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Agriscience Teachers Beliefs about STEM Illumination after an Immersive Professional Development Experience: A Q Sort Study

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Abstract

This study examined agriscience teachers' beliefs regarding how a professional development (PD) experience illuminated the importance of integrating STEM into the floriculture curriculum. Sixteen teachers from 12 states were selected through a competitive application process to participate in a USDA-NIFA funded PD program. The PD included five months of virtual sessions and a 10-day domestic travel experience, exposing participants to the floral distribution channel, site visits with industry professionals, and hands-on learning with scientists. Q methodology was used to explore participants' beliefs. Teachers sorted 36 statements, developed using Ajzen's (1991) Theory of Planned Behavior, into a quasi-normal distribution. Factor analysis revealed three belief types: (a) STEM Advocates, (b) STEM Illuminators, and (c) Illumination Attempters. STEM Advocates emphasized the importance of STEM for critical thinking and student engagement. STEM Illuminators valued technical STEM content knowledge gained through PD. Illumination Attempters acknowledged STEM's importance but reported a need for additional support and training. Findings suggest immersive, content-specific PD can positively influence teachers' self-efficacy and behavioral intentions. We recommend additional support tailored to teacher needs and use of Q methodology to explore how teacher beliefs influence instructional behaviors.

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Introduction and Problem Statement

A significant gap has been reported regarding the number of students entering and remaining in the fields of science, technology, engineering, and mathematics (STEM; Akcan et al., 2023). There is a need for more purposeful and direct connections between content, educators, and students in School-Based Agricultural Education (SBAE; Roberts et al., 2020). The need for seamless integration of STEM content and technical agricultural concepts has been noted as particularly acute within floriculture curricula (Ferand, Bommidi, et al., 2025; Ferand, DiBenedetto, et al., 2022, 2023). STEM integration has been defined as the merger of disciplines to enhance students' knowledge, understanding, and interest in STEM (Wang & Knobloch, 2022). Despite this notion, the effective transfer of STEM knowledge and skills from agriscience teachers to students is contingent on educators being proficient in the STEM subject matter as well as possessing a comprehensive understanding of industry practices (Wang & Knobloch, 2022).

Such deficiencies in the synthesis of STEM and agricultural content have been addressed through teacher professional development (PD) programs. When exposed to a PD experience designed to enhance agriscience teachers' understanding of illuminating STEM concepts in floriculture, Ferand et al. (2020) reported that teachers had marked increases in their science teaching efficacy beliefs and their science teaching outcomes expectancy scores. However, there were no statistically significant differences among teachers' scores on these measures using pre-, post-, and post-post assessment comparisons. As such, a key implication from the previous findings was the need for a greater understanding of designing effective PD to enhance agriscience teachers' self-efficacy to integrate STEM concepts when teaching floriculture (Ferand, Bommidi, et al., 2025; Ferand, DiBenedetto, et al., 2020). This study builds upon that implication by examining a different immersive PD program aimed at supporting STEM integration in floriculture, using similar outcome measures to evaluate changes in teacher efficacy.

Theoretical and Conceptual Framework

We examined this phenomenon using Ajzen's (1991, 2006) theory of planned behavior (TPB). Initially proposed by Ajzen (1985), TPB integrates central components of self-efficacy, motivation to complete a task, and control. TPB has suggested that an individual's engagement in a particular behavior is driven by their beliefs and intentions toward an action. These beliefs are categorized into three distinct dimensions: (a) behavioral beliefs (attitudes), (b) normative beliefs (subjective or social norms), and (c) control beliefs (perceived behavioral control). Behavioral beliefs represent an individual's perceptions of the potential positive or negative outcomes of executing a behavior. Such beliefs significantly shape an individual's attitude toward a related action (Ajzen, 2006).

On the other hand, normative beliefs pertain to the perceived social pressures influencing the decision to engage in a behavior (Ajzen, 1991). Lastly, control beliefs represent the perceived ease associated with performing the behavior. As a result, these belief systems serve as antecedents to individuals' planned behaviors. In this investigation, each of the beliefs outlined by Ajzen (1991, 2006) structured how we analyzed the participants' views of the PD experience.

Teachers' knowledge bases are challenging to quantify and conceptualize (Ferguson et al., 2022; Shulman, 1987). McKim et al. (2017) theorized agriscience teachers can be categorized based on their levels of declarative knowledge and core STEM ideas with procedural agricultural content and posed only three categories of teachers: Vocational Purist, Illumination Attempter, and Science Illuminator. When juxtaposed with STEM integration, science illumination enables teachers to highlight core ideas and technical content seamlessly. Integration of STEM ideas is broadly divided into two groups: those that attempt illumination and those that are illuminators of science (McKim et al., 2017). Both of these groups are motivated to integrate science into the SBAE classroom, but the difference is noted in proficiency of science knowledge (McKim et al., 2017). Science Illuminators are proficient in science knowledge and are motivated to illuminate science in the SBAE curriculum. Illumination Attempters may be deficient in science knowledge but are motivated to illuminate science in the SBAE curriculum. Based on the expectancy-value motivational theory (Wigfield, 1994) , a third teacher type is noted, the vocational purists; these teachers lack competence to illuminate science, are not motivated to integrate science into the SBAE curriculum and do not illuminate science and its link with society (McKim et al., 2017). As teachers are the access point through which students engage with content, and to be efficient STEM illuminators, teachers must have equal levels of STEM content knowledge and awareness of technical agriculture (McKim et al., 2017). Additionally, previous studies have also shown that students who engage in STEM illuminated content score higher on both technical agricultural and core science concepts (Ferand et al., 2020) and have comparable scores to their peers who learn STEM concepts in a traditional core-focused class (Nolin & Parr, 2013).

It has been documented the lower a teacher's perceived self-efficacy in a subject, the less time students will receive instruction on the topic (Ramey-Gassert & Shroyer, 1992). Student achievement of expected learning outcomes is also directly related to the self-efficacy of the teachers' beliefs (Tschannen-Moran & Hoy, 2001). Additionally, teachers' level of content knowledge has been shown to increase student STEM learning (National Research Council, 2013). Teachers have also inaccurately perceived their level of STEM content knowledge (Hendrix et al., 2020; Scales et al., 2009). If teachers are to teach a specific topic or method in their classrooms, they should have intentional and purposeful professional development covering these concepts (Guskey, 1995). Furthermore, teachers should have opportunities for experiential learning to be "in the shoes" of their students and engage with the content, or better yet, plan the content, from the perspective of their students (Jeanpierre et al., 2005).

When operationalized for this study, behavioral beliefs and attitudes, were viewed as teacher perceptions of STEM illumination. Normative beliefs, or subjective or social norms, were operationalized as perceived support of illumination from stakeholder groups. Lastly, control beliefs, or perceived behavioral control, were seen as possible barriers or consequences of STEM illumination.

Purpose

A better understanding of how agriscience teachers approach the implementation of STEM concepts after an immersive PD experience may inform future decisions for PD program design. This study examined participants' beliefs regarding how a PD experience illuminated the importance of integrating STEM when teaching floriculture for agriscience teachers. One research question guided this study: What patterns emerge about agriscience teachers' beliefs on integrating STEM into the floriculture curriculum after a PD experience?

Methods

We created a PD experience for agriscience teachers that focused on enhancing their STEM knowledge and skills in floriculture. This PD experience used a combination of virtual and in-person exploration of the floriculture industry. Despite this method, little was known about whether the participants believed this PD experience was an approach that enhanced their integration of STEM when teaching floriculture.

The PD experience examined in this study was funded by the Immersive Professional Development Experiences for Agriscience Teachers to Explore the Floriculture Industry project award no. 2023-67037-39955, from the U.S Department of Agriculture's National Institute of Food and Agriculture . In total, 16 agriscience teachers from across the U.S. were selected using a competitive application process. The participants represented 12 unique states, all teaching floriculture or horticulture-related courses. For the first five months, the participants engaged in monthly virtual sessions to help expand their knowledge about STEM concepts in the floriculture industry. Example session topics included the floral distribution channel, the international floriculture market, and the wholesale cut flower industry. STEM principles were illuminated throughout each session. Then, in July 2024, the participants engaged in a 10-day domestic travel experience, including site visits in South Carolina, Kentucky, and Florida. During the domestic travel experience, the participants were exposed to multiple phases of the floral distribution channel, such as the importing of flowers and the distribution process at the Miami International Airport. Further, the participants conducted a site visit to a domestic fresh-cut flower grower in Kentucky. Finally, the agriscience teachers had hands-on experiences with scientists at Clemson University and FloraLife Inc. research facility while in South Carolina to help them understand ways to address disease and post-harvest-related practices. Throughout each site visit, we highlighted relevant STEM concepts and required participants to reflect on their growth in STEM knowledge at the end of each day.

In this study, we utilized Q methodology (Brown, 1980). Q methodology aims to uncover participants' comprehensive patterns of thought (Brown, 1980). To achieve this, researchers correlate participants' sorted statements using factor analysis to reduce the data into factor arrays. These arrays are then interpreted using naturalistic methods to reveal different viewpoints on a given phenomenon (Watts & Stenner, 2013).

A fundamental principle of Q methodology is concourse theory, which reflects the full range of participants' opinions expressed through statements (Watts & Stenner, 2013). To build this concourse, we analyzed written reflective statements collected from previous cohorts of this PD experience and relevant academic literature. This process resulted in 189 initial statements. Using Ajzen's (1991) TPB, we then categorized the statements into three belief systems: (a) behavioral, (b) normative, and (c) control, which helped us sample 36 statements to use for this study, creating a Q-Set of 36 statements. Data were collected from the participants (*N* =16) in July 2024 on the final evening of a domestic travel PD experience. The agriscience teachers sorted the 36 sampled statements onto a quasi-normal distribution curve, ranging from -4 to +4. The full Q-Set of statements can be accessed as an instrument appendix for this article.

Findings

Using PQ Method® version 2.35 (Schmolck, 2014), three statistical analyses were conducted: (a) correlation, (b) principal components factor analysis, and (c) factor score calculations. A Varimax rotation was applied to obtain a simple structure, and we chose a three-factor solution with a significance threshold of .42. This solution accounted for all 16 agriscience teachers and explained 67% of the total variance, with minimal correlations between factors. To interpret the factors, we followed Mauldin's (2012) guidelines, examining array positions, distinctive and consensus statements, factor loadings, teachers' personal and professional backgrounds, as well as their written reflections after the sorting process. Table 1 provides a factor matrix with participants' personal and professional characteristics.

Table 1

Factor Matrix with Participants' Personal and Professional Characteristics

P Number/ Gender	Age	Years Teaching	Ethnicity	Factor Loadings 1	2	3
1-female	39	19	White	0.64[a]	0.33	0.08
2-female	40	14	White	0.81[a]	0.27	0.01
3-female	36	12	White	0.80[a]	0.32	0.24
4-male	29	7	Black	0.82[a]	0.04	0.31
5-female	26	4	White	0.50[a]	0.03	0.38
6-male	28	5	White	0.79[a]	-0.01	0.34
7-female	65	18	White	0.84[a]	0.12	0.02
8-female	63	40	White	0.87[a]	0.13	0.27
9-male	29	1	White	0.73[a]	0.26	0.23
10-male	50	28	White	0.73[a]	0.17	0.26
11-female	32	7	White	0.65[a]	0.34	0.11
12-female	44	14	Native American	0.38	0.66[b]	0.23
13-female	41	11	White	-0.06	0.91[b]	0.03
14-female	42	17	White	0.32	0.09	0.54[c]
15-female	40	6	White	-0.03	0.16	0.88[c]
16-female	34	11	White	0.26	-0.07	0.49[c]

Note. P was the identifier for each participant. [a]Indicated a defining sort for Factor 1. [b]Indicated a defining sort for Factor 2. [c]Indicated a defining sort for Factor 3.

Our analysis produced three factors: (a) STEM Advocates, (b) STEM Illuminators, and (c) Illumination Attempters. The factors represent the agriscience teachers' beliefs about how their PD experience emphasized the importance of integrating STEM when teaching floriculture. In our descriptions of each factor, we provided data notations that reflected the array position, z-score, and theoretical category from Ajzen's (1991) TPB that the statement represented. Table 2 displays each item number from the Q-Set (see Appendix A), as well as the z-score and array position for each of the three factors. Finally, the theoretical category as aligned with the theoretical framework for each statement is also presented.

Table 2

Z-Scores and Array Positions of Each Statement By Factor and Theoretical Category

Item Number	Array Pos (F1)	Z (F1)	Array Pos (F2)	Z (F2)	Array Pos (F3)	Z (F3)	Theoretical Category
1	4	1.63	3	1.27	4	1.68	BB
2	3	1.27	3	1.27	2	0.79	BB
3	-4	-1.63	-3	-1.53	2	0.87	BB
4	-2	-1.12	-3	-1.45	-3	-1.38	BB
5	-1	-0.31	0	-0.13	1	0.64	BB
6	3	1.58	-2	-0.88	3	1.1	BB
7	4	1.71	-2	-0.88	2	1.05	BB
8	3	1.16	-1	-0.52	1	0.58	BB
9	2	0.72	-2	-0.57	-1	-0.28	BB
10	1	0.35	4	1.75	1	0.6	BB
11	0	0.07	3	1.27	0	0.03	BB
12	0	0.18	3	1.27	0	0.06	BB
13	2	0.84	0	0	-2	-1.03	NB
14	1	0.55	0	0	-1	-0.64	NB
15	2	0.77	4	1.75	4	1.61	NB
16	0	0.03	1	0.39	-3	-1.04	NB
17	1	0.51	2	1.05	-4	-1.95	NB
18	-2	-0.65	-3	-1.45	-2	-0.97	NB
19	-3	-1.51	-2	-0.57	-3	-1.44	NB
20	-2	-1.09	-1	-0.26	2	1.04	NB
21	0	-0.07	1	0.39	-1	-0.65	NB
22	-1	-0.18	1	0.39	-1	-0.2	NB
23	-1	-0.39	2	0.7	-2	-0.73	NB
24	-1	-0.34	1	0.39	-1	-0.45	NB
25	-4	-1.83	-4	-1.93	0	0.24	CB
26	-3	-1.24	-4	-1.84	-4	-1.77	CB
27	-2	-0.79	0	0.22	3	1.11	CB
28	3	1.35	0	0.26	3	1.2	CB
29	0	-0.13	0	-0.09	-2	-0.98	CB
30	-3	-1.47	2	0.61	-3	-1.45	CB
31	-1	-0.64	-3	-1.27	3	1.32	CB
32	2	0.97	-2	-0.61	0	0.21	CB
33	1	0.64	-1	-0.22	1	0.41	CB
34	0	0.01	1	0.35	1	0.41	CB
35	1	0.41	-1	-0.31	0	-0.19	CB
36	-3	-1.35	2	1.14	0	0.24	CB

Note. BB = Behavioral Beliefs; NB = Normative Beliefs; CB = Control Beliefs

Factor 1: STEM Advocates

The first factor, STEM Advocates, represented 11 agriscience teachers' views about how the PD influenced their beliefs about integrating STEM in the floriculture curriculum. It should be noted that all four male participants loaded significantly, purely because of this factor. Further, this factor was overwhelmingly influenced by individuals' behavioral beliefs. Overall, teachers displayed a philosophy to engage students, which was further supported through the program as the PD made them recognize that integrating STEM into floriculture content helps learners gain crucial critical thinking skills (Array Position = +3; Z = 1.58; Behavioral Belief). The STEM Advocates expressed that the PD experience encouraged them to champion the critical role of STEM when teaching floriculture, and that they saw the benefits in integrating STEM into the SBAE classroom. For example, the participants reported that the PD helped them understand how integrating STEM into the floriculture content may help future generations solve global issues and problems (Array Position = +4; z = 1.62; Behavioral Belief) while also assisting students to gain a better understanding of the world (Array Position = +3; z = 1.26; Behavioral Belief) and gain critical thinking skills that can prepare them for the future (Array Position = +3; z = 1.16; Behavioral Belief).

As a result of the PD experience, the STEM Advocates also maintained that illuminating STEM concepts in the floriculture curriculum could positively affect the relationship between educators and learners because the learning environment could become more engaging (Array Position = +4; z = 1.71; Behavioral Belief). Related to this, STEM Advocates were differentiated from other groups by agreeing that the PD helped them understand that leaders whose opinions they value will encourage them to improve their knowledge and skills in STEM integration to improve their teaching of floriculture content (Array Position = +1; Z = 0.55; Normative Belief).

Factor 2: STEM Illuminators

In the second factor, the STEM Illuminators expressed that the PD experience reinforced their belief that agriscience teachers needed to enhance their knowledge and skills in STEM to effectively teach floriculture in SBAE (Array Position = +4; z = 1.75; Normative Belief). It should be noted that both participants who loaded significantly and purely on this factor were female and had more than ten years of teaching experience. In particular, the STEM Illuminators revealed that the PD experience encouraged them to gain more technical knowledge in *technology* (Array Position = +4; z = 1.75; Behavioral Belief), *engineering* (Array Position = +3; z = 1.269; Behavioral Belief), and *mathematics* (Array Position = +3; z = 1.26; Behavioral Belief). Through this enhanced technical knowledge, the agriscience teachers perceived they could integrate STEM into the floriculture content more effectively.

The STEM Illuminators did not see many major barrier in integrating STEM into their curriculum as the PD brought to their attention that although financial challenges exist, STEM integration is still achievable (Array Position = +2; Z = 0.61; Control Belief); PD made them aware that integrating STEM concepts into floriculture is not as difficult as expected because students can be supported using simple strategies (Array Position = 0; Z = 0.22; Control Belief); and PD helped them recognize that integrating STEM into floriculture is easier because many concepts fit naturally into the curriculum (Array Position = 0; Z = 0.26; Control Belief).

Factor 3: Illumination Attempters

The final factor, Illumination Attempters, reflected the belief that integrating STEM into the floriculture curriculum should be encouraged because it could positively influence students, but not as enthusiastically as through the STEM Advocates factor. However, the PD experience helped these participants understand they needed more advanced knowledge and skills and greater support to achieve such aims. Of note, the three sorters who loaded significantly and purely on the final factor had considerable variability in teaching experience, ranging from six to 17 years of teaching experience.

The Illumination Attempters perceived that integrating STEM into floriculture content may help future generations solve global issues and problems (Array Position = +4; z = 1.675; Behavioral Belief) as well as gain key critical thinking skills (Array Position = +3; z = 1.102; Behavioral Belief). Despite this, the Illumination Attempters also reported that integrating STEM into floriculture was difficult because many learners are uncomfortable applying the concepts in the real world (Array Position = +3; z = 1.195: Control Beliefs). As a result, the Illumination Attempters believed they needed additional training and support to improve their STEM knowledge and skills to effectively teach floriculture (Array Position = +4; z = 1.611; Normative Belief). Illuminator Attempters see the value of STEM illumination; however, the PD did not increase their perception that integrating STEM is socially expected or valued in their environment (Array Position = –1 to –4 across multiple items; Normative Beliefs); and the PD made them realize that the people they work with, whose opinions matter to them, are unlikely to encourage STEM integration (Array Position = –2; Z = –1.03; Normative Belief).

Conclusions, Discussion, and Recommendations

Three factors emerged regarding agriscience teachers' beliefs on integrating STEM into the floriculture curriculum after a professional development (PD) experience: (a) STEM Advocates, (b) STEM Illuminators, and (c) Illumination Attempters. The majority (n = 11) identified as STEM Advocates, suggesting the PD positively influenced their behavioral beliefs (Ajzen, 1991) and self-efficacy to integrate STEM into floriculture content. These participants supported hands-on, engaging instruction but acknowledged gaps in their own STEM or technical agricultural knowledge. However, they reported feeling supported by stakeholders such as mentors, colleagues, and students, which reinforced their intent to continue seeking content-specific PD.

Originally McKim et al. (2017) presented only three categories of teachers related to science illumination: Vocational Purists, Science Illuminators, and Illumination Attempters. As Vocational Purists do not see the benefit of integrating science, and solely teach technical agricultural content, none of the participants in the PD program identified as a Vocational Purist. Interestingly, a fourth group, STEM Advocates, emerged from our research that was not proposed by McKim et al. (2017). Based on our findings, we categorized the majority of participants in this fourth group. STEM Advocates are differentiated by their self-efficacy or their ability to illuminate, which was not considered by McKim et al. (2017) in their original model because only science knowledge and motivation were considered as factors. We recommend with the discovery of a fourth group more research is needed to develop an updated philosophical model for science illumination to additionally categorize agriscience teachers as STEM Advocates. Future research should also focus on developing teachers' self-efficacy along with their science and agricultural content knowledge.

We recommend encouraging STEM Advocates to persist in integrating STEM, as it enhances student engagement and fosters critical thinking and problem-solving. As Ajzen (1991) and McKim et al. (2017) indicated, these individuals demonstrate strong intentions to implement change. We further recommend expanding McKim et al.'s (2017) typology to include a distinction between teachers who lack content knowledge but perceive high stakeholder support versus those who do not. Teachers may believe in their capacity, but their intention levels are likely to wane having perceived their environment as unsupportive.

Two mid-career participants, identified as STEM Illuminators, perceived the PD improved their STEM teaching by enhancing their content knowledge in technology, engineering, and mathematics. Consistent with Wang and Knobloch (2022), educators' content proficiency and understanding of industry practices are critical for effective STEM instruction. These teachers felt confident in their ability to adapt materials and noted support from their school communities. They viewed STEM illumination as feasible and beneficial without requiring significant additional effort. Their belief in the value of teaching STEM through agriculture distinguished them from vocational purists.

Three participants were categorized as Illumination Attempters. Although they believed in the value of integrating STEM to promote student success and global awareness, they expressed a clear need for additional training and support. Unlike STEM Advocates, they felt a lack of stakeholder support or awareness of STEM integration efforts. These teachers expressed realistic concerns about their knowledge depth and students' challenges in applying STEM concepts. As noted by Hendrix et al. (2020) and Scales et al. (2009), teachers often struggle to accurately assess their own content mastery.

We recommend that future PD target specific technical and pedagogical competencies to increase both STEM Illuminators and Illumination Attempters confidence and ability to teach floriculture through a STEM lens. Though Illumination Attempters could be misinterpreted as less optimistic, they may actually offer a more grounded view of what is needed to sustain meaningful STEM integration.

The PD experience successfully connected content, educators, and students (Roberts et al., 2020). We recommend Q methodology (Brown, 1980) as a valuable tool for uncovering nuanced belief patterns in similar contexts. Future research should explore students' perspectives on STEM integration in agriscience, which may further inform teacher support strategies (Ajzen, 1991). Additionally, studies that examine teaching practices—not just beliefs—can help determine whether PD influences actual classroom implementation. While STEM Advocates and Illumination Attempters agreed on the importance of STEM, their perceived behavioral control varied, suggesting that future research should investigate the link between belief, support, and practice.

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