

Preservice Educators' Beliefs and Practices of Teaching STEM through Agriculture, Food, and Natural Resources

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Abstract

Teaching integrative science, technology, engineering, and mathematics (STEM) is gradually moving into agriculture, food, and natural resources (AFNR) education. Numerous researchers have emphasized that educators' beliefs are at the heart of framing effective educational practices. Although integrated STEM teaching and learning literature is growing, little research has focused on how preservice educators' beliefs inform integrated STEM through AFNR practices. By conducting an interpretivist, multiple-case study, the purpose of this study was to explore how preservice educators' beliefs and practices of their integrated STEM through AFNR lesson plans and instruction. The preservice educators' beliefs of integrated STEM through AFNR lessons showed three stages of development: (1) preconceived stage, (2) broadened horizons stage, and (3) perceived reality stage. The findings revealed preservice educators have similar beliefs as science teachers in regard to learning outcomes when using integrated STEM approaches. Further, preservice educators designed integrated STEM lessons using AFNR content, in which they were most familiar. Finally, the perceived reality phase was the most challenging for preservice educators because they needed to transition their integrated STEM through AFNR views from being broad to how they could concretely facilitate meaningful integrated learning experiences for their students.

Keywords: STEM integration; beliefs and practices; interdisciplinary learning; informal/non-formal educators

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Introduction

Interests in integrated science, technology, engineering, and math (STEM) curriculum and instruction have increased rapidly crossing K-16 in the last 10 years (Bybee, 2010; NRC, 2014). Although research studies have investigated how to improve teaching and learning in STEM education, a majority of the studies focused on a single discipline (English, 2016; NRC, 2014). For

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example, in school-based, agricultural education (SBAE), the STEM acronym is often used to reference the integration of science and agriculture, but engineering and mathematics were rarely mentioned (Smith et al., 2015; Stubbs & Myers, 2015, 2016). In general, little attention has focused on STEM integration to enhance learning (Johnson, 2013), and more focus should be on the nature, scope and practices of integration as disciplines become more interconnected and interdependent (English, 2016). Integrated STEM has been ill-defined and has become a slogan that yields myriad of operational definitions and implementation models (Bybee, 2013; English, 2016; NRC, 2014; Scherer et al., 2019; Wang & Knobloch, 2018). Without a clear definition and model, integrated STEM is a moving target and teachers are challenged with understanding its purpose, value, and effective implementation. Furthermore, few researchers attempt to define integrated STEM in context such as agriculture, food, and natural resources (AFNR).

Educators' existing conceptions (based on epistemological beliefs) inform the design and implementation of integrated STEM lessons. Epistemological beliefs play an essential role in how one teaches (Woolfolk Hoy et al., 2006) and how one learns and interprets knowledge (Hofer, 2000; Schraw, 2013). Beliefs are informed by previous educational experiences (Pajares, 1992) and common assumptions one has about a discipline (Buehl & Alexander, 2002). After researchers develop an understanding of educators' beliefs about integrated learning, researchers would be able to understand better what constitutes quality integrated STEM through AFNR curriculum and instruction. Aligned with the American Association for Agricultural Education's Research Priority 3, (Stripling & Ricketts, 2016), understanding quality integrated STEM experiences and how educators implement integrated STEM learning experiences could help curriculum developers construct guidelines that could direct educators' practices. The research was conducted to answer the following questions: (1) What were the preservice educators' beliefs of integrated STEM teaching and learning through AFNR throughout the graduate-level, teaching methods course? (2) What were preservice educators' interpretations of the integrated STEM through AFNR teaching and learning process after developing and implementing integrated STEM through AFNR lessons?

Literature Review and Conceptual Framework

Beliefs and Their Influences on Instructional Practices

Educators' instructional practices are often guided by their personal beliefs, and educational beliefs can be inferred from instructional practices (Jones & Carter, 2007; Pajares, 1992; Wheatley, 2002). Teachers' beliefs play a large role in implementation and strategy choice when teaching a curriculum (Cronin-Jones, 1991; Luft et al., 2003; Lumpe et al., 2000; Pajares, 1992; Rice & Kitchel, 2018; Richardson, 1996). The relationship between teachers' beliefs and practices has shown complex results in the current literature. Researchers suggest that beliefs influence practices, and teachers' beliefs are predictive indicators of certain instructional practices, such as inquiry (Wilkins, 2008). Teachers' self-efficacy beliefs predict teaching practices in the classroom (Brown et al., 2012). However, other researchers found that the relationship between teacher beliefs and practices is misaligned or unequivocal (Lim & Chai, 2008; Liu, 2011). As such, teachers may hold learner-centered or constructivist beliefs, but their practices are inclined to more didactic teaching style (Lim & Chai, 2008; Liu, 2011).

Experienced teachers' beliefs are more consistent with their practices than preservice teachers (Basturkmen, 2012; Ogan-Bekiroglu & Akkoc, 2009). Teachers have at least two belief systems—central and peripheral. Central beliefs are both stated and enacted, but peripheral beliefs are stated but not enacted (Haney & McArthur, 2002). Moreover, the relationship between teachers' beliefs and practices is reciprocal but complex, and involves both internal factors (e.g., other beliefs,

experience, and knowledge) and external factors (e.g., class size, time, school culture and community; Buehl & Beck, 2014).

Core reflection (Korthagen & Vasalos, 2005) was chosen as a theoretical framework because experience engages preservice teachers to interrogate their beliefs, skills, and behaviors when they reflect on and make sense of their experiences in practical situations. Core reflection provides a process of structured reflection that aligns with experiential learning (Dewey, 1938; Kolb, 1984), and an onion model framework that provides the contents of reflection, promotes an awareness of one's professional identity, and integrates levels of context in an authentic manner (Korthagen & Vasalos, 2005). As such, core reflection helps educators identify their personal strengths and sources of motivation, which are activated by reflecting-in-action (Schön, 1987). Core reflection aligns with the context of the study because environmental expectations and pressures can play a role in how agricultural educators express their identities, epistemological beliefs and instructional practices (Roberts & Montgomery, 2017).

Educators' Beliefs on Integrated STEM

Many researchers and educators are intentionally using engineering design as the driver of integration to engage students in learning other contents, such as science and math (Bryan et al., 2016). Science teachers believed that engineering-based curriculum increases students' engagement for learning science content and using their problem-solving abilities (Kendall & Wendell, 2012), and that science, mathematics, and engineering are commonly used together to solve real-world problems (Wang et al., 2011).

Few researchers have studied how agricultural educators' beliefs inform integrated STEM education. Rice and Kitchel (2018) researched eight experienced high school agriculture teachers to explore their beliefs about teaching plant sciences. They found that teachers, in general, viewed agriculture as an applied science and plant sciences as a way to teach STEM in agriculture. Viewing agriculture as an applied science has influenced the integration of science content in the lessons, as well as the accountability to teaching science content in agriculture classes (Rice & Kitchel, 2018). Beliefs about the purpose of agricultural education influenced agricultural educators' pedagogical content knowledge, including "how much content they knew, how much content they felt they needed to know, what content they decided to teach, and how they decided to teach it" (Rice & Kitchel, 2018, p. 208). By systematically reviewing existing documents, such as the *STEM Career Cluster: Cluster Knowledge and Skill Statements* (Advance CTE, 2008) and NGSS (NGSS, 2013), Swafford (2018) illustrated an integrated STEM-AFNR education model. He concluded that STEM and AFNR education are naturally aligned, and STEM content and skills can be learned using STEM-based agricultural careers.

As the result, the STEM-AFNR model proposed by Swafford (2018) placed STEM education at the center of the SBAE's comprehensive, three-circle model (Croom, 2008). Swafford argued that STEM learning fits in the middle of the Venn diagram because it helps integrate AFNR learning. Next, Stubbs and Myers (2016) explored three SBAE teachers' perceptions of STEM integration, and found they believed that they continuously integrated science and technology in their teaching each day. However, the teachers had a narrow definition, using instructional technology in the classrooms, to represent technology as a content area domain. In addition, the agriculture teachers had incomplete definitions of engineering, and lacked explicit integration of engineering and mathematics in their classes (Stubbs & Myers, 2016). Science and mathematics teachers encountered similar challenges as agricultural educators in using engineering in their teaching (Gattie & Wicklein, 2007; Nathan et al., 2013).

Although agriculture teachers' beliefs regarding STEM have been studied (Baker et al., 2015; Stubbs & Myers, 2016), two studies were found that investigated preservice educators' epistemological beliefs regarding integrated STEM through AFNR. First, preservice teachers in agricultural education demonstrated a chasm between beliefs and behaviors—they embraced experientially based beliefs, yet reverted to didactic pedagogical beliefs they had witnessed as students (Roberts et al., 2016). Next, Roberts and Montgomery (2017) studied epistemological beliefs of agricultural educators and found that their epistemological beliefs helped inform their instructional identities. Additionally, Ryu and her colleagues (2018) found that science, technology and agriculture preservice teachers successfully developed and taught integrated STEM lessons despite the following challenges: (1) current school practices; (2) limited interdisciplinary understandings, and (3) lack of role models.

Research Methods

Qualitative Research Study and Participants

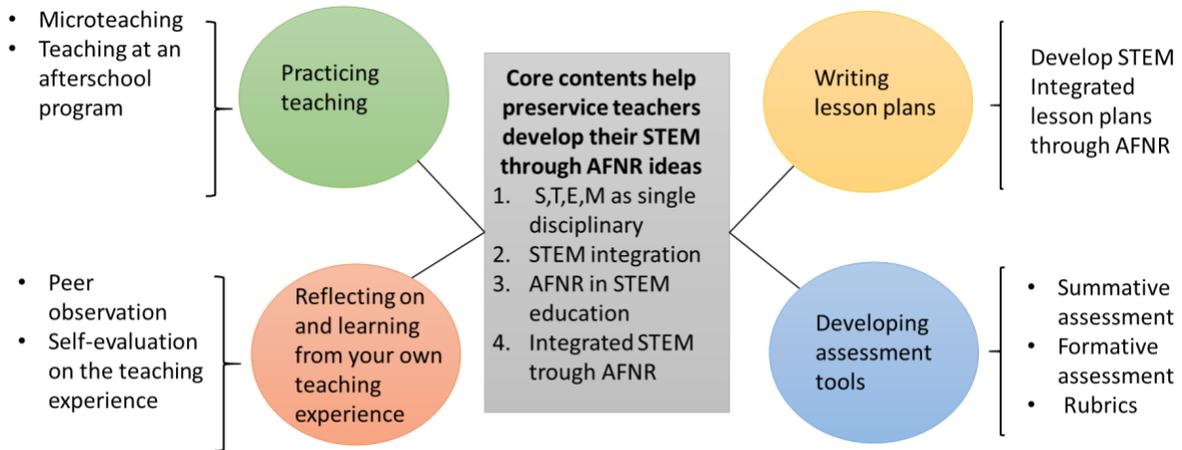
An interpretivist multiple case study design (Stake, 1995) was used to conduct an in-depth investigation of preservice educators' beliefs and instructional practices. Constructionism was chosen as a theoretical perspective because the purpose of the multiple case study research was to gain insights and understandings related to the phenomenon being studied in a specific context (Stake, 1995). Using constructionism, participants make meaning out of their interpretations of real-world experiences, and knowledge is constructed when people interact between each other and their world (Crotty, 1998). The research was conducted in a semester-long graduate-level course that was co-taught by two instructors, each representing STEM and AFNR. The lead researcher had a doctorate degree in science education with an emphasis on integrated STEM education. The other researcher had a doctorate degree in agricultural education and had previously taught a teaching methods course with an emphasis on learner-centered teaching strategies. Both were trained and experienced as qualitative researchers.

The course was a three-credit graduate level course that consisted of 3-hour weekly sessions for 15 weeks. The course was taught twice in a two-year period, and the data was collected in a two-year period as well. The instructors framed this innovative course as interdisciplinary learning (Ivanitskaya et al., 2002) for the development of integrated STEM through AFNR lessons. The course aimed to equip graduate students with the knowledge and skills to become youth educators. From week one to week four, students experienced the nature of S, T, E, M as single disciplines (Fig. 1). In addition, they explored their views of STEM integration, both individually and as groups by drawing concept maps. During week five and six, integrating AFNR into STEM was introduced to students. Different examples of STEM integration were shared in the course to generate discussion of the different characteristics of STEM integration through AFNR instruction. After sharing examples, students started to develop their big idea of integrated STEM through AFNR. Although the course was a teaching method course, instead of teaching specific methods, the instructors focused on different approaches to integration. The instructors introduced five teaching methods (i.e., learner-centered teaching, inquiry-based teaching, engineering design, modeling, and BSCS 5 E Instructional Model; Bybee et al., 2006), to students. These teaching methods were references for the course. Students were instructed that no one existing integrated model or teaching method was the best model or teaching method to teach integrated STEM through AFNR, which supported an openness to facilitate creative thinking using experiential learning strategies (Roberts et al., 2016). Students had freedom to develop their STEM integrated lesson plans by using what they believed would be the best integrated model and practices for teaching STEM through AFNR. Then, the course instructors introduced assessment in week seven to nine. From week 10 to week 13, students conducted a microteaching of their integrated STEM

through AFNR lessons that they developed, and then delivered their lessons in an informal educational setting. As for weeks 14 to 15, students reflected on their teaching experiences to modify their lesson plans and submitted the final lesson plans (Fig. 1).

Figure 1

The Structure of the Course



The graduate students, who took the course and interested in becoming youth educators in informal or non-formal education settings (e.g., Extension educators, non-profit outreach educators, industry field representatives), were the research participants. A total of nine students' data was collected and analyzed (Table 1).

Table 1

Participants' Teaching Experience and Subject Expertise

Name (Pseudonym)	Previous Teaching Experience	Subject Expertise
April	Formal agriculture licensure program	Animal science
Bill	Formal agriculture licensure program	Animal science
Pat	Formal elementary licensure program	Language and reading
Beth	Non-formal environmental education programs	Nature resources
Sarah	Non-formal environmental education programs	Nature reasources
Tina	Non-formal youth science programs	Plant and solar science
Kate	No teaching experience	Animal science
Qi	No teaching experience	Technology
Young	One summer camp	Multicultural education

Data Collection

Stake (1995) recommended observation, interview, and artifacts in qualitative case study research. As such, students' assignments served as artifacts of data sources (Fig. 1). These assignments included six reflections, lesson plans, an assessment plan, a post-teaching self-evaluation paper, and a statement to articulate the rationale of STEM integrated lesson plans. In addition to students' assignments, a post-course face-to-face semi-structured interview was conducted as well. Each interview was about 60 minutes in length. Example interview questions included "What previous learning experiences (as a youth, K-12 student, college student) helped shape how you think about teaching and learning, in general?" and "Did your experiences and your

identity inform how you planned, delivered and reflected on your integrated STEM lesson in the course?"

Data Analysis

Based on experience and reflection, the two instructors of the course also conducted the collection and analysis of data that worked for this case study (Stake, 1995). Guided by application of constructivism, the researchers conducted consolidation, reduction, and interpretation through the analyses of data (Merriam, 1998). Initial data coding was primarily done by the first author to establish consistency in identifying codes. The researcher used both in vivo and value (Saldaña, 2016) coding to conduct the first cycle coding. In vivo coding is "literal coding" (Saldaña, 2016, p. 105) to try to capture the actual language that was used by research subjects without losing the true meaning. For example, Sarah said in her interview, "like what I even remember from middle school and it's those lessons where our inquiry-based learning." The coding for this sentence was "inquiry-based learning." Value coding particularly uses to analyze "a participant's value, attitudes, and beliefs representing his or her perspectives" (Saldaña, 2016, p. 131). For example, Sarah also said in her interview, "You are using mathematics but to me like a sheet of numbers doesn't mean a whole lot. It's something when you put these trends on a graph you can see these things." The coding for this sentence was "mathematics is trends and patterns." After initially summarized the first cycle coding, the researcher used pattern coding (Saldaña, 2016), as the second cycle coding, to identify emergent theme categories for individual students. For example, six codes, inquiry-based learning, creating and experimenting, real-world problems, fun and exciting, don't want to lecture, and students use knowledge that teacher teach, emerged from Sarah's interview when she talked about effective teaching strategies by reflecting on her own past learning experience. The pattern code that represented all six codes to describe Sarah's beliefs about effective teachings method was learning by doing. After the researcher summarized the first cycle codes and identified the categories from the second cycle coding for individual participants, the second author conducted independent coding and compared first author's analytic memos and codebook for intercoder agreement. Upon independent review, the second rater, reviewed the data sources and first coder's analytical notes. The second rater compared his analytical notes to the first coder's analytical notes. There were no major discrepancies and minor language differences were reconciled between the two raters. Regarding disagreements, the two researchers engaged in peer debriefing until consensus was reached for discrepancies of codes, and description of each feature. By the end of the second cycle coding, each participant had a concept map that represents their beliefs and practices in different theme categories.

The last cycle data analysis was transferring the emergent categories into a cross-case thematic/conceptual model (Saldaña, 2016). At this stage, the two researchers carefully examined all the theme categories and pattern codes from individual concept maps. The researchers discussed the discrepancies and reached consensus to infer categories from individual to cross-case thematic models. After cross-case thematic models emerged, the researchers took one step further to systematically arrange the cross-case theme categories based on timeline (such as reflection one vs. reflection five), interrelated concepts (such as learning by doing and hands-on activity), principles that were used (such as STEM structure and teaching theories), and practices (such as lesson design and teaching self-evaluation). Using these analytical strategies, the researchers conducted data source triangulation with each case, methodological triangulation across the cases, investigator triangulation through peer debriefing, and theory triangulation for data validation by addressing questions suggested by Stake (1995, p. 107), such as "Do we have it right? Are we generating a comprehensive and accurate description of the case? Are we developing the interpretations we want?" As such, the researchers followed the analytic protocol to reach the most credible interpretation and knowledge about each case.

Results

There were three stages emerged from the cross-case analysis: (1) preconceived; (2) broaden horizons; and (3) perceive reality. Two categories—learning-by-doing and initial beliefs of integrated STEM through AFNR were associated with the preconceived stage. Three categories—centering on problem-solving, purpose and expected learning outcomes, and engineering design process were related to the broaden horizons stage. Three categories—defining STEM integration through AFNR, designing integrated STEM through AFNR lessons, and process of designing integrated STEM through AFNR lessons, involved the perceive reality stage. In each category, we provided selected quotes to support assertions that we made in the results.

Preconceived Stage

Learning by Doing

Almost without exception, all participants regardless of their teaching experiences, conveyed strong support of learning by doing to engage students' learning. Many of them traced back to their 4-H memories when they pointed out that experiences played an important role in terms of learning (April, Pat, Bill, and Kate; interview). Moreover, other participants shared the best way of learning was by doing through their AFNR undergraduate majors. They described one of the advantages of studying in a college of agriculture was that learning by doing was built in the curricula (Sarah, Tina, Beth, and Bill; interview).

Some participants recalled their middle and high school experiences that they were “frequently bored” if they just sat still to listen to instruction. They always felt excited and engaged when teachers had them “do” some hands-on activities (Sarah, Bill, and Young; interview). Some participants used the word “fun” to describe how the hands-on activity engaged students. In the integrated STEM through AFNR lessons developed by the preservice educators, they described the “fun” components (e.g., making ice cream, designing a bee garden or an animal husbandry for cattle, or mimicking grocery shopping to make a healthy purchasing decision; Bill, Pat, Kate, and Young; lessons and lesson rationale), to engage students. Some participants described that hands-on activities cannot only be just “fun,” but also provided “challenges” to students. Students learn more when they are challenged (Qi and Tina; interview). When students feel they are challenged, the to-be-learned content knowledge sticks with them longer even after they graduated from school (Bill and Beth; interview). Students need to be challenged so they do not feel that learning is boring (Bill, Beth, Qi, Sarah, Tina; lesson rationale and interview). In addition, some participants described how they used “everyday items” that can be found in students' everyday life, such as food, dogs, salt and pepper, or bees and gardens (Tina, Qi, April, Young, and Pat; lessons and lesson rationale), to engage their learning. Some participants believed when learning is relevant to students, they cared more about what they need to learn (Qi and Beth; interview), especially if they needed to apply what they learned to solve real-world problems through hands-on activities (Sarah and Beth; interview).

Defining STEM Integration through AFNR

Before the course, one participant indicated that she had some previous STEM integration in agricultural teaching experience when she was watching her mentor teach a class (Pat; interview). Another participant mentioned that she took an integrated physics and chemistry course in high school and that was the only learning experience she had close to STEM integration (April; interview). The other seven participants had no STEM integration through AFNR learning and teaching experiences. Some participants suggested that STEM appeared in AFNR courses that they

took, such as anatomy, wildlife management, and agronomy, but their instructors did not explicitly talk about how STEM were integrated in these subjects. Because STEM were never explicitly mentioned by the instructors, they did not see STEM, even though STEM were there (Kate, April, Sarah, and Tina; interview). Therefore, some participants believed that integrated STEM through AFNR is a non-traditional way to teach STEM subjects (Beth and April; interview) because it helps students see interdisciplinary connections.

Before the course, many participants believed that integrated STEM through AFNR meant that they have to integrate as many STEM subjects/concepts as possible into AFNR. As represented in the following remarks from the participants: “We’re just gonna have science in this, and technology in this, and this and this, and math in this... (Bill; interview),” “Oh, it’s like the STEM integration just involved the concept from the STEM disciplinary (Young; interview),” “You know my visions were scrambled. I think my visions were, you know, throwing in some science, throwing in some math and maybe some engineering, and so on (Qi; interview),” and “Before taking the course, I thought it was just incorporating one letter piece of STEM into your lesson plan and moving on. That’s how we were taught before (April; interview).” In addition, when asked if there is a best way to do STEM integration through AFNR in week 3 (at early stage of the course), almost all participants pointed out that transdisciplinary (Vasquez et al., 2013) is the best model of doing STEM integration through AFNR (Tina, Becca, Abby, Young, Qi, and Bill; second reflection).

Broaden Horizons Stage

Centering on Problem Solving

Almost without exception, all participants shared that problem solving is the core of their integrated STEM through AFNR lessons. Some participants even suggested that integrated STEM through AFNR is a “full cycle” of problem solving (Qi, April, Sarah, Young; interview and lesson rationale).

Purpose and Expected Learning Outcomes

Many participants believed that learning content knowledge was the main purpose of doing STEM integration through AFNR. The to-be-learned content knowledge could be either STEM or AFNR, or both. For example, Bill shared in his interview, “In my personal opinion, I feel that STEM [integration] obviously... I really feel like they are a tool that’s utilized to teach the content.” Tina said, “You have to lay the foundation of content knowledge first.” Beth explained why she adds abandon content knowledge in her lessons, she said, “Yes. I think it [content knowledge] is important. They [students] need that [content knowledge] to solve problems.” Young wrote in her last reflection, “The ultimate goal of incorporating STEM [integration] is to solve problems in AFNR with knowledge from STEM.” These quotes showed that content knowledge is the foundation that needs to be taught before educators could use integrated STEM through AFNR instruction.

Evidently, from the quotes above, learning content knowledge is about solving problems. To some participants, one of the learning outcomes was to help students see the interdisciplinary connections when students try to solve problems. In her last reflection, Kate wrote, “Students need to see the interrelated concepts and how the ‘gears’ of each area works as a system, not individually as it may initially appear.” Bill also discussed the similar idea in his interview when he explained how he developed the lessons, he stated, “We [my partner and I] really wanted them [students] to understand that everyday household items that they see actually come from animals. They [students] didn’t set foot on a farm. They did not see these [STEM and AFNR] connections.” In addition,

applying learning to real life was another learning outcome. To many participants, applying content knowledge to solve a real-world problem was the reason why they used integrated STEM through AFNR instruction. Beth stated, "So, being able to make learning [content knowledge] a more connected experience and a more applicable experience, more practical, I figured that we would learn how to integrate each part of STEM." Qi explained her lesson plan design by saying, "What we used was to get them [students] to start to look at problems and to understand that you can apply a process to solve that problem...to the point where it [a complex problem] becomes very relatable to AFNR." Bill summarized his thoughts in his last reflection. He wrote, "Everyone eats something, lives somewhere and wears something...learning STEM can be boring when they are taught alone, but when we are able to bring them together to utilize in real-life problems, it can make learning more meaningful." Young also wrote a similar comment in her last reflection, "The purpose of integration AFNR and STEM is to apply knowledge with sets of skills to solve real-life problems. AFNR provides a context/content to do that."

In addition to content learning, most of the participants also talked about skill sets (aka, soft skills) in their interview and/or reflections as the previous quote from Young. Many soft skills had been named, such as critical thinking to make decisions (April, Tina, Sarah, Young, and Pat; interview and reflections), teamwork (Bill, April, Tina, Qi, and Kate; interview, lesson rationale, and reflections), communication (Beth, Sarah, and Kate; interview and reflections), and learn from failure experience (Bill; interview). When these essential skills were mentioned, they were all associated with problem solving. However, the researchers were not able to determine from the data if the development of essential skills was an expected learning outcome. Therefore, the researchers decided essential skills could be a by-product when placing problem solving as a core learning outcome in integrated STEM through AFNR lessons.

Engineering Design Process

Engineering was identified as the most challenging subject to integrate by many participants (April, Beth, Pat, Young, Kate, Tina; interview). For example, Pat explained how the course helped her to think about STEM integration, she said, "My kind of favorite thing was looking at engineering...you don't have to be building something...was really beneficial for me, because I don't really know a ton about engineering." Young wrote in her first reflection, "I feel that some subjects are easy to incorporate with, but other subjects are more difficult. I think math is kind of 'easy' subject to be integrated into various disciplines while engineering is more difficult to be incorporated."

Many participants believed that engineering design process conveyed problem solving in integrated STEM through AFNR. For example, Qi said, "We use the engineering design process to get the children thinking about critical thinking, problem solving and planning...you know, thinking about how you're going to solve this problem." Tina stated, "We kind of led them [students] through the engineering and design process where they were given a problem. They [students] were given a problem to design a dog food." Bill explained how engineering design process helped problem solving, he wrote, "Our students are given a client to create each by-product and then are asked to do it again...kind of take them [students] through the steps of how we start with animals and how we get to the end product." In addition, engineering design is an integrator that build up other STEM concepts and bring in real-life aspects to learning (Pat, Tina, Bill, April, Young, and Qi; interview, lesson rationale, and reflections).

Perceive Reality Stage

Defining STEM Integration through AFNR

After the course, participants expanded their views of STEM integration. Some participants said that STEM is in everything [AFNR], but educators need to make an explicit connection about STEM so their students can see it (Tina, Kate, Beth and April; interview). In addition, STEM integration through AFNR is not about quantity, but quality of STEM subjects that educators can integrate. April wrote in her last reflection, "STEM integration doesn't necessarily mean incorporating all of the four letters into one." Pat shared in her interview, "To make it [STEM] integrated, even if you're only doing two or three of the letters here, it is tough to really make each portion shine and make them all blend." Bill said, "It's okay if you use two different...use math and engineering in one. And really taking it step down and being able to build from lessons to kind of work your way up." Beth claimed, "It's about how you teach, not just what you teach. And it's about what other people are teaching, like if you're working with other teachers to make it a holistic curriculum. That's really the breadth of knowledge of STEM." In her last reflection Young wrote, "My initial thought was trying to bring in all four components in each lesson plan. This made the lesson kind of 'busy' and out of focus. I learned that it is not quantity, but quality of connection matters." In her lesson rationale, Sarah wrote, "I think that if you choose to integrate science, technology, engineering, and mathematics equally, it can make a lesson feel forced or artificial and be hard to create authentic inquiry-based learning." In the perceive reality stage, each letter, S, T, E, and M, played different roles in the integrated STEM through AFNR lessons. Overall, engineering (E) closely connected with problem solving as described above. Mathematics (M) was a tool and existing skills to do budget and some basic calculation (Tina, April, Beth, Bill, and Young; lessons and interview), and graphing and statistics, such as standard division (Sarah; lessons and lesson rationale). Science (S) was the content knowledge that students needed to learn and apply to solve problems (Beth, Young, Kate, Pat, Tina; interview, and lesson rationale). In addition, science is also scientific process to do inquiry (Sarah, Pat, and Beth; interview and lesson rationale). Only Bill distinguished that science also is AFNR content (Bill, lesson rationale). Technology (T) was the digital devices that were used in the lessons, such as Internet, computers, and videos (Tina, Beth, Sarah, Young, Bill, and April; lessons, lesson rationale, and interview). As for AFNR, although at the end of the course, all the participants agreed that AFNR could be both content and context in integrated STEM through AFNR, from the lessons that participants had developed, however, it seemed to researchers that participants demonstrated AFNR could only play one role, either content or context. For example, Tina said in her interview, "AFNR as context... to help make connections, real-world connection, in our lessons." Bill explained the role of AFNR in his lessons by saying, "AFNR is the content, the by-products, that students need to understand. Students need to see the connection that these by-products come from animals."

Designing Integrated STEM through AFNR Lessons

All the participants designed their integrated STEM through AFNR lessons based on the concepts that they felt the most comfortable to teach. For example, Sarah was studying applied ecology, and the lessons that she designed were about wildlife management and clear-cutting forests issues. Kate was in a pre-veterinary program and had animal science degree. Her lessons were about designing an animal housing. Bill also had a degree in animal science. His lessons were about animal by-products. As for participants who did not have AFNR background, they picked the AFNR concepts that they most familiar with to design their lessons. For example, Young taught one summer camp about nutrition to high school students. When she worked with Beth to design their integrated STEM through AFNR lessons, she added the components of nutrition into the lessons. Pat taught a bee lesson when she was student teaching. She developed her integrated STEM through AFNR lessons based on the bee lesson that she taught before. In addition, in the beginning of the course, although most of the participants believed that transdisciplinary (Vasquez, et al. 2013) was the best model to teach STEM through AFNR, at the end of course, they all felt that their

integrated STEM through AFNR lessons were either interdisciplinary (April, Qi, Beth, Sarah, and Tina; lessons and lesson rationale, and interview) or multidisciplinary (Bill; lessons and lesson rationale), or both models (Pat, Kate, and Young; lessons and lesson rationale, and interview) (Vasquez, et al., 2013). No participants believed that their integrated STEM through AFNR lessons reached the transdisciplinary level.

Process of Designing Integrated STEM through AFNR Lessons

To most participants, the first step to develop their lessons was to identify the content knowledge that they wanted to teach. As Tina said in the interview, “First, we [me and my partner] talked about an area of interest like what would the students be interested in learning and what would we be interested in teaching, finding an area of content in interest.” Pat wrote in her lesson rationale, “I thought of the main concepts I wanted to address...incorporating the STEM components was done through some background knowledge of teaching...” Sarah and Kate also shared the idea of developing the lessons based on something that interesting to instructors. Sarah said, “So, I just don’t find chemistry to be interesting so I wouldn’t be good at trying to get other people excited about it...I have the ecology knowledge, because that’s what I’m excited about.” In her lesson rationale, Kate wrote, “When developing this lesson, I attempted to take into consideration the many components of not only my areas of interests, but also interests of my target audiences. Being passionate about agriculture, I knew I wanted to incorporate aspects of agriculture.”

On the contrary, some participants already had an idea for their lesson plans that they wanted to use, and they added STEM and/or AFNR components into the lessons. For example, April said in her interview, “I mean we randomly found this [lesson]. Finding that activity first I think helped us like, ‘Oh, we can easily incorporate all of this [integrated STEM through AFNR] into it.’ We almost worked backwards when we planned.”

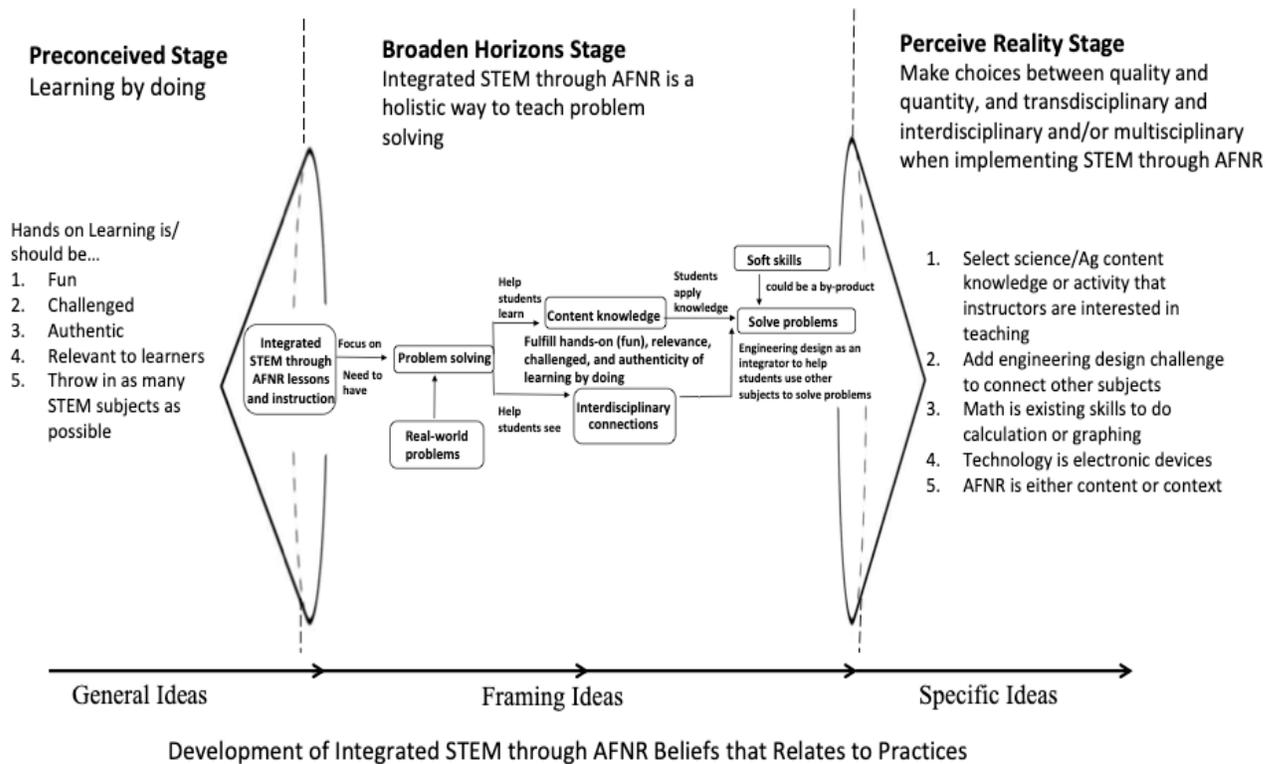
Conclusions

The participants’ beliefs of integrated STEM through AFNR lessons showed three stages of development—preconceived stage, broaden horizons stage, and perceive reality stage (Fig. 2). Preservice educators went through a planning process that evolved from having general ideas to framing their ideas to be an integrated lesson that blended different disciplinary content to being a specific idea for STEM integration. This conclusion aligned with a previous study conducted by Ryu and her colleagues (2018) recommended, “it important to consider an incremental approach with small changes to gradually mitigate the challenges preservice teachers experienced in designing and implementing integrated STEM lessons” (p. 510).

In the preconceived stage, based on their personal learning experiences, the preservice educators had general ideas of integrated STEM teaching and learning through AFNR, which supported Stubbs and Myers’ (2016) findings that agriculture teachers had limited and simplistic understandings of STEM integration. Participants believed integrated STEM through AFNR should be hands-on (fun), challenging, authentic, and relevant to learners, which aligned with principles of experiential learning (Knobloch, 2003). In terms of the concept of integration, the participants were general ideas and believed that they needed to “add” as many STEM subjects as possible when use integrated STEM through AFNR lessons and instructions. In other words, quantity of STEM subjects played an important brainstorming idea than quality of integrated learning at this stage.

Figure 2

Three Stage of Preservice Educators' Beliefs of Integrated STEM through AFNR Lessons and Instruction



In the broaden horizons stage, the preservice educators started to see STEM is everywhere in AFNR. Preservice educators believed that integrated STEM through AFNR was a nontraditional teaching strategy and a holistic way to teach problem solving. The concept of learning by doing, from the preconceived stage, was not discarded, but evolved to a more purposeful and intentional integrated learning strategy. When integrated STEM through AFNR focused on problem solving, the preservice educators could fulfill the elements of fun, relevance, challenged, and authenticity for learning by doing. At this stage, the preservice educators considered many possibilities as they planned their lessons, but they transitioned their thinking to framing ideas for integrated learning. They did this by focusing on problem solving that were based on real-world problems that would help students: (1) learn content knowledge; (2) see interdisciplinary connections; (3) apply knowledge that would help students solve problems; and, likely result in essential skills (Knobloch et al., 2020; Scherer, et al., 2019; Wang & Knobloch, 2018). At this stage, engineering design played a role as an integrator to help students see interdisciplinary connections and apply knowledge to solve problems. The preservice educators evolved to seeing AFNR content connections to STEM and how STEM could be used to help their students solve problems holistically, which supported interdisciplinary learning (Knobloch et al., 2020). However, their ideas were too large for the amount of time they were given to plan for their STEM lessons, which lead them to adjust in fine-tuning their lessons.

In the perceive reality stage, the preservice educators realized that they could not integrate everything (after they saw STEM was everywhere in AFNR) into their integrated lessons. They structured their integrated STEM lessons based on the learning outcomes and specific ideas as they transitioned from the broaden horizons stage. Consequently, each STEM subject and AFNR played

specific roles. Science was the content knowledge that students needed to learn and apply to solve problems. Mathematics was the existing knowledge and skills (as tools) that students should use to solve problems. Technology was the electronic devices (also could be considered as tools) that students used to solve problems. Engineering was the integrator to bring science, mathematics, and technology together to solve design problems. AFNR was either content (as science) or context to provide real-world problems, which had a similar function as engineering. Overall, the preservice educators at this stage started to think ways of meaningfully integrate STEM and AFNR content and/or context, but not tried to integrate every STEM subject into their lessons. They realized the limitation of their integrated STEM through AFNR lessons. They believed, even if they used AFNR real-world challenges, they did not reach the level of transdisciplinary STEM integration (Vasquez et al., 2013), which was primarily explained by the limited amount of time they had for their lessons. In other words, to achieve the desired learning outcomes, helping students learn and apply content knowledge to solve problems, and/or helping students see interdisciplinary connections, meaningfully integrated each STEM subjects dominated this stage.

Discussion, Implications, and Recommendations

The development of preservice educators' beliefs and practices regarding integrated STEM through AFNR added to the knowledge base in three ways. First, although the preservice educators from AFNR majors had general ideas at the preconceived stage (Stubbs & Myers, 2016), and how they perceived integrated STEM through AFNR at the broaden horizons stage was similar to science teachers' and school-based agriculture teachers' beliefs (Gattie & Wicklein, 2007; Nathan et al., 2013). As both science and school-based agriculture teachers, preservice educators also identified engineering as the most difficult subject to integrated in their lessons (Guzey et al., 2017). Therefore, we suggest teacher educators plan professional development programs to purposefully teach and facilitate discussions about the role that engineering plays in integrated STEM through AFNR lessons and instruction. Interestingly, another resemblance was that both preservice agricultural educators and science teachers believed they have to teach the to-be-learned science (or agriculture) content first, which aligned with a deductive, behaviorist approach to teaching (Lim & Chai, 2008; Liu, 2011). After students have a good grasp of the content, engineering design challenges acts as an integrator to set up a stage for problem solving, and connect what students learned with real-world application (Crotty et al., 2017; Guzey, et al., 2017). We learned both science teachers and preservice educators have similar expected learning outcomes, which included: (1) helping students learn and apply content knowledge to solve problems (Rice & Kitchel, 2018); and, (2) helping students see interdisciplinary connections for their integrated STEM through AFNR instruction (Swafford, 2018). Evidently, integrated STEM through AFNR has limited definition and description in the literature, but integrative approaches are gradually moving into AFNR education (Scherer, et al., 2019) and curriculum developers for SBAE should consider learning outcomes to be more inclusive of STEM learning. These two learning outcomes may represent a comprehensive view of integrated STEM through AFNR, and help provide focus (and purpose) for professional development programs. Identifying concepts, processes, and outcomes in professional development programs could help both preservice and inservice teachers structure instruction to achieve learning outcomes and provide seamless integrated learning experiences.

Second, preservice educators designed integrated STEM lessons using AFNR content, in which they were most familiar. This finding aligns with three theories: (1) the role teachers' beliefs (personal & epistemological) play in how one teaches (Cronin-Jones, 1991; Luft et al., 2003; Lumpe et al., 2000; Pajares, 1992; Rice & Kitchel, 2018; Richardson, 1996; Woolfolk Hoy et al., 2006) and reflected in the common assumptions about a discipline (Buehl & Alexander, 2002); (2) Bandura's (1997) assertion that mastery experiences help teachers feel more confident in their abilities to teach (Brown et al., 2012; Ryu et al., 2018); and, (3) the role prior learning experiences

(Pajares, 1992) informed instructional planning, which supported Lortie's (1975) apprenticeship of observation. Preservice educators' prior learning experiences informed their pedagogical beliefs that students should be engaged to learn by doing, especially through hands-on activities and solving problems, which supported the principles of experiential learning. Preservice educators identified several learning theories that their beliefs were aligned with, including engineering design, inquiry-based learning, the BSCS 5E Instructional Model; and, the ARCS Model. All of these theories focus on engaging students to apply content and solve problems; however, experiential learning and inquiry-based learning are most commonly cited principles of teaching and learning in agricultural education (Baker et al., 2012; Knobloch, 2003; Parr & Edwards, 2004; Roberts, 2006) to support the notion of "hands-on" learning.

Teacher educators should encourage preservice and inservice teachers to explore ways to teach STEM in the context of AFNR by starting with topics they are familiar with and consider ways to make connections among the content areas. Moreover, teacher educators should consider a developmental process described in Figure 2 to help preservice teachers to transitions through the three stages: (1) Preconceived Stage – overview of agricultural education, how students learn, and learner-centered teaching strategies; (2) Broaden Horizons Stage – levels of integration (Exploring, Developing & Advancing; Wang & Knobloch, 2018), ways of knowing for S, T/E and M and examples of instructional activities to demonstrate scientific inquiry, engineering design, and mathematical modeling; and, (3) Perceived Reality Stage – multiple examples of AFNR integrated learning activities, analyze and critique lesson plans using integrated STEM rubric (Wang & Knobloch, 2018). These strategies reflect how the course (described in the methods section) has been revised.

Teacher educators should also assist single content area teachers perceive the reality when using integrated STEM through AFNR approaches. For example, time constraints are common limitations teachers face in when integrated AFNR in education (Knobloch et al., 2007). The preservice educators in our study overestimated their abilities by trying to create transdisciplinary integrated STEM lessons. Although this can be done, they could see the value of multidisciplinary and interdisciplinary lessons because of the level of their students' engagement in solving relevant problems (Wang & Knobloch, 2018). In addition, both multidisciplinary and interdisciplinary also could connect content areas that are traditionally learned independently, but could be learned interdependently (Galt et al., 2013; Hilimire, 2016). Our results indicated that in the beginning stage, educators might consider transdisciplinary (Vasquez et al., 2013) as the best way to do STEM integration through AFNR. Yet, at the end, teaching less does not mean educators cannot provide students with rich learning experience (Sadegholvad et al., 2017). In addition, preservice educators realized that transdisciplinary learning does not mean it is the best way to do STEM integration through AFNR, but different levels can accomplish desired learning outcomes. A continuum of disciplinary content mixing (i.e., multidisciplinary, interdisciplinary, transdisciplinary; Vasquez et al., 2013) can be used to help preservice educators see how the interplay of disciplines can be blurred to the point that disciplines lose their individual identities and become mixed by solving complex problems. Transdisciplinary solutions are an amalgamation of different disciplines, which can result in a new form of knowledge, understanding, and complex problem-solving (e.g., systems thinking, evidence-based decision-making).

Finally, preservice educators were able to illustrate differences in how they were able to develop integrated STEM lessons, yet they streamlined their lessons in the perceive reality phase by clearly identifying targeted outcomes, considering quality versus quantity of learning S-T-E-M, and identifying an appropriate level of integration for the time allotted for the lessons. The perceive reality phase was most challenging for preservice educators. This was partly because of the challenging nature of instructional planning (Ball et al., 2007), but was magnified by the nature and

scope of considering the ways up to four different content areas (S-T-E-M) would be present and play a role in helping K-12 students to meet the learning objectives of the lessons (Wang & Knobloch, 2018). The participants in this study acknowledged a more inclusive nature of STEM in AFNR, which was in contrast to other studies that found the integration of science in AFNR would address the need for integrated STEM through AFNR (Baker et al., 2015; Stubbs & Myers, 2016). Moreover, preservice educators unpacked the complexity of their lessons by considering the integration of AFNR with S, T, E and M separately. Although this seems counter-intuitive to integrated thinking, it helped preservice educators systematically process the role each content area played in the lesson, and then they were able to think about the integrated nature of the entire lesson by identifying if the lesson engaged students in multidisciplinary, interdisciplinary, or transdisciplinary thinking (Vasquez et al., 2013). Teacher educators and curriculum development specialists should explore and identify essential skills (e.g., problem-solving & collaboration) that could be a result of integrated STEM learning experiences.

Limitations

This study was limited in four ways. First, some preservice educators had difficulty understanding the differences of levels of integration, and therefore, were limited in the extent they were able to describe their interpretations of STEM integration through AFNR. Future research studies should continue to follow-up with preservice educators after they are able to develop a better understanding of learning theories and levels of STEM integration through professional teaching experiences (Brandstädter et al., 2012; Roychoudhury et al., 2017). Second, preservice educators may have responses accordingly to their instructors' expectations. Although numerous attempts to encourage preservice educators to develop their own views, ideas and lessons, educators' beliefs and practices should be studied in their professional contexts where they implement integrated STEM lessons based on their professional autonomy. In addition, because nonformal educational settings where preservice educators taught their lessons are less formal, future studies should consider the role environmental expectations (e.g., SBAE) may provide affordances and hindrances to implementing integrated lessons. Third, integrated STEM learning may change the way in which individuals teach, in general. Although this study did not study cause-effect outcomes, future studies should continue to explore the impact integrated STEM lessons through AFNR have on various academic and career outcomes. Finally, the balance of single discipline-based learning compared to multidisciplinary, interdisciplinary and transdisciplinary is unclear. Future studies should focus on the extent learning experiences should be structured and focused around core disciplinary concepts in a single discipline versus applying core disciplinary concepts through blended interdisciplinary or transdisciplinary learning experiences.

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