignificant, negative, and weak correlations were identified between technology course load and science (r = -.01, p = .96), technology (r = -.01, p = .88), engineering (r = -.02, p = .82), and mathematics (r = -.05, p = .67) outcome expectancy scores. Table 66 displays the correlation between the number of science courses completed and agricultural educators' outcome expectancy towards STEM subjects.

Table 66 Correlation coefficients between number of technology courses completed and outcome expectancy towards STEM subjects

Variables	1	2	3	4	5
1. Tech. courses completed	-				
2. Science	-.01	-			
3. Technology	-.01	.92**	-		
4. Engineering	-.02	.95**	.95**	-	
5. Mathematics	-.05	.96**	.93**	.96**	-

* p < .05, ** p < .001

Engineering

A bivariate correlation was used to examine the relationship between the number of postsecondary engineering courses completed by participants and participants' STEM teaching outcome expectancy scores. Nonsignificant, positive, and weak correlations were identified between engineering course load and science (*r* = .19, *p* = .17), technology (*r* = .17, *p* = .28), engineering (*r* = .19, *p* = .16), and mathematics (*r* = .17, *p* = .23) outcome expectancy scores. Table 67 displays the correlation between the number of science courses completed and agricultural educators' outcome expectancy towards STEM subjects.

Table 67 Correlation coefficients between number of engineering courses completed and outcome expectancy towards STEM subjects

Variables	1	2	3	4	5
1. Science courses completed	-				
2. Science	.19	-			
3. Technology	.17	.92**	-		
4. Engineering	.19	.95**	.95**	-	
5. Mathematics	.17	.96**	.93**	.96**	-

* p < .05, ** p < .001

Mathematics

A bivariate correlation was used to examine the relationship between the number of postsecondary mathematics courses completed by participants and participants' STEM teaching outcome expectancy scores. A significant correlation was found between the number of mathematics courses completed and participants' science teaching efficacy scores (*r* = .24, *p* = .02). Nonsignificant, positive, and weak correlations were identified between engineering course load and technology (*r* = .14, *p* = .21), engineering (*r* = .21, *p*

= .06), and mathematics (r = .21, p = .06) outcome expectancy scores. Table 68 displays the correlation between the number of science courses completed and agricultural educators' outcome expectancy towards STEM subjects.

Table 68 Correlation coefficients between number of mathematics courses completed and efficacy towards STEM subjects

Variables	1	2	3	4	5
1. Science courses completed	-				
2. Science	.24*	-			
3. Technology	.14	.92**	-		
4. Engineering	.21	.95**	.95**	-	
5. Mathematics	.21	.96**	.93**	.96**	-

* p < .05, ** p < .001

Professional Development – CASE

Science

An independent samples t-test was utilized to determine if completion of Curriculum for Agricultural Science Education (CASE) professional development courses significantly affected participants' outcome expectancy scores in the field of science. Overall, 11 participants had completed at least one CASE course (M = 31.27, SD = 4.02), and 68 indicated that they had not taken any CASE courses (M = 32.77, SD = 3.25). Results indicated that CASE attendance did not significantly affect participants' science teaching outcome expectancy scores ($t(6) = 1.37$, $p = .17$). Table 69 shows the results of the t-test in greater detail.

Table 69 Comparison between agricultural educators' outcome expectancy towards science and CASE course completion

Group	*n*	*M*	*SD*	*t*	*df*	*p*
Attended CASE	11	31.27	4.02	.17	6	.17
Did not attend CASE	68	32.77	3.25			

Technology

An independent samples t-test was utilized to determine if completion of Curriculum for Agricultural Science Education (CASE) professional development courses significantly affected participants' outcome expectancy scores towards technology. Eleven participants indicated their completion of at least one CASE course ($M = 31.36$, $SD = 2.76$), and 68 indicated that they had not completed any CASE courses ($M = 32.33$, $SD = 3.42$). Results indicated that CASE attendance did not significantly affect participants' technology outcome expectancy scores ($t(6) = .89$, $p = .37$). Table 70 shows the results of the t-test in greater detail.

Table 70 Comparison between agricultural educators' outcome expectancy towards technology and CASE course completion

Group	*n*	*M*	*SD*	*t*	*df*	*p*
Attended CASE	11	31.36	2.76	.89	6	.37
Did not attend CASE	68	32.33	3.42			

Engineering

An independent samples t-test was utilized to determine if completion of Curriculum for Agricultural Science Education (CASE) professional development courses significantly affected participants' outcome expectancy scores in the field of engineering. Overall, 11 participants had completed at least one CASE course (M = 30.72, SD = 3.28), and 68 indicated that they had not taken any CASE courses (M = 32.47, SD = 3.38). Results indicated that CASE attendance did not significantly affect participants' engineering teaching outcome expectancy scores ($t(76) = 1.58$, $p = .11$). Table 71 shows the results of the t-test in greater detail.

Table 71 Comparison between agricultural educators' outcome expectancy towards engineering and CASE course completion

Group	*n*	*M*	*SD*	*t*	*df*	*p*
Attended CASE	11	30.72	3.28	1.58	6	.11
Did not attend CASE	68	32.47	3.38			

Mathematics

An independent samples t-test was utilized to determine if completion of Curriculum for Agricultural Science Education (CASE) professional development courses significantly affected participants' outcome expectancy scores in the field of mathematics. Overall, 11 participants had completed at least one CASE course (M = 30.90, SD = 3.47), and 68 indicated that they had not taken any CASE courses (M = 32.57, SD = 3.23). Results indicated that CASE attendance did not significantly affect participants' mathematics outcome expectancy scores ($t(76) = 1.56$, $p = .12$). Table 72 shows the results of the t-test in greater detail.

Table 72 Comparison between agricultural educators' outcome expectancy towards mathematics and CASE course completion

Group	*n*	*M*	*SD*	*t*	*df*	*p*
Attended CASE	11	30.90	3.47	1.56	6	.12
Did not attend CASE	68	32.57	3.23			

Professional Development – Other

Science

A bivariate correlation was used to examine the relationship between the number of STEM-related professional development opportunities completed by participants and participants' science outcome expectancy scores. A nonsignificant correlation was found between the two variables (r =-.01, p = .96). Table 73 shows the relationships that existed between participants' outcome expectancy towards science and the number of professional development opportunities attended.

Technology

A bivariate correlation was used to examine the relationship between the number of STEM-related professional development opportunities completed by participants and participants' technology outcome expectancy scores. A nonsignificant yet positive correlation was found between the two variables (r = -.05, p = .79). Table 73 shows the relationships that existed between participants' outcome expectancy towards science and the number of professional development opportunities attended.

Engineering

A bivariate correlation was used to examine the relationship between the number of STEM-related professional development opportunities completed by participants and participants' engineering outcome expectancy scores. A nonsignificant correlation was found between the two variables (r = -.04 p = .82). Table 73 shows the relationships that existed between participants' outcome expectancy towards science and the number of professional development opportunities attended.

Mathematics

A bivariate correlation was used to examine the relationship between the number of STEM-related professional development opportunities completed by participants and participants' mathematics outcome expectancy scores. A nonsignificant correlation was found between the two variables (r = -.02, p = .91). Table 73 shows the relationships that existed between participants' outcome expectancy towards science and the number of professional development opportunities attended.

Table 73 Correlation coefficients between the number of professional development courses completed and efficacy towards STEM subjects

Variables	1	2	3	4	5
1. PD Completed	-				
2. Science	-.01	-			
3. Technology	-.05	.92**	-		
4. Engineering	-.04	.95**	.95**	-	
5. Mathematics	-.02	.96**	.93**	.96**	-

* p < .005, ** p < .001

Other Identified Correlations

While examining relationships between various factors and outcome expectancy, other correlations of note were identified. Strong, positive, and significant correlations were identified between participants' science outcome expectancy scores and their efficacy scores for technology ($r = .92$, $p < .001$), engineering ($r = .95$, $p < .001$), and mathematics ($r = .96$, $p < .001$). Strong, positive, and significant correlations were identified between technology efficacy and engineering efficacy ($r = .95$, $p < .001$), and between technology efficacy and mathematics efficacy ($r = .93$, $p < .001$). Finally, a strong, positive, and significant correlation was found to exist between engineering efficacy and mathematics efficacy ($r = .96$, $p < .001$). Table 74 displays the correlations that were identified between agricultural educators' science, technology, engineering, and mathematics outcome expectancy scores.

Table 74 Correlation coefficients between agricultural educators' science, technology, engineering, and mathematics outcome expectancy scores

Variables	1	2	3	4
1. Science	-			
2. Technology	.92**	-		
3. Engineering	.95**	.95**	-	
4. Mathematics	.96**	.93*	.96**	-

* p < .05, ** p < .001

CHAPTER V

CONCLUSION, DISCUSSION, AND RECOMMENDATIONS

Even though agricultural education and STEM education have long shared similar principles, goals, and backgrounds, recent initiatives have made the integration of STEM into agricultural education more important than ever. Understanding the factors that affect agricultural educators' abilities to teach STEM is an important step in ensuring that the integration is successful. The data and results presented in this research study offer an exploration into factors that can influence agricultural educators' abilities to teach STEM content effectively within an agricultural context.

Research Objective One

Personal Teaching Efficacy

Objective one sought to identify agricultural educators' personal teaching efficacy scores. Personal teaching efficacy is concerned with a teacher's level of confidence in their ability to perform a specific task within a specific setting or context. In this study, teachers' personal teaching efficacy towards the four STEM fields of science, technology, engineering, and mathematics was examined.

Agricultural educators' personal teaching efficacy scores were generally high, especially regarding the fields of science and technology. Statements on those portions of the instrument had mean scores that ranged from 3.02 to 4.53 out of 5. Engineering and mathematics had noticeably lower mean scores, with scores for statements ranging from 2.84 to 3.48 out of 5. When statements were arranged from highest mean to lowest mean, the order for engineering and mathematics statements was also quite different than it was for science and technology statements.

Science

Agricultural educators felt the most efficacious towards the field of science, with a mean score of 46.04 (*SD* = 5.21) out of a possible total of 55. They noted that they were "continually improving [their] science teaching practice," that they were "confident that [they] could teach science effectively," and that they were confident in their ability to welcome and answer students' science-related questions. They agreed least with the negatively-worded statement, "I wonder if I have the necessary skills to teach science."

These results agree with Bandura (1994), who wrote that highly-self efficacious people are more likely to appraise themselves and their abilities in a positive light. Teachers felt efficacious in the field of science, thus they appraised themselves positively in this field. The results confirm the research of Hamilton and Swortzel (2007), who found that Mississippi agricultural educators had high personal teaching efficacy for science. They also agree with the work of McCall (2017), who found that science instruction courses for teachers can increase efficacy. Twenty-four (24) teachers indicated they had completed at least one postsecondary science education course, which was more than any other STEM area. In the same vein, these results confirm the work of Darling-Hammond (2000), who noted that increased course load in science and mathematics was effective up to a point of diminishing returns. Generally, science teaching efficacy rose steadily until teachers had completed around 15 courses, after which they dropped slightly. Teachers with the fewest science courses had the lowest science teaching efficacy levels of all. Self-efficacy is also concerned with personal growth and development (Bandura, 1986). Teachers who are able to improve themselves and their teaching practices by rebounding from failures, trying new approaches, and developing "strategies for overcoming obstacles" usually have higher levels of self-efficacy (Tschannen-Moran & Wolfolk Hoy, 2001, p. 785). The fact that agricultural educators felt positively about continually improving their science teaching practice and welcoming student science questions demonstrates that they truly were highly efficacious.

Conversely, agricultural educators stated that they were not as amenable to allowing a colleague to evaluate their science teaching, and that they were unsure about how to increase student interest in science. This conflicts with Tschannen-Moran & Wolfolk Hoy (2001) and Bandura (1986), who linked higher self-efficacy with an increased desire to improve oneself and one's abilities in order to achieve set goals. Not allowing a colleague to evaluate and provide feedback for a teaching performance does not indicate such a desire. Teachers were also less confident in their ability to interest students in science and to help struggling students master science content. This disagrees with Bandura (1994), Protheroe (2008), and Tschannen-Moran and Woolfolk Hoy (2001), who wrote that high efficacy teachers are better able to motivate and work with students regardless of their learning difficulties, behavior issues, or backgrounds.

Technology

Agricultural educator responses showed relatively high efficacy towards technology, with a mean of 41.06 (*SD* = 5.80) out of a possible 55. Educators felt that, much like the field of science, they were continually improving their technology teaching practice. They also expressed particular confidence in their ability to welcome student questions about technology. They felt slightly less efficacious about their ability to teach technology effectively and their understanding of technology-based concepts. They disagreed most with the negatively-worded statement, "I wonder if I have the necessary skills to teach technology."

Like with science, the technology results agree with Bandura (1994) in that higher-efficacy teachers would assess their abilities more positively. Although teachers' technology-related personal teaching self-efficacy scores were not as high as their science scores, results show they were still highly efficacious towards technology. Teacher training and education is another factor that impacts technology self-efficacy (Redmann et al., 2003). Fifteen teachers had completed at least one postsecondary technology education course, which is the second-most of the four STEM areas. Agricultural educators felt the most confident about their ability to improve their technology teaching practice and welcome student questions, much as they did with science. This agrees with Tschannen-Moran and Wolfolk Hoy (2001), who noted that efficacious teachers are more willing to experiment and learn while being better able to handle setbacks.

Educators stated that they were not likely to invite a colleague to evaluate their technology teaching, and that they were not sure how to increase student interest in technology. They also felt that they did not know "the steps necessary to teach technology effectively," and that they were unsure if they could help a struggling student understand technology-related material better. This contrasts with the findings of Bandura (1994), Protheroe (2008), and Tschannen-Moran and Woolfolk Hoy (2001), whose work shows that teachers with higher levels of efficacy are usually more confident in their ability to work with difficult or challenging students, and more open to improving their own teaching ability.

Engineering

Educators reported the lowest levels of efficacy towards the field of engineering, with a mean of 35.39 (*SD* = 7.76) out of 55. This agrees with the work of Smith et al. (2015), who found that agricultural educators were least efficacious when integrating engineering content

Engineering efficacy scores also had a higher standard deviation than scores for any of the other STEM fields, which indicates that educators' individual efficacy levels towards engineering were more varied. Teachers felt most efficacious about their ability to welcome students' engineering questions, and thought that they could explain to students why engineering experiments worked. Like with the other three STEM fields, teachers disagreed most with the statement "I wonder if I have the necessary skills to teach engineering."

Unlike science and technology, teachers stated they knew how to increase student interest in engineering and that they were more willing to allow a colleague to evaluate their engineering teaching. This difference may be because teachers themselves recognize they lack extensive knowledge or training in engineering, and are open to learning experiences. Additionally, teachers felt better about being able to explain engineering concepts to a struggling student than they did for science and technology, which may indicate that teachers are familiar with the fundamentals of engineering.

Agricultural educators reported that they were not "continually improving [their] engineering teaching practice," which stands in stark contrast to the fields of science and technology. This may be due to the fact that teachers do not know how to improve their engineering teaching, or because they do not recognize the value of doing so. They also stated that they had less confidence in their ability to "understand engineering concepts well enough to be effective in teaching it." Similarly to science and technology, however, teachers reported that they were not confident in their knowledge of "the steps necessary to teach engineering effectively."

Previous studies have noted that teachers, including agricultural educators, have "muddled" (Stubbs & Myers, 2015, p. 198) understandings of engineering and are often not adequately trained in its principles (Yoon et al., 2012). An individual's perceptions of engineering and related teaching methods can also shape teacher efficacy as well (Smith et al., 2015). Slightly less than half of participating agricultural educators ($f = 39$, 48%) had only one engineering course, with agricultural engineering being the most common. Eighteen teachers (22%) reported completing no engineering courses at all. The total number of engineering courses completed by teachers ($f = 101$) pales in comparison to the number of science courses completed ($f = 699$), and trails far behind the number of technology ($f = 161$) and mathematics ($f = 252$) courses completed. Only 7% of teachers had a course in engineering instruction. This lack of instruction, along with popular perceptions of what engineering entails, has likely caused teachers to express lower levels of efficacy towards engineering. It is also likely that students, too, are underexposed to engineering, which makes it easier for teachers to know how to interest them in the field.

Mathematics

Agricultural educators felt the second least efficacious towards mathematics, scoring ahead of engineering (*M* = 37.95, *SD* = 7.49). Mathematics scores, like their engineering counterparts, had a much higher standard deviation than science or technology, indicating that teachers' responses to mathematics-related statements were more varied in scope. This result agrees with Haynes and Stripling's (2014) study, which found that Wyoming agricultural educators were "moderately efficacious" toward mathematics (p. 57).

Educators stated that they were confident enough to welcome student questions about mathematics and felt they could explain to students why mathematics experiments worked. They also knew "what to do to increase student interest in mathematics," and felt that they could answer students' mathematics-related questions and help struggling students better understand mathematical concepts. They also disagreed most with the statement "I wonder if I have the necessary skills to teach mathematics."

Teachers felt the least efficacious about their knowledge of the steps needed to teach mathematics effectively, much as they did for the other STEM fields. They also had doubts about their overall understanding of mathematics concepts and were not continually improving their mathematics teaching practices. However, they were more willing to allow a colleague to evaluate their mathematics teaching, which does indicate efficacy through a desire for self-improvement.

These findings agree with Darling-Hammond (2000), who found that increased course load in science and mathematics was effective up to a point. Teachers who had completed 3-5 mathematics courses had higher efficacy levels than those who completed more than 5 or fewer than 3. Haynes and Stripling (2014) stated that teachers with “moderate” levels of mathematics efficacy would benefit most from courses or professional development sessions that help them find specific ways of integrating mathematics into agriculture (p. 58). Very few agricultural educators in the study ($f = 6$) had completed a courses in mathematics instruction, which may play a role in lowering educator efficacy. Educator background with and attitude towards mathematics may also affect efficacy scores (Hilby et al., 2014; Stripling & Roberts, 2012), although these factors were not explored within this study.

Research Objective Two

Age

Teacher age did not have a significant effect on agricultural educators’ personal teaching efficacy towards science, technology, engineering, or math. This agrees with Margot (2017) and Hammack and Ivey (2017), who did not identify age as a factor when relating to science or engineering teaching efficacy, respectively, but disagrees with Redmann et al. (2003) and Stripling and Roberts (2013b) who found that age was a significant indicator of technology and mathematics efficacy. There was a weak but positive relationship between age and science and technology personal teaching efficacy scores, indicating that as age rose, so too did a teacher’s efficacy towards science and technology. There was also a weak but negative relationship between efficacy and engineering and mathematics, indicating that as teacher age increased, efficacy levels towards engineering and mathematics fell. This agrees with the findings of Stripling and Roberts (2013b), who reported that mathematics efficacy fell after 10 semesters of teaching.

Gender

Gender did not significantly affect personal teaching efficacy towards science or technology. This disagrees with the findings of Margot (2017), who found that gender did affect science teaching efficacy. However, it also agrees with the work of Redmann et al. (2003), who noted that gender was not a significant factor in technology teaching efficacy.

This study did find a significant differences between teacher gender and efficacy in engineering. Men had higher personal teaching efficacy scores than women. This is in agreement with the findings of Stripling and Roberts (2013b), who found that male agricultural educators had significantly higher engineering personal teaching efficacy scores than female agricultural educators.

Ethnic Background

Ethnicity did not play a role in educators' personal teaching efficacy towards science, technology, engineering, or mathematics. These results agree with previous studies that did not identify ethnic background as a significant factor of STEM teaching efficacy (Tschanen-Moran et al., 1998; Miller & Roberts, 2009; Stripling & Roberts, 2013; Margot, 2017). However, in this study there was low or no representation for most ethnic groups. The majority of teachers who identified their ethnicity were Caucasian/White, while only 2 described themselves as "African-American/Black," and one described themselves as "other." The fact that there was little ethnic representation amongst study participants may have influenced results. There currently a lack of minorities in both agricultural education and STEM (Myers & Dyer, 2004; NSF, 2014; NACME, 2019), which makes it difficult to gauge the true relationship between ethnic background and efficacy. Increasing the number of minority participants would provide a more accurate picture of this relationship in its current form. It is also possible that participants who consider themselves ethnic minorities may not have responded to the survey instrument for various reasons including lack of efficacy, interest, or perceived ability towards STEM.

Certification Type

This study found no significant differences in the STEM personal teaching efficacy scores of agricultural educators when compared by certification type. Traditionally certified teachers did not have teaching efficacy levels that were significantly different from alternatively certified teachers. This agrees with the findings of Duncan and Ricketts (2006) and Rocca and Washburn (2006), who also found no significant differences when it came to teaching and learning.

Teaching Career Length

Teaching career length had no significant effects on personal teaching efficacy towards STEM subjects. As career length increased, science teaching efficacy rose slightly, while technology, engineering, and mathematics efficacy fell. Teaching career length in agricultural education did not have significant effects on STEM outcome expectancy either. Increased career length in agricultural education saw minimal increases in efficacy towards science and technology. The opposite effect was observed regarding engineering and mathematics. The difference in technology efficacy between overall career length and agricultural education career length may be explained by the fact that agricultural educators use many different types of technology – both educational and career-based – in the classroom. This study did not explore teacher efficacy towards different types of technology, but only technology as a general concept.

These findings agree with the work of Burris et al. (2010), who found that agricultural educators in their fifth year had higher self-efficacy levels towards technology than first year teachers. It also confirms the findings of Stripling and Roberts (2013) that showed mathematics teaching efficacy decreased after 10 semesters of teaching.

Postsecondary STEM Background

Participants who completed more postsecondary science courses generally showed higher personal teaching efficacy towards science. Higher numbers of science courses were also weakly, yet positively, correlated with higher efficacy towards the other three STEM subjects. Study results agree with Rubeck and Enoch (1995), who suggested increasing the number of science courses completed at the university level to increase teacher efficacy towards science. Results agree with Darling-Hammond (2000), who stated that increased courses in science were only useful until subject material outpaced the needs of the curriculum being taught. Although there was an overall trend of increased science course load correlating with increased personal teaching efficacy towards science, those who completed more than 15 courses had slightly lower efficacy.

Participants who completed more technology courses had higher levels of efficacy towards technology, science, and mathematics. There was a significant, positive correlation identified between increased numbers of technology courses and engineering personal teaching efficacy. This may be because many engineering fields, such as computer, electrical, and mechanical engineering, do heavily utilize various types of technology in their daily operations. By learning to better master technology, agricultural educators are also becoming more comfortable with the tools of the engineering trade, and thus the engineering field in general.

Increased numbers of engineering courses had a significantly positive effect on engineering efficacy. Considering that educators' understanding of engineering is often "muddled" compared to their understanding of other STEM fields (Stubbs & Myers, 2015), and considering that participants completed fewer engineering courses by far than they did science, technology, or math courses, it is reasonable that those with more knowledge in the field would be more efficacious. Nonsignificant, weak, and negative correlations were also found between the number of engineering courses completed and teacher efficacy towards science, technology, and mathematics.

Increasing the number of mathematics courses completed significantly increased teachers' mathematics personal teaching efficacy scores. These findings agree with the work of Stripling and Roberts (2013), who found that preservice educators with the highest number of mathematics courses completed also had the highest efficacy levels in mathematics. Findings support the research of Darling-Hammond (2000), who noted that increasing preservice teachers' mathematics course load was effective up to a point, after which the information taught exceeded the teacher's needs. Teachers who had more than five mathematics courses showed slightly decreased levels of mathematics efficacy.

Professional Development – CASE

This study examined the relationship between personal teaching efficacy towards STEM and completion of a Curriculum for Agricultural Science Education (CASE) course. Results indicated that completion of at least one CASE course significantly affected teachers' personal teaching efficacy towards technology. These findings agree with Murphrey et al. (2009), who recommended professional development opportunities as a method for helping agricultural educators learn more about technology. Zambo and Zambo (2008) found that professional development was also an effective way to increase teacher efficacy towards and understanding of mathematics. CASE provides agricultural educators with training that integrates technology and mathematics into agriculture-based areas such as animal science, plant science, and mechanics (CASE Pathways, 2018). Completion of a CASE course was not found to have any significant impact on science, engineering, or mathematics teaching efficacy.

Professional Development – Other

Participants who completed more STEM-related professional development opportunities had lower levels of science, engineering, and mathematics efficacy. However, participants with more STEM-related professional development were more efficacious towards technology. This agrees with the study's finding showing that technology efficacy was affected by CASE professional development.

Results disagree with the findings of Margot (2017) and Zambo and Zambo (2008), who found that professional development was an effective method for increasing science and mathematics teaching efficacy, respectively. This study's findings agree with Murphrey et al. (2009) who noted that professional development was an opportunity for teachers to improve their technology efficacy. The findings also support the idea that Curriculum for Agricultural Science Education (CASE) professional development is a beneficial tool for increasing outcome expectancy towards technology.

Research Objective Three

Outcome Expectancy

Research objective three sought to identify agricultural educators' levels of outcome expectancy towards the four STEM fields of science, technology, engineering, and mathematics. Outcome expectancy involves a teacher's belief in their ability to influence things that are largely out of the teacher's control. Examples of things a teacher might influence but not control include a student's interests, the local school community, and family attitudes towards education.

Overall, outcome expectancy scores for the four fields were lower than personal teaching efficacy scores. Across all four STEM fields, no statement received a mean score higher than a 3.94 out of 5. Total mean scores for each STEM field also ranged from 32.20 to 32.56 out of a possible 45. This shows that teachers were more neutral towards the impact of outcome expectancy beliefs and that they had less confidence in their ability to influence various factors related to educational success.

Outcome expectancy means across the four STEM fields were also very similar to one another in two regards. First, the total mean scores for each area varied by only tenths of a point, unlike the wider-ranging scores for personal teaching efficacy. Second, when outcome expectancy survey statements were individually arranged by mean value, each area had the statements falling into a similar order with similar scores. These patterns indicate that agricultural educators felt the same about their outcome expectancy beliefs regardless of the STEM field in question.

Overall, responses were consistent with expected moderate to high teacher outcome expectancy levels. A teacher with such beliefs would feel that they could improve student learning outcomes through such behavior as providing extra attention, utilizing more effective teaching methods, and improving their overall teaching performance (Protheroe, 2008; Tschannen-Moran & Woolfolk Hoy, 200l; Bandura 1994). Teachers with higher outcome expectancy beliefs would also focus on the positive ways that they could impact students instead of the negative, which was observed in the results (Tschannen-Moran & Woolfolk Hoy, 2001).

Science

Agricultural educators felt slightly more efficacious towards their science teaching outcome expectancy than they did for any other field (M = 32.56, SD = 3.38). Teachers felt most confident in their ability to make positive differences in students' lives and learning trajectories. They felt that providing a quality teaching performance could increase student achievement and interest in science, even if the student were "low achieving" or in possession of an inadequate science background. Identifying and utilizing the most effective teaching methods was also named as an important factor in helping students succeed.

Teachers agreed that they were generally responsible for student learning in science, but did not feel as strongly that student learning was directly related to their effectiveness in the subject area. They also had more neutral feelings about a teacher's potential for fostering negative learning outcomes, associating such outcomes more with student performance instead of teacher performance. They disagreed most with the idea that poor learning progress or minimal learning overall was related to ineffective teaching.

Technology

Agricultural educators showed the lowest levels of outcome expectancy towards technology (M = 32.20, SD = 3.34). Teachers felt the most confident in their ability to influence student outcomes in a positive manner, agreeing that extra attention and extra effort from the teacher, alongside a good teaching performance, could greatly assist students in overcoming learning difficulties or deficiencies related to technology. Teacher efficacy towards technology was also viewed as a way of increasing student interest in the field. Teachers felt that they were responsible for student learning regarding technology. However, they did not feel that an ineffective teaching performance would necessarily impact learning for the worse.

Engineering

Teachers showed the second-lowest levels of outcome expectancy towards engineering (M = 32.22, SD = 3.40), ahead of the field of technology. They believed most strongly that providing children with extra attention could help those children making engineering-related learning gains, and that increased student interest in engineering was "probably due to the performance of" the teacher. Teachers also felt that a student's lack of an engineering background was a minor obstacle that could be "overcome by good teaching." They saw themselves as generally responsible for student learning in engineering-related areas, but were much less agreeable that negative learning outcomes were directly related to their abilities and performances.

Mathematics

Mathematics had the second-highest levels of outcome expectancy (M = 32.24, SD = 3.29), falling behind only science. Much like with the other three fields, teachers felt that offering extra attention and effort to a student could help them improve their mathematics ability. Increased student interest in mathematics was also closely related to a teacher's performance and outcome expectancy, as were unexpected increases in student performance. Teachers also felt that inadequacies in a student's mathematics background could be overcome by quality teaching. Again, they agreed that they were responsible for students' learning in mathematics, but felt that negative learning outcomes were not as much a function of teacher performance.

Research Objective Four

Age

Teacher age did not have a significant effect on efficacy towards STEM subjects. Overall, older teachers were slightly less efficacious than younger teachers. These findings disagree with the research of Redmann et al. (2003) and Stripling and Roberts (2013), who found that teacher age could affect efficacy towards technology and mathematics, respectively.

Gender

Male and female teachers had similar outcome expectancy scores towards STEM subjects. Overall there were no significant differences between the two groups. This disagrees with the work of Margot (2017), Hammack and Ivey (2017), and Stripling and Roberts (2013) who found that gender significantly affected efficacy towards science, engineering, and mathematics.

Ethnic Background

Ethnic background was not found to play a role in outcome expectancy towards science, technology, engineering, or mathematics. These results agree with previous studies that did not identify ethnic background as a significant factor of STEM teaching efficacy (Tschanen-Moran et al., 1998; Miller & Roberts, 2009; Stripling & Roberts, 2013; Margot, 2017). There was a lack of ethnic variance in the study, with the vast majority of participants identifying themselves as Caucasian/White. Increasing the amount of minority participants would have given a more accurate picture of teachers' efficacy towards STEM subjects. Currently, there is a need to increase minority representation in both agricultural education and STEM (Myers & Dyer, 2004; NSF, 2014; NACME, 2019).

Certification Type

Teachers who were traditionally certified had no differences in outcome expectancy scores from those who were alternatively certified. These results demonstrate that completion of a university-level teacher education program and a student teaching internship did not significantly affect efficacy. This agrees with the findings of Duncan and Ricketts (2006) and Rocca and Washburn (2006), who also found no significant differences when it came to teaching and learning.

Teaching Career Length

No significant correlations were found between career length and outcome expectancy towards STEM. As teaching career length increased, outcome expectancy levels decreased slightly. There were also no significant correlations found between participants' agricultural education career lengths and outcome expectancy towards STEM. As agricultural education teaching careers lengthened, outcome expectancy levels decreased slightly.

Postsecondary STEM Background

For science, engineering, and mathematics outcome expectancy, increased course load led to increased outcome expectancy levels. This shows that as teachers completed more courses in those areas, their beliefs in their ability to influence student learning outcomes and attitudes rose, too. Increased numbers of mathematics courses was significantly correlated with increased science teaching outcome expectancy levels. This finding may result from the fact that many scientific concepts rely heavily on mathematical principles. As teachers gain further insight into these principles, their ability to deliver them in new, interesting, and student-friendly ways also increases. However, this did not hold true for technology courses, which saw small decreases in efficacy towards STEM subjects.

Professional Development – CASE

CASE course attendance did not significantly affect teachers' outcome expectancy for any of the STEM fields. This disagrees with research that suggests professional development can improve teacher efficacy (Tschannen-Moran et al., 1998). Study results may be caused by the fact that outcome expectancy does not concern itself with a teacher's confidence with the subject matter alone, but also with the teacher's belief that they can influence a student's learning habits and performance for the better. CASE training is more focused on helping students and teachers master subject matter in an engaging and interactive manner.

Professional Development – Other

There were no significant correlations between the number of professional development sessions attended and STEM teaching efficacy. Professional development decreased science outcome expectancy, which is consistent with other findings that state increased courses and CASE training saw decreases as well. Overall, increasing teachers' exposure to science caused their efficacy to decrease. Conversely, technology, engineering, and mathematics all saw nonsignificant positive correlations, with efficacy rising as professional development session completion rose.

Discussion

Teacher Efficacy

Teaching efficacy is an important concept that involves a teacher's belief in their ability to accomplish specific tasks within an educational setting (Tschannen-Moran et al., 1998). There are two types of teaching efficacy: personal teaching efficacy and outcome expectancy. Personal teaching efficacy is concerned with a teacher's confidence in their own teaching abilities, (Protheroe, 2008) and outcome expectancy is related to factors that teachers cannot control but still believe they can influence. Helping teachers improve their efficacy towards specific subject matter such as STEM can also improve their overall teaching ability, quality of life, and effect on students.

Teaching efficacy affects many different aspects of a teacher's career including their classroom performance and management, chosen teaching methods, resilience, and ability to motivate students (Protheroe, 2008; Tschannen-Moran et al., 1998). Teachers with high levels of efficacy are shown to respond to challenges more effectively than those who do not, and they are overall happier with their careers and more likely to work effectively with students of all needs and backgrounds (Protheroe, 2008; Tschannen-Moran et al., 1998).

With the looming reality of an ever-growing world population, agriculturists of tomorrow will be required to become more productive and do more with less. Accomplishing such a challenge is not an easy feat, but so far it has been possible through advancements in the STEM fields of science, technology, engineering, and mathematics. If American agriculturists are to continue feeding and clothing the nation while remaining competitive on a global stage, it is essential that the agriculturists of tomorrow are well prepared for the high-tech jobs they are likely to enter. We need a workforce of agricultural educators who are fronting this initiative; educators who are confident in their ability to master and explain STEM subjects within an agricultural context. By focusing on teacher efficacy towards STEM, we can examine the factors that currently underlie teachers' STEM beliefs and identify what makes them effective at teaching such subject material. With this knowledge, teacher educators can take the steps necessary to ensure that the next generation of agricultural educators is confident and well prepared to address rising needs.

Factors Affecting Personal Teaching Efficacy and Outcome Expectancy

This study examined several factors that may serve as potential influences upon teachers' personal teaching efficacy and outcome expectancy levels including age (Redmann et al., 2003; Stripling & Roberts, 2013), career length (Blackburn & Robinson, 2008; Rodriguez, 1997; Swan et al., 2011), teaching certification type (Duncan & Ricketts, 2006; Rocca & Washburn, 2006), gender (Hammack & Ivey, 2017; Smith et al., 2015; Stripling & Roberts, 2013); ethnic background (Bandura, 1994; NACME, 2019; National Science Foundation, 2014), educational background (Darling-Hammond, 2000; McCall, 2017; Stripling & Roberts, 2013; Watson, 2006.)

Personal teaching efficacy is defined as efficacy related "to a teacher's own feeling of confidence in regard to teaching abilities" (Protheroe, 2008, p. 43), and it involves teachers expressing faith in their own capacity to "develop strategies for overcoming obstacles to student learning" (Tschannen-Moran & Woolfolk Hoy, 2001, p. 785). For personal teaching efficacy, the only factors observed to have any significant effect were gender, the number of science, technology, and engineering classes completed, and the completion of at least one Curriculum for Agricultural Science Education (CASE) course. Results showed that women had significantly higher efficacy levels than men did towards engineering and mathematics. In addition, results indicated that as the number of science, technology, and engineering courses taken increased, teaching efficacy decreased. Teaching efficacy towards technology was also higher for those who had completed at least one CASE course. Age, ethnic background, certification type, career length, and non-CASE professional development opportunities were found to have no significant effects on personal teaching efficacy.

For outcome expectancy, only one significant factor was identified. Interestingly, the number of postsecondary mathematics courses completed by participants was shown to be significantly correlated with science teaching general efficacy scores. Factors such as age, gender, ethnic background, certification type, career length, CASE attendance, and non-CASE professional development opportunities were found to have no significant effects on outcome expectancy.

Implications

Information discovered from this study can be of use in educational programs that train future agricultural educators. If programs are to integrate STEM subjects into agricultural education curricula, it is vital that teacher educators realize and implement the best methods of doing so. Building efficacy is a function of one's knowledge, past experiences, and thought processes, and teacher educators must structure their programs so that future agricultural educators complete the courses and experiences necessary for success. Teacher educators must know how to strike a balance that maximizes the potential for all factors while still preparing future educators with the pedagogical knowledge they will need. In order to do so, teacher educators must take course requirements and assignments, state educational standards, licensure requirements, student needs, and school needs into account.

Agricultural educators are efficacious about their ability to teach science and technology, but less so for engineering and mathematics. Teacher educators must help students gain more understanding for all parts of STEM, not just science and technology. They can help both current and future teachers by building engineering and mathematics topics into agricultural education coursework and ensuring that students recognize how each field is used in the modern agricultural industry. This should not just include the field of agricultural mechanics, but also product design and testing, problem solving, economics and marketing, genetic engineering, and more. Modern agricultural education curriculums should ensure that agricultural educators have more concrete understandings of what STEM employees – including engineers of different types – do every day, and how they affect the agricultural industry at large.

Recommendations

Recommendations for Research

1. Further study should examine agricultural educators' perceptions of engineering and its use in the agriculture industry. Results of this study indicate that agricultural educators did not have much experience in the engineering field and had efficacy scores that were much lower than they were for science or technology.

Engineering is often the least understood and least integrated field of STEM (Stubbs & Myers, 2015; Yoon et al., 2012), and it is important to understand how agricultural educators view the subject area so that needs can be effectively addressed in teacher education programs and professional development opportunities.

2. Future research should examine how engineering concepts are taught in both preservice agricultural educator teacher training programs and in secondary agricultural education programs. A teacher's efficacy level has an effect on the teaching methods that a teacher chooses to use (Riggs, 1995), with lower efficacy teachers usually avoiding methods that are more student-centered and "hands-on, activity based" (Tschannen-Moran et al., 1998, p. 216). Agricultural and STEM education are both founded on similar principles that espouse learning by doing and placing subject matter within a real-world context (Stubbs & Myers, 2016). Agricultural educators had lower levels of efficacy towards engineering, which may indicate that their engineering teaching methods and techniques are not consistent with agricultural education and STEM values. Recognizing the methods through which engineering is taught to preservice teachers and to students could help further the mission of successfully integrating STEM into agricultural education.

3. Research on the relationship between minorities and STEM is essential as well. Minorities are currently underrepresented in STEM fields and in agricultural education (NACME, 2019), and studying their specific beliefs about and experiences with STEM could help create a fuller picture of the industry. This study did not have a particularly diverse population, which leaves room for exploration into minorities' viewpoints and levels of understanding regarding STEM.

4. Research on teachers' STEM career awareness should be performed. One function of agricultural education is to prepare students for success in their future careers. With STEM careers becoming a growing area of interest for agriculture students, we should understand how current teachers view the careers available in STEM and the methods through which they are readying students for such positions. This is especially relevant regarding engineering, as teachers are not as knowledgeable regarding the field and its implications as a whole (Stubbs & Myers, 2015; Yoon et al., 2012).

5. Research into how educators use, implement, and teach technology in their classes is also a possible field of study. The term 'technology' is very broad, and teachers may interpret it differently depending upon their backgrounds, beliefs, and training, as well as the accessibility of technology within their schools (Murphrey et al., 2009; Redmann et al., 2003; Watson, 2006). Future research should examine both classroom-based technology such as smart boards and grading software, and career-based technology used in agriculture such as GPS units and hydroponics systems.

Recommendations for Practice

1. Teacher educators should examine the usefulness of their current teacher preparation program course loads. This study found that agricultural educators completed many science courses and few technology or engineering courses. Teacher educators must ensure that their universities' programs of study are striking the appropriate balance amongst all four STEM fields. These programs of study must ensure that students are exposed to the appropriate amount of information they will need to teach, but not overexposed to the point where knowledge outpaces the curriculum and they feel

uncomfortable with the material. Preservice agricultural educators should be required to complete broad overviews of the STEM fields instead of more in-depth courses that focus on specific STEM areas. This should include at least one engineering and one technology course related to agriculture in some way, as well as a course instructing teachers in basic STEM principles.

2. Because STEM education is focused on application and context, postsecondary agricultural educators should also highlight STEM concepts in agriculture courses and explain their significance to the industry and the world at large. In addition, they should also help students make connections between STEM-related general education courses and agriculture courses.

3. As advancements in STEM fields and agricultural education progress, programs of study for future educators must be continually updated to ensure that needs for both knowledge and efficacy are being met. Teacher educators should assess their students' knowledge and efficacy towards STEM subjects through instruments like the T-STEM. This will help them to meet individual needs and determine the most effective path that a preservice educator should complete.

5. It is recommended that teacher educators help both current and future agricultural educators improve outcome expectancy levels. While outcome expectancy levels were not extremely low and teachers did recognize the positive impact they could have upon students, increasing outcome expectancy could benefit teachers who work under stressful conditions or in difficult assignments. High outcome expectancy can have many benefits for both teachers and students, including increased resilience, patience, and interest in the subject matter. Assisting agricultural educators in understanding the role of

outcome expectancy and helping them develop it further would be a valuable tool for preservice educators beginning their career, or for those who have only a few years of service.

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APPENDIX A

TEACHER EFFICACY AND ATTITUDES TOWARDS STEM (T-STEM) SURVEY INSTRUMENT

Teacher Efficacy and Attitudes Towards STEM Survey

Directions:

Read the following statements and indicate your level of agreement with each as it relates to your personal integration of the four STEM fields into agricultural education. There are no “right” or “wrong” answers. The only correct responses are those that are true for you. Whenever possible, let the things that have happened to you help make your choice.

Please indicate your level of agreement or disagreement using the following system:

1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree

Part 1 –Teaching Efficacy and Beliefs

	Science	**Technology**	**Engineering**	**Math**
1. I am continually improving my ______ teaching practice.				
2. I know the steps necessary to teach ______effectively.				
3. I am confident that I can explain to students why ______ experiments work.				
4. I am confident that I can teach ______effectively.				
5. I wonder if I have the necessary skills to teach _____.				
6. I understand _____ concepts well enough to be effective in teaching it.				
7. Given a chance, I would invite a colleague to evaluate my teaching.				
8. I am confident that I can answer students’ _____ questions.				
9. When a student has difficulty understanding a _____ concept, I am confident that I know how to help the student understand it better.				
10. When teaching _____, I am confident enough to welcome student questions.				
11. I know what to do to increase student interest in _____.				

Part 2 –Teaching General teaching efficacy

	Science	Technology	Engineering	Math
12. When a student does better than usual in _____, it is often because the teacher exerted a little extra effort.				
13. The inadequacy of a student's _____ background can be overcome by good teaching.				
14. When a student's learning in _____ is greater than expected, it is most often due to the teacher having found a more effective teaching approach.				
15. The teacher is generally responsible for students' learning in _____.				
16. If students' learning in _____ is less than expected, it is most likely due to ineffective teaching.				
17. Students' learning in _____ is directly related to their teacher's effectiveness in teaching that subject.				
18. When a low achieving child progresses more than expected in _____, it is usually due to extra attention given by the teacher.				
19. If parents comment that their child is showing more interest in _____ at school, it is probably due to the performance of the child's teacher.				
20. Minimal student learning in _____ can generally be attributed to their teachers.				

Part 3: Educator Characteristics

21. In which state do you teach?

Mississippi Tennessee

22. What is your current age in years? __________

23. Which best describes your gender? (Please indicate one.)

Male	Female	Other	Prefer not to respond

24. Which best describes your ethnic background?

African-American/ Black	Asian American/ Pacific Islander	Hispanic/ Latino	Native American/ Alaska Native	White/ Caucasian	Other

25.How many years total have you been a teacher? __________

26. How many years total have you been an agricultural education teacher? __________

27. Please list your degrees, the subject area of each, and the institution(s) which conferred them.

28. Which type of teaching certification do you possess?

Traditional (completed student teaching)	Nontraditional (did not complete student teaching)	Not sure

29. Have you attended any CASE institutes? (If yes, go to the next question. If no, skip to 33.)

30. Please list any Curriculum for Agricultural Science Education (CASE) institutes that you have attended.

31. Are you certified to teach any CASE institutes? (If yes, go to the next question. If no, skip to 33.)

32. Please list any CASE institutes that you are certified to teach.

33. Please list any STEM-related workshops or professional development sessions that you have attended within the last year.

34. Please describe methods or lessons that you use to integrate STEM content into your agricultural education classroom.

35. Please indicate subjects for which you have completed at least one course in college (at the graduate or undergraduate level).

Science

Anatomy/physiology	
Animal science/zoology	
Astronomy	
Biology	
Chemistry	
Entomology	
Environmental science	
Food science	
Genetics	
Geology	
Microbiology	
Organic chemistry	
Physical science	
Physics	
Plant science/botany	
Science education	
Soil science	

Please list any other science courses you have completed:

Technology

Agricultural mechanics	
Computer programming	
Educational technology	
Electronics	
Global Positioning Systems/Geographic Information Systems	
Information technology	
Medical technology	

Technology education	
Web design	

Please list any other technology courses you have completed:

Engineering

Aerospace/aeronautical	
Agricultural	
Architectural	
Automotive	
Biomedical	
Chemical	
Civil	
Computer	
Electrical/electronics	
Engineering education	
Environmental	
Mechanical	

Please list any other engineering courses you have completed:

Mathematics

Accounting	
Calculus	
College algebra	
Differential equations	
Economics	
Finance	
Geometry	
Mathematics education	
Statistics	
Trigonometry	

Please list any other mathematics courses you have completed:

APPENDIX B

MISSISSIPPI STATE UNIVERSITY INSTITUTONAL REVIEW BOARD (IRB)

APPROVAL

MISSISSIPPI STATE UNIVERSITY

Office of Research Compliance

Institutional Review Board for the Protection of
Human Subjects in Research
P.O. Box 6223
53 Morgan Avenue
Mississippi State, MS 39762
P. 662.325.3294

www.orc.msstate.edu

NOTICE OF DETERMINATION FROM THE HUMAN RESEARCH PROTECTION PROGRAM

DATE:	November 20, 2018
TO:	Kirk Swortzel, PhD, School of Human Sciences, Carla Jagger;Laura Greenhaw;Ryan Walker
PROTOCOL TITLE:	The Relationship Between Agricultural Educators Personal Characteristics and Self Efficacy Beliefs Regarding STEM Education
PROTOCOL NUMBER:	IRB-18-482
	Approval Date: November 20, 2018 Expiration Date: November 19, 2023

EXEMPTION DETERMINATION

The review of your research study referenced above has been completed. The HRPP had made an Exemption Determination as defined by 45 CFR 46.101(b)2. Based on this determination, and in accordance with Federal Regulations, your research does not require further oversight by the HRPP.

Employing best practices for Exempt studies are strongly encouraged such as adherence to the ethical principles articulated in the Belmont Report, found at www.hhs.gov/ohrp/regulations-and-policy/belmont-report/# as well as the MSU HRPP Operations Manual, found at www.orc.msstate.edu/humansubjects. Additionally, to protect the confidentiality of research participants, we encourage you to destroy private information which can be linked to the identities of individuals as soon as it is reasonable to do so.

Based on this determination, this study has been inactivated in our system. This means that recruitment, enrollment, data collection, and/or data analysis **CAN** continue, yet personnel and procedural amendments to this study are no longer required. **If at any point, however, the risk to participants increases, you must contact the HRPP immediately. If you are unsure if your proposed change would increase the risk, please call the HRPP office and they can guide you.**

If this research is for a thesis or dissertation, this notification is your official documentation that the HRPP has made this determination.

If you have any questions relating to the protection of human research participants, please contact the HRPP Office at irb@research.msstate.edu. We wish you success in carrying out your research project.

APPENDIX C

T-STEM INSTRUMENT USE APPROVAL

Thank you for your interest in using our evaluation instruments. These evaluation instruments were identified, modified, or developed through support provided by the Friday Institute. The Friday Institute grants you permission to use these instruments for educational, non-commercial purposes only. You may use an instrument "as is", or modify it to suit your needs, but in either case you must credit its original source. By using this instrument you agree to allow the Friday Institute to use the de-identified data collected for additional validity and reliability analysis. You also agree to share with the Friday Institute publications, presentations, evaluation reports, etc. that include data collected and/or results from your use of these instruments. The Friday Institute will take appropriate measures to maintain the confidentiality of all data.

The STEM surveys (as pdfs) can be accessed and downloaded from here: go.ncsu.edu/fisstemandtstemsurveys. Please feel free to contact me if you have any further questions or inquiries related to the S-STEM and T-STEM surveys. Thank you.

Instruments related to **technology innovation, professional development and workforce development** can be downloaded (as pdfs) here: **https://eval.fi.ncsu.edu/instruments-2/**. This includes all 1:1 instruments and technology needs assessment.

Additionally, please see attached for the elementary, middle, and high school versions of our STEM Implementation Rubric. The elementary and middle school versions are identical, and there are some slight differences in the high school rubric. We hope you find this useful in your work and would be happy to hear of any thoughts you have on its usefulness, improvements, etc. We have recommended citations on the front page of each rubric as well.

Please use the recommended citation for the S-STEM and T-STEM surveys:

Friday Institute for Educational Innovation (2012). *Middle and High School STEM-Student Survey*. Raleigh, NC: Author.

Friday Institute for Educational Innovation (2012). *Elementary School STEM - Student Survey*. Raleigh, NC: Author.

Friday Institute for Educational Innovation (2012). *Teacher Efficacy and Attitudes Toward STEM Survey- Elementary Teachers.* Raleigh, NC: Author.

Friday Institute for Educational Innovation (2012). *Teacher Efficacy and Attitudes Toward STEM Survey- Science Teachers.* Raleigh, NC: Author.

Friday Institute for Educational Innovation (2012). *Teacher Efficacy and Attitudes Toward STEM Survey- Technology Teachers.* Raleigh, NC: Author.

Friday Institute for Educational Innovation (2012). *Teacher Efficacy and Attitudes Toward STEM Survey- Engineering Teachers.* Raleigh, NC: Author.

Friday Institute for Educational Innovation (2012). *Teacher Efficacy and Attitudes Toward STEM Survey- Mathematics Teachers.* Raleigh, NC: Author.

We want to make you aware that the following article has been published:

Unfried, A., Faber, M., Stanhope, D. & Wiebe, E. (2015). *The development and validation of a measure of student attitudes toward science, technology, mathematics, and engineering*. Journal of Psychoeducational Assessment. doi: 10.1177/0734282915571160

You can access an online copy of this article at: http://jpa.sagepub.com/cgi/reprint/0734282915571160v1.pdf?ijkey=4uXpGzzDfz3Pyuy&keytype=finite

This article can be cited when you are providing background validation on the S-STEM instrument. We encourage you to read the article in detail to better inform how you might utilize this instrument.

The development of these surveys were partially supported by the National Science Foundation under Grant No. 1038154 and by the Golden LEAF foundation.