Journal of Agricultural Education, 61(4), 189-202
https://doi.org/10.5032/jae.2020.04189

Agriscience Teacher Professional Development Focused on Teaching STEM Principles in the Floriculture Curriculum

Natalie K. Ferand[1], Catherine A. DiBenedetto[2], Andrew C. Thoron[3], and Brian E. Myers[4]

Abstract

Agriscience teachers help support the mission of the American Floral Endowment to inspire people to pursue careers working with plants by providing curricula related to ornamental horticulture. Nevertheless, an overall understanding of how the horticulture industry is connected to the studies of science, technology, engineering, and mathematics (STEM) has left a shortage of skilled professionals. A professional development program was designed to provide agriscience teachers with experiences focused on STEM concepts taught in horticulture and floriculture curricula. The Science Teaching Efficacy Belief (STEB) instrument was used before and after the three days of content specific inquiry-based instruction to determine participants' perceptions of their performance pre, post, and post-post. While teachers showed growth in their mean scores for the Science Teaching Outcome Expectancy (STOE) and Personal Science Teaching Efficacy Beliefs (PSTEB) constructs of the STEB between all three testing periods, no significant difference was found across the period-of-time. It is recommended that teacher educators consider how to create professional development experiences for agriscience teachers that target content to positively impact teacher self-efficacy. Further, it is recommended that professional development opportunities contain follow-up communication to determine whether teachers utilize curricular resources and ascertain how the teacher's new knowledge is transferred to inform instructional change. The final recommendation is to measure student learning outcomes as a result of content-specific teacher professional development.

Keywords: floriculture; horticulture; plant science; professional development; science efficacy teaching instrument; self-efficacy; STEM

Introduction and Literature Review

For over fifty years, the central mission of the American Floral Endowment (AFE) has been to fund research and scholarships in floriculture and environmental horticulture to benefit growers, wholesalers, retailers, allied industry organizations and the general public (American Floral Endowment, 2019a). There are many benefits to the floriculture industry from both the

[1] Natalie K. Ferand is a Doctoral Candidate and Graduate Assistant of Agricultural Education in the Department of Agricultural Education and Communication at the University of Florida, 310 Rolfs Hall, PO Box 110540, Gainesville, FL 32611, nferand@ufl.edu, https://orcid.org/0000-0001-9505-1764

[2] Catherine A. DiBenedetto is an Assistant Professor in the Agricultural Sciences Department at Clemson University, 251 McAdams Hall, Clemson, SC 29634, cdibene@clemson.edu.

[3] Andrew C. Thoron is an Associate Professor and Department Head in the Department of Agricultural Education and Communication at Abraham Baldwin Agricultural College, ABAC 8, 2802 Moore Hwy, Tifton, GA 31793, andrew.thoron@abac.edu, https://orcid.org/0000-0002-9905-3692

[4] Brian E. Myers is a Professor and Department Chair in the Department of Agricultural Education and Communication at the University of Florida, 305 Rolfs Hall, PO Box 110540, Gainesville, FL 32611, bmyers@ufl.edu.

environmental and psychological perspectives (Bradley et al., 2017; Hall & Hodges, 2011). Lack of understanding and awareness of horticulture and related industries impacts perceived importance and value of how ornamentals are deeply rooted in our lives, culture, and society (Irani et al., 2009). Consequently, the horticulture industry faces shortages of skilled professionals (Shepherd, 2011), as well as those with adequate knowledge and capacity to teach the science, technology, engineering, and mathematics (STEM) principles to prepare students for careers in this field. In 2017, AFE supported Seed your Future™ with the mission to promote horticulture and inspire people to pursue careers working with plants. The AFE established a strategic plan to help combat these deficits. The strategic plan included five goals: awareness, education, workforce development, partnerships, and resource development (American Floral Endowment, 2019b).

Numerous reports throughout the past decade indicated a need for developing skills for careers closely related to STEM (Carnevale et al., 2014; Honey et al., 2014; National Research Council, 2000; National Research Council, 2011). Further, research has indicated that time spent teaching specific content areas directly correlates to the teacher's perceived self-efficacy. If a teacher is not efficacious in a specific area, students will receive less instruction related to that topic. A low level of background knowledge in a topic, specifically science, has been reported as a primary reason for avoiding the content area, such as the science of agriculture (Ramey-Gassert & Shroyer, 1992). Starting with the preamble of the Hatch Act of 1887, which enacted scientific investigation in the name of agricultural advancement, science and agriculture are indelibly linked (Hatch Act of 1887). Chambers and Chambers Encyclopedia (1897) defined agriculture as the application of scientific principles and reasoning related to the *art* of agriculture. Despite this clear connection, some students fail to link the science within agriculture and ornamental horticulture when they contemplate careers. Exposure to topics related to the ornamental horticulture industry may assist students in connecting their experiences to the science within horticulture careers (Marsh et al., 2011). This knowledge can help to increase the supply of skilled professionals needed throughout the industry. More recently, research priority area three of the American Association for Agricultural Education's National Research Agenda called for a sufficient scientific and professional workforce that addresses the challenges of the 21st century (Stripling & Ricketts, 2016). School-based Agricultural Education (SBAE) programs provide direct paths to career development for students in secondary schools. Agriscience teachers serve as mentors to their students (Roberts et al., 2006) and can encourage students to enter agriculturally related careers.

Teacher professional development is an intentional and purposeful process that can be considered fundamental to improving professional skills and is extremely important for one's advancement as an educator (Guskey & Huberman, 1995). The goal of professional development for teachers is to improve their professional knowledge, skills, and attitudes to enhance student learning (Guskey & Sparks, 2000). According to Guskey and Sparks (2000), professional development involves three defining characteristics that include intentional, ongoing, and systematic processes. Programs should be intentionally planned with clarity and include an intended purpose and worthwhile goals that can be evaluated. Professional development should be ongoing and embedded in the daily process of teaching (Guskey & Sparks, 2000).

It is crucial to create opportunities for teachers to experience similar types of scientific inquiry as is expected of their students. Given the relationship between teacher and student learning, professional development must be grounded in academic content to affect instructional practices and student outcomes. The program should also include structured time for discussion and planning, which can assist with the teachers' change in instructional practices (Jeanpierre et al., 2005).

The STEM-it Up: Everything You Need to Know to Get Your Floriculture Curriculum in Bloom (STEM-it Up) program was designed to deliver intentional and systematic professional development, embedded with experiential learning opportunities, and focused on promoting exposure to horticulture/floriculture curricula. This emphasis was based upon the research around quality teacher professional development and the need to better prepare teachers to instruct students on STEM concepts. Aligned with the mission of AFE, and to address industry needs, the content focus included: laboratory investigations, unit plans, and curricular resources specifically related to the STEM concepts present in the floriculture industry. An established criterion for selection was determined to target a particular group of agriscience teachers from around the United States who were invited to apply and participate. STEM-it Up was supported by grant funds from AFE.

STEM and Curriculum

The topic of STEM integration related to SBAE has been a standard line of inquiry in recent years (Rice & Kitchel, 2018; Smith et al., 2015; Stubbs & Myers, 2015; Stubbs & Myers, 2016). In a qualitative study aimed to investigate teachers' views of STEM and its integration in SBAE courses, Stubbs and Myers (2016) noted that teachers considered agriculture a scientific discipline with STEM consistently being integrated into agriculture before a name was devised. STEM professional development and education allowed the teachers to successfully highlight the STEM concepts naturally found in agriculture in their classes. However, the teachers' use of and understanding of engineering and math concepts varied more when compared to science. This variance was attributed to the teachers' level of personal experience with engineering, as well as their personal feelings toward math (Stubbs & Myers, 2016). While teachers' experiences with, and feeling towards, the science of agriculture are varied, teachers' past educational experiences in all areas of STEM influenced their perceptions of how STEM concepts can be integrated, consistent with Ramey-Gassert and Shroyer (1992).

Smith et al. (2015) reported that teachers indicated a high level of importance to integrate all four STEM areas, with science being ranked the highest in importance, followed by technology, mathematics, then engineering. While the authors found significant differences in perceptions of the importance of integrating STEM by gender, there was no identified difference between genders for confidence to embed STEM concepts. Further, the authors noted there were no differences discovered for either importance or confidence in integrating STEM concepts between traditionally and alternatively certified teachers, as well as when compared by the length of the teaching career. Results indicated that science and agriculture remain tightly connected ideas (Smith et al., 2015).

Specific to plant sciences, Rice and Kitchel (2018) indicated that plant science was an outlet for practical application of scientific ideas. The notion of complementing core science courses, such as biology, instead of replicating the content, was also seen as a common theme. Additionally, the concepts in plant science are considered to be more conventional regarding concepts students have been familiar with for many years. Rice and Kitchel (2018) suggested a focus in the classroom on scientific careers within plant sciences to complement the current emphasis placed on the integration of STEM concepts.

Faculty in higher education also recognized the importance of relaying STEM concepts to preservice agriscience teachers. Swafford (2018) remarked that faculty in agricultural education believe students in preservice teacher programs should be instructed on how to utilize experiential teaching, as well as how to highlight STEM concepts in their classroom. A majority of faculty reported modeling inquiry-based teaching methods in their classes, in addition to integrating STEM into their courses. However, even if these methods and concepts are being reported as taught in teacher education programs, teacher efficacy in teaching STEM areas should still be an area of concern and investigation (Swafford, 2018).

Teacher Self-Efficacy

Hasselquist et al. (2017) explored how the combination of factors influenced the self-efficacy and job satisfaction of beginning teachers. Overall, the teachers included in the study reported moderate levels of support and teacher efficacy, with a high level of job satisfaction. Further analysis found that collegial support was a significant factor in teacher self-efficacy, while teaching and personal efficacy did not indicate significance in the model. Additionally, district, administration, colleagues, and program financial support were also found to be significant factors in the teacher job satisfaction model (Hasselquist et al., 2017). The authors opined the value of teachers forming relationships within their administration and school district. These types of relationships were found to not only directly influence teacher efficacy, but also create an opportunity for peer support, also mentioned by Wolf et al. (2010). Opportunities to build relationships can be provided through professional development conferences where teachers collaborate.

Through examining teacher candidates' professional development experiences, Wolf et al. (2010) sought to explore the impact of such experiences on self-efficacy and perceived level of preparedness to become an agriscience teacher. Using the *Teacher Sense of Efficacy Scale* (Tschannen-Moran et al., 1998), the authors analyzed efficacy and preparedness in three domains of classroom management, instructional strategies, and student engagement. The authors concluded that due to the similarities between self-efficacy and preparedness beliefs, the two areas coincide. Furthermore, while observations of teachers of similar skill levels were found to have a positive relationship with self-efficacy, this was not true when observing more experienced teachers. The authors suggested that viewing teachers with greater skill sets might prove intimidating; therefore, limiting self-efficacy. Feedback was also found to be a significant factor in preservice teacher self-efficacy. Written feedback was found not to impact self-efficacy, while verbal feedback indicated a moderate, positive influence on self-efficacy (Wolf et al., 2010). These results are similar to recommendations by Ulmer et al. (2013) for continued peer support and feedback. Ulmer et al. (2013) sought to explore the impact of the Curriculum for Agricultural Science Education (CASE) Institute and provided curriculum on teachers' science teaching efficacy. It was suggested that seeing peer teachers succeed in teaching as well as interaction with other teachers, who attended the same professional development workshop, successfully implement lessons into their curriculum increased self-efficacy.

McKim and Velez (2015) further considered self-efficacy among early career teachers. Teachers indicated mid-levels of science teaching self-efficacy; however, no significant difference in science teaching efficacy was found due to the number of years teaching. Science teaching efficacy was found to be a significant variable in career commitment indicating teachers may expect challenges related to teaching science concepts, which outweighs their perceived self-efficacy (McKim & Velez, 2015). Additionally, STEM learning opportunities have been credited for successful career preparation with interdisciplinary curricula, development of critical thinking, and enhancement of students' problem-solving skills. Assisting agriscience teachers understanding of the rationale for emphasizing STEM in the Agriculture and Food and Natural Resource curricula could improve teacher quality, career readiness, and increase student motivation and learning outcomes supportive of student success (Scherer et al., 2019).

Teacher self-efficacy in both STEM concepts, particularly science and mathematics, as well as teacher self-efficacy in these subjects presented varied findings (Graves et al., 2016; Hasselquist et al., 2017; Haynes & Stripling, 2014; McKim & Velez, 2015; Stripling & Roberts, 2013; Ulmer et al., 2013; Wolf, 2011; Wolf et al., 2010). This contrast can be aligned with the findings of Ramey-Gassert and Shroyer (1992), which indicated an inadequate foundational understanding of science could lead to varying levels of teaching. Thus, high quality, content-focused professional development is needed for teachers to obtain adequate amounts of scientific knowledge to implement science into their curriculum.

Theoretical Framework and Conceptual Model

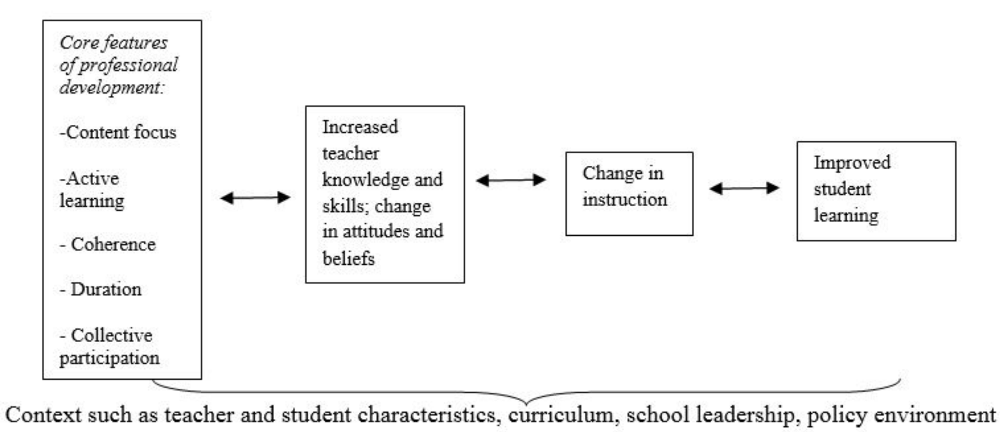
A positive relationship exists between self-efficacy and achievement (Bandura & Schunk, 1981; Schunk, 2012). Self-efficacy is defined as "people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performances" (Bandura, 1986, p.361). When teachers experience occasions to become aware of their self-efficacy and are encouraged to set goals, they become more intrinsically motivated to change their instructional practices. Personal performance, observations of models (vicarious experiences), forms of social persuasion, and physiological indexes are the four main areas in which people develop information about their self-efficacy (Schunk, 2012). Beliefs related to personal mastery and perceived competence can be determined when investigating self-efficacy (Maddux, 2016). Directly related to Ramey-Gassert and Shroyer (1992), people engage in activities they believe they can do, such as teaching content of which they are more familiar (Maddux, 2016). Therefore, it was theorized that self-efficacy would determine our participants' perceptions of their performance before and after engaging in the STEM-it Up professional development program.

The impacts of teacher learning and professional development that have been identified as significant indicators to improve the quality of schools in the United States are well documented (Borko & Putnam, 1996; Darling-Hammond & McLaughlin, 2011; Desimone, 2011). Schools are merely as proficient as the teachers and administrators who work within them (Guskey, 2002). As teachers work on the frontline of education, their roles increasingly become more difficult as they are challenged with numerous responsibilities that require continual support to meet the demands of the 21st century. Differentiating instruction for diverse student populations; teaching curriculum standards; preparing students for state testing procedures; regulating behavioral issues; adhering to evaluation procedures; allocating classroom resources; and advancing knowledge of content and pedagogy are a few obligations teachers face.

Desimone (2009) posited the successes and failures of educational reform could be measured by the effectiveness of teacher professional development. Research has indicated that high-quality teacher professional development has the following factors: (a) content focus, (b) active learning, (c) coherence, (d) duration, and (e) collective participation (Desimone, 2009). Therefore, the following conceptual model was used to guide the STEM-it Up professional development program and research (Figure 1).

Figure 1

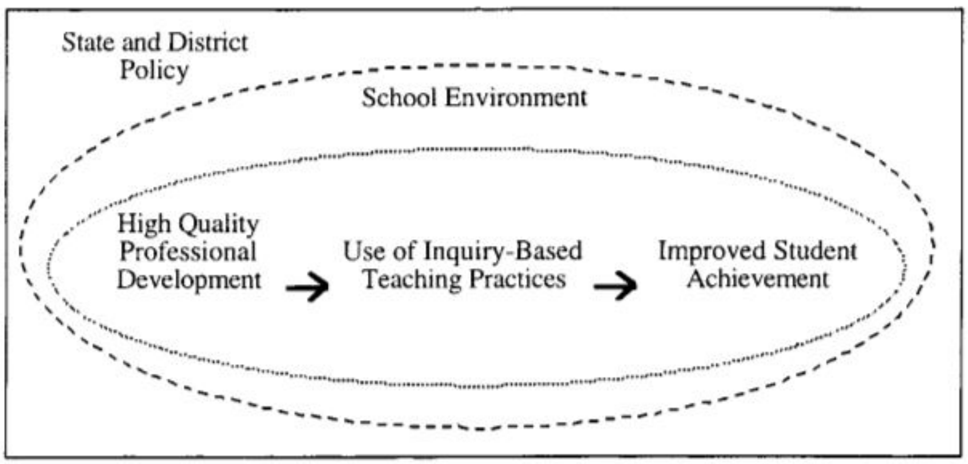
Conceptual Framework for Studying the Effects of Professional Development (Desimone, 2009, p. 185)



In addition to the five core features that Desimone (2009) provided, professional development should also be intensive and sustained over time (Hawley & Valli, 1999). Bybee (1993) suggested that participants must be engaged in inquiry, questioning, and experimentation through modeling. Since the mid-1990s, the emphasis of essential science content has been called for through the National Science Education Standards (NRC, 2000). "Programs that focus on subject matter knowledge and student learning of particular subject matter are likely to have larger positive effects on student learning than are programs that focus on teaching behaviors" (Kennedy, 1998, p.11). Finally, the purpose of professional development is to generate exceptional teaching intended to render better student achievement (Supovitz & Turner, 2000). Policy, school environment, and the type of professional development all drive the overall success of the teacher and, ultimately, student achievement (Figure 2).

Figure 2

Model Depicting the Theoretical Relationship Between Professional Development and Student Achievement. (Supovitz & Turner, 2000)



Darling-Hammond and McLaughlin (2011) asserted:

> Teachers learn by doing, reading, and reflecting (just as students do); by collaborating with other teachers; by looking closely at students and their work, and by sharing what they see.... To understand deeply, teachers must learn about, see, and experience successful learning-centered and learner-centered teaching practices. (p. 83)

Consideration of the conceptual model by Desimone (2009) and the theoretical model of professional development, inquiry-based teaching practices, and student achievement (Supovitz & Turner, 2000) led to the design and delivery of STEM-it Up.

Purpose and Objectives

The purpose of this study was to determine our participants' perceptions of self-efficacy in teaching the science of agriculture immediately before and after, as well as five months after engaging in the STEM-it Up professional development program. Specific objectives of this study were to:

1. Describe the mean levels of teacher efficacy in Personal Science Teaching Efficacy and Science Teaching Outcome Expectancy for pre, post, and post-post test assessments.

2. Describe differences, if any, in mean levels of teacher efficacy in Personal Science Teaching Efficacy and Science Teaching Outcome Expectancy for both pre, post, and post-post test assessments.

Methods

Program Description

Agriscience teachers (*N* = 14) from around the nation were selected through a nomination and application process to participate in a professional development program focused on applying STEM concepts within the horticulture/floriculture curricula. Topics of focus included greenhouse electrical controls, microgreens propagation, STEM laboratory investigations in floriculture and floral design techniques, and plant and environmental science research laboratory and industry tours. The STEM-it Up professional development program was designed to help agriscience teachers learn, and think about, teaching STEM concepts related to the horticulture/floriculture industry in a new way, by highlighting the science that is embedded into the curricula. Curricula were delivered through an inquiry-based, hands-on approach and modeled by the instructors as recommended by Bybee (1993), to allow participants to gain full knowledge and complete the lessons as a student and thus have a deeper understanding of the content, context, and pedagogy.

Population and Sampling

The target population for this study was all agriscience teachers (*N* = 14*)* registered for STEM-it Up, which was held at Clemson University in June 2019. Participants were selected through an application process. To disseminate the application, state leaders in agricultural education were contacted in 20 states where the researchers had personal contacts. State leaders were asked to nominate outstanding agriscience teachers who taught curricula in the horticulture and floriculture pathways. The nominated teachers were then contacted and invited to complete an application. Twenty-four complete applications were received. Participants were selected by the researchers based on the current curricula taught (such as floriculture specific courses), level of self-perceived experience teaching floriculture and horticulture, and depth of interest in learning about inquiry-based instruction and STEM concepts.

This study utilized a pre-experimental, exploratory design. Data for the pre and post tests were collected during the first and last sessions of the three-day program to obtain pre and post test scores. A hardcopy instrument was utilized and was collected face-to-face. A 100% response rate was achieved as all 14 teachers completed the pre and post instruments. A post-post instrument was distributed via Qualtrics online survey software approximately six months after the completion of the program and a 93% (*n* = 13) response rate was achieved. A prenotice, cover letter, and two follow-up emails for the post-post-test were distributed via email. A final contact and reminder were made by phone, where necessary.

Most of the agriscience teachers who participated in this study had been teaching one to three years (*f* = 7; 46.7%), with 33.3% teaching for four to eight years (*f* = 5), and 20% for nine to fifteen years (*f* = 3). All teachers reported having only taught agricultural subjects during their teaching career (*f* = 15; 100%). Nearly half of the teachers reported teaching 50 – 99 unduplicated students (*f* = 7, 46.7%), with 100 – 150 students being the second largest group (*f* = 5; 33.3%). Horticulture was the most frequently reported course taught (*f* = 9; 60.0%), while introductory agriculture (*f* = 7; 46.7%), and advanced horticulture were the next frequently reported (*f* = 5; 33.3%). Some teachers reported teaching floral design (*f* = 3; 20%) and advanced floral design, and others reported teaching floriculture (*f* = 4, 26.7%). It should be noted that the results of this study are limited to those teachers who attended and participated in the professional development program.

Instrumentation

Riggs and Enochs' (1989) Science Teaching Efficacy Belief Instrument was adapted for use in this study according to the authors' suggestion to align measurement to specific situations. Modifications included slight changes in language to tailor the instrument for high school teaching and the science of agriculture. The purpose of this instrument was to measure the self-efficacy of agriscience teachers towards teaching the science of agriculture. The instrument consisted of 25 items with response categories of "strongly disagree," "disagree," "uncertain," "agree," and "strongly agree." Each of the five categories was scored one to five, with "strongly disagree" receiving one and "strongly agree," receiving a score of five. Face and content validity of the instrument were addressed using a panel of two faculty and one graduate student. The expert panel specialized in preparation of preservice agriscience teachers and in-service teacher professional development using methods of inquiry-based instruction.

The instrument encompassed two constructs. The first construct, Science Teaching Outcome Expectancy (STOE), targeted teacher beliefs connected to inabilities to produce specific outcomes and consisted of 12 questions (Enochs & Riggs, 1990). Example questions included, "The teacher is generally responsible for the achievement of students" and "The inadequacy of a student's background in the science of agriculture can be overcome by good teaching." Personal Science Teaching Efficacy Beliefs (PSTEB) composed the second construct, which focused on behaviors related explicitly to science teaching to be an accurate predictor of distinct teaching behaviors (Riggs & Enochs, 1989). Example questions from the PSTEB construct included "I am continually finding better ways to teach the science of agriculture" and "I am typically able to answer students' questions on the science of agriculture." Cronbach's alpha reliability coefficients from Riggs and Enochs' (1989) original instrument were .92 for PSTEB and .76 for STOE.

Data Analysis

Data were analyzed using SPSS version 26 for PC and Microsoft Excel. Descriptive statistics, which included frequency, mean, standard deviation, and percentage, were utilized to describe the population, as well as summarize data by item and construct. Negatively worded items (3, 6, 8, 10, 13, 17, 19, 20, 21, 22, 24, and 25) were reverse coded before any analysis, according to Riggs and Enochs (1989). For objective two, a repeated-measures ANOVA was utilized in conjunction with summated mean scores for each construct. Results from Maluchly's test for the PSTEB construct indicated the assumption of sphericity was not violated, $X^2(2) = 0.33$, $p<.05$. When examining the means of the STOE construct, Mauchly's test revealed sphericity was violated, $X^2(2) = 0.03$, $p<.05$. Therefore, the Greenhouse-Geiser was utilized for epsilon adjustment.

Post-hoc analysis was utilized to determine internal reliability using Cronbach's alpha coefficients. Pre, post, and post-post test reliabilities for PSTEB were .80, .64, and .88 respectively, while STOE pre, post, and post-post test reliabilities were .63, .69, and .69. A lower reliability score for the STOE construct is consistent with Riggs and Enochs (1989), who noted there are complexities in measuring outcome expectancy due to variations in teacher background, students' background, and student motivation. An alpha level of .05 was set *a priori*.

Results

The first objective of this study was to describe the mean level of teacher efficacy in Personal Science Teaching Efficacy Belief (PSTEB) and Science Teaching Outcome Expectancy

(STOE) for the pre, post, and post-post test assessments (Table 1). Teachers reported a mean PSTEB pretest score of 3.44 (*SD* = 0.49) and a mean STOE score of 3.31 (*SD* = 0.41). After the program, teachers reported a slight increase in both post-test mean PSTEB score of 3.79 (*SD* = 0.34) and STOE score of 3.48 (*SD* = 0.41). Finally, during the last phase of the study, a mean PSTEB post-post test score of 3.72 (*SD* = 0.59) and a mean STOE score of 3.33 (*SD* = 0.43) displayed a slight decrease from the post-test, but still higher than the participants original perceptions from the pretest.

Table 1

Means, Standard Deviations, and Repeated-Measures Analyses of Variance for PSTEB and STOE Constructs

Measure	Pre Test (n = 14)		Post Test (n = 14)		Post-Post Test (n = 13)		*F*
	Mean	*SD*	Mean	*SD*	Mean	*SD*	
PSTEB	3.44	0.49	3.79	0.34	3.72	0.59	(2,11) = 3.52
STOE	3.30	0.40	3.48	0.41	3.33	0.43	(1.350, 16.194) = 2.02

Objective two was to describe any possible difference in the mean levels of both constructs over the three testing periods (Table 1). A one-way repeated-measures ANOVA was conducted to compare scores in both the PSTEB and STOE constructs across the three testing periods. A significant effect of time for the testing period was not found for the PSTEB construct, $F_{(2, 11)} = 3.52$, $p = 0.66$. Additionally, a significant effect for the testing period was not found for the STOE construct, $F_{(1.350, 16.194)} = 2.02$, $p = 0.17$.

Conclusions and Discussion

The results of this research are limited to the purposively selected population of the STEM-it Up professional development program. The authors note this as a limitation of the study. Therefore, the results of this study are only representative of the group of teachers who participated in the program and are not generalizable beyond the population utilized.

Overall, teachers displayed increased scores in both the PSTEB and STOE constructs across the total period, with a slight decrease from the post to post-post test periods. This result indicates the professional development was able to provide focused time and aid the teachers overall in both PSTEB and STOE. This conclusion is congruent with Ulmer et al. (2013), who also found increases in both areas after targeted professional development occurred, with a slight decrease seen in the STOE construct.

STEM-it Up highlighted many areas of the technical and scientific aspects of the floriculture and horticulture industries. The focus of scientific concepts within the professional development program and standard practices within the curriculum facilitated the teachers' belief they can convey the same concepts and ideas to their students as supported by Darling-Hammond and McLaughlin (2011) who posited that "teachers learn by doing, reading, and reflecting (just as students do)" (p.83). Additionally, the mean of the PSTEB construct displayed higher scores than the STOE construct across all three testing periods. When teachers have increased confidence in their level of knowledge, as well as the tools needed to deliver this information to their students, they can display higher levels of confidence in their abilities to assist and engage their students. Participation in the program provided teachers with the focused and specific content needed for increased efficacy. Rice and Kitchel (2018) noted similar findings, reporting teachers found ease in incorporating science into the plant science curriculum.

Further, background knowledge of curriculum related to scientific concepts was a focus of STEM-it Up. An increase in teachers' perceived understanding, such as an increase in the PSTEB construct, which we observed, remained relatively stable from the post to post-post testing period, supporting the achievement of this goal. Additionally, this finding indicated an increased likelihood for the participants to teach scientific concepts in their curriculum, which aligns with findings by Ramsey and Edwards (2011) and is supported by Desimone's (2009) conceptual framework and the theoretical underpinnings of self-efficacy (Bandura & Schunk, 1981; Schunk, 2012).

Recommendations

Evaluating self-efficacy helped determine our participants' perceptions of their performance before and after engaging in the program. Using STEM-it Up as a model, we recommend that teacher educators should consider how to create professional development experiences for agriscience teachers that target specific content to impact self-efficacy. No matter the structure or focus of professional development, it is recommended to continue to follow the guidelines for high-quality professional development set forth by Desimone (2009) including content focus, active participation, coherence, duration, and collective participation.

The post-post test design provided participants time to apply their new knowledge and skills from the program. Ulmer et al. (2013) also used a post-post test design for CASE institute training. As people engage in activities they believe they can do, such as teaching content of which they are more familiar, it is recommended similar studies should also be designed for professional development with different content areas of focus to determine if our model for professional development could be applicable for other AFNR career pathways (Maddux, 2016). It is also recommended that follow-up communication with participants be planned to determine if and how they utilized what they learned as a result of engaging in the three-day STEM-it Up program.

Recommendations for research include repeating this study with a larger sample. Additionally, Supovitz and Turner (2000) posited that high-quality professional development coupled with inquiry-based instruction increases student achievement; it is recommended that follow-up research be designed to better determine how participants' increase in self-efficacy after engaging in professional development benefits student achievement. It would be beneficial to curriculum developers to know how agriscience teachers utilize the resources and transfer the knowledge from professional development sessions to change their instruction and improve student learning (Desimone, 2009). Finally, it would be helpful to explore teacher adaptation of curriculum and impacts on student learning. Data could be collected via survey design and/or qualitative research design to inform decisions for the development and structure of future professional development.

References

American Floral Endowment. (2019a). *About the American Floral Endowment.* https://endowment.org/about-american-floral-endowment-afe/

American Floral Endowment. (2019b). *Seed your future.* https://endowment.org/seed-your-future/

Bandura, A. (1986). *Social cognitive foundations of thought and action: A social cognitive theory.* Prentice Hall.

Bandura, A., & Schunk, D. H. (1981). Cultivating competence, self-efficacy, and intrinsic interest through proximal self-motivation. *Journal of Personality and Social Psychology, 41*(3), 586-598.

Borko, H., & Putnam, R. T. (1996). Learning to teach. In D. C. Berlinger & R. C. Calfee (Eds.), *Handbook of educational psychology* (p. 673-708). Teachers College Press.

Bradley, L. K., Behe, B. K., Bumgarner, N. R., Glen, C. D., Donaldson, J. L., Bauske, E. M., Dorn, S., & Langellotto, G. (2017). Assessing the economic contributions and benefits of consumer horticulture. *HortTechnology*, *27*(5), 591–598. https://doi.org/10.21273/HORTTECH03784-17

Bybee, R. W. (1993). Reforming science education: Social perspectives and personal reflections. Teacher's College Press.

Carnevale, A. P., Smith, N., & Melton, M. (2014). *STEM Executive Summary*. https://cew.georgetown.edu/wp-content/uploads/2014/11/stem-execsum.pdf

Chambers, W., & Chambers, R. (1897). *Chamber's encyclopedia: A dictionary of universal knowledge.* (New ed.). W. R. Chambers. http://hdl.handle.net/2027/uva.x030751742

Darling-Hammond, L. & McLaughlin, M. (2011). Policies that support professional development in an era of reform. *Phi delta kappan*, *92*(6), 81-92. http://dx.doi.org/10.1177/003172171109200622

Desimone, L. M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher*, *38*(3), 181-199. https://doi:10.3102/0013189X08331140

Desimone, L. M. (2011). A primer on effective professional development. *Phi delta kappan*, *92*(6), 68-71. http://dx.doi.org/10.1177/003172171109200616

Enochs, L. G., & Riggs, I. M. (1990). Further development of an elementary science teaching efficacy belief instrument: A preservice elementary scale. In *National Association of Research in Science Teaching*. Atlanta, GA. http://dx.doi.org/10.1111/j.1949-8594.1990.tb12048.x

Graves, L. A., Hughes, H., & Balgopal, M. M. (2016). Teaching STEM through horticulture: implementing an edible plant curriculum at a STEM-centric elementary school. *Journal of Agricultural Education*, *57*(3), 197–207. https://doi.org/10.5032/jae.2016.03192

Guskey, T. R. (2002). Professional development and teacher change. *Teachers and Teaching: theory and practice, 8*(3/4), 381-391. http://dx.doi.org/10.1080/135406002100000512

Guskey, T. R., & Huberman, M. (1995). *Professional development in education: New paradigms and practices.* Teachers College Press.

Guskey, T. R., & Sparks, D. (2000). *Evaluating professional development.* Corwin Press.

Hall, C. R., & Hodges, A. W. (2011). Economic, environmental, and well-being benefits of lifestyle horticulture. *Chronica Horiculturae*, *51*(4), 5–8. https://pdfs.semanticscholar.org/46a0/68333135a1d2bc20168e0fad37263e71e4bb.pdf

Hawley, W. D., & Valli, L. (1999). The essentials of effective professional development: A new consensus. In G. Sykes & L. Darling-Hammond (Eds.), *Handbook of teaching and policy*. Teachers College Press.

Hasselquist, L., Herndon, K., & Kitchel, T. (2017). School culture's influence on beginning agriculture teachers' job satisfaction and teacher self-efficacy. *Journal of Agricultural Education*, *58*(1), 267–279. hhttps://doi.org/10.5032/jae.2017.01267

Hatch Act of 1887, 7 U.S.C. § 361 (1887). https://nifa.usda.gov/sites/default/files/program/Compilation%20The%20Hatch%20Act%20of%201887.pdf

Haynes, J. C., & Stripling, C. T. (2014). Mathematics efficacy and professional development needs of Wyoming agricultural education teachers. *Journal of Agricultural Education*, *55*(5), 48–64. https://doi.org/10.5032/jae.2014.05048

Honey, M. A., Pearson, G., & Schweingruber, H. (2014). *STEM integration in K-12 education: status, prospects, and an agenda for research*. National Academies Press. https://doi.org/10.17226/18612

Irani, T., Baker, L. M., & Abrams, K. (2009). *Building the capacity of the 21st century floriculture industry: Assessing ways to impact student career choice and enhance post secondary education*. https://endowment.org/wp-content/uploads/2011/07/2010_irani_final_report_student_recruitment .pdf

Jeanpierre, B., Oberhauser, K., & Freeman, C. (2005). Characteristics of professional development that effect change in secondary science teachers' classroom practices. *Journal of Research in Science Teaching, 42*(6), 668-690. http://dx.doi.org/10.1002/tea.20069

Kennedy, M. M. (1998). *The relevance of content in inservice teacher education.* Paper presented at the annual meeting of the American Educational Research Association. April, 1998. San Diego, CA.

Marsh, L. E., Cotton, C. P., Hashem, F. M., & Dadson, R. B. (2011). An Ornamental Summer Program for High School Students: Issues and Perspectives. *NACTA Journal*, *55*(2), 8-13. https://www.nactateachers.org/attachments/article/1152/Marsh_JUNE%202011%20NACTA%20Journal-4.pdf

Maddux, J. E. (2016). Self-efficacy. In P. B. Sławomir Trusz (Ed.), *Interpersonal and Intrapersonal Expectancies* (1st ed., pp. 57–78). Routledge. https://doi.org/10.4324/9781315652535

McKim, A. J., & Velez, J. J. (2015). Exploring the relationship between self-efficacy and career commitment among early career agriculture teachers. *Journal of Agricultural Education*, *56*(1), 127–140. https://doi.org/10.5032/jae.2015.01127

National Research Council. (2000). *Inquiry and the national science education standards: A guide for teaching and learning.* Washington, DC: The National Academies Press. https://doi.org/10.17226/9596

National Research Council (2011). *Successful K-12 STEM education: Identifying effective approaches in science, technology, engineering, and mathematics.* Washington, DC: The National Academies Press. https://doi.org/10.17226/13158

Ramey-Gassert, L., & Shroyer, M. G. (1992). Enhancing science teaching self-efficacy in preservice elementary teachers. *Journal of Elementary Science Education*, *4*(1), 26–34. http://dx.doi.org/10.1007/BF03173752

Ramsey, J., & Edwards, C. (2011). Entry–level technical skills that agricultural industry experts expected students to learn through their supervised agricultural experiences: A Modified Delphi Study. *Journal of Agricultural Education, 52*(2), 82-94. https://doi.org/10.5032/jae.2011.02082

Rice, A., & Kitchel, T. (2018). Agriculture teachers' integrated belief systems and its influence on their pedagogical content knowledge. *Journal of Agricultural Education*, *59*(1), 21–69. https://doi.org/10.5032/jae.2018.01059

Riggs, I. M., & Enochs, L. G. (1989). Toward the development of an elementary teacher's science teaching efficacy belief instrument. In *National Association for Research in Science Teaching, 74*(6), 625-637. http://dx.doi.org/10.1002/sce.3730740605

Roberts, T., Dooley, K., Harlin, J., & Murphey, P. (2006) Competencies and traits of successful agricultural science teachers. *Journal of Career and Technical Education, 22*(2). http://dx.doi.org/10.21061/jcte.v22i2.429

Scherer, H. H., McKim, A. J., Wang, H. H., DiBenedetto, C. A., & Robinson, K. (2019). Making sense of the buzz: A systematic review of "STEM" in agriculture, food, and natural resources education literature. *Journal of Agricultural Education*, *60*(2), 28-53. https://doi.org/10.5032/jae.2019.02028

Schunk, D. H. (2012). *Learning theories: An educational perspective.* (6th ed.). Pearson Education Inc.

Shepherd, M. (2011). Careers in horticultural industries (PFA 4/5.5). *Science Education News*, *60*(2), 67.

Smith, K. L., Rayfield, J., & McKim, B. R. (2015). Effective practices in STEM integration: Describing teacher perceptions and instructional methods use. *Journal of Agricultural Education*, *56*(4), 182–201. https://doi.org/10.5032/jae.2015.04183

Stripling, C.T., & Ricketts, J.C. (2016). Research priority 3: Sufficient scientific and professional workforce that addresses the challenges of the 21st century. In T.G. Roberts, A. Harder, & M.T. Brashears (Eds.), *American Association for Agricultural Education National Research Agenda: 2016-2020* (pp. 29-35). Gainesville, FL: Department of Agricultural Education and Communication.

Stripling, C., & Roberts, T. G. (2013). Effects of mathematics integration in a teaching methods course on self-efficacy of preservice agricultural education teachers. *Journal of Agricultural Education*, *54*(2), 114–129. https://doi.org/10.5032/jae.2013.02114

Stubbs, E. A., & Myers, B. E. (2015). Multiple case study of STEM in school-based agricultural education. *Journal of Agricultural Education, 56*(2), 188-203. https://doi.org/10.5032/jae.2015.02188

Stubbs, E. A., & Myers, B. E. (2016). Part of what we do: Teacher perceptions of STEM integration. *Journal of Agricultural Education*, *57*(3), 87–100. https://doi.org/10.5032/jae.2016.0308

Supovitz, J. A., & Turner, M. H. (2000). The effects of professional development on science teaching practices and classroom culture. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *37*(9), 963-980. http://dx.doi.org/10.1002/1098-2736(200011)37:9%3C963::AID-

TEA6%3E3.0.CO;2-0

Swafford, M. (2018). STEM education at the nexus of the 3-circle model. *Journal of Agricultural Education*, *59*(1), 297–315. https://doi.org/10.5032/jae.2018.01297

Tschannen-Moran, M., Hoy, A. W., & Hoy, W. K. (1998). Teacher efficacy: Its meaning and measure. *Review of Educational Research*, *68*(2), 202–248. http://dx.doi.org/10.3102/00346543068002202

Ulmer, J., Velez, J., Lambert, M., Thompson, G., Burris, S., & Witt, P. (2013). Exploring science teaching efficacy of CASE curriculum teachers: A post-then-pre assessment. *Journal of Agricultural Education*, *54*(2), 121–133. https://doi.org/10.5032/jae.2013.04121

Wolf, K. (2011). Agricultural education perceived teacher self-efficacy: A descriptive study of beginning agricultural education teachers. *Journal of Agricultural Education*, *52*(2), 163–176. https://doi.org/10.5032/jae.2011.02163

Wolf, K., Foster, D., & Birkenholz, R. (2010). The relationship between teacher self-efficacy and the professional development experiences of agricultural education teacher candidates. *Journal of Agricultural Education*, *51*(4), 38–48. https://doi.org/10.5032/jae.2010.04038