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Making Sense of the Buzz: A Systematic Review of "STEM" in Agriculture, Food, and Natural Resources Education Literature

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Abstract

The world demands individuals with knowledge and skills in agriculture, food, and natural resources (AFNR) paired with proficiency in science, technology, engineering, and mathematics (STEM) concepts. Current models for STEM education call for interdisciplinary approaches in which learners address real-world challenges, indicating high potential for collaboration with researchers and practitioners in AFNR. The purpose of this study was to articulate the state of the 2010-2017 literature for STEM in AFNR education to inform future research, innovations in practice, and interdisciplinary collaborations. Using a systematic review approach and qualitative analysis techniques, 52 peer-reviewed STEM in AFNR education articles were analyzed for general characteristics, instructional approaches, STEM subjects, relationship between STEM subjects, relationship between STEM and AFNR, justifications, foci, and operationalization of STEM in research. Within each category, we identified themes that resulted in a summary of STEM in AFNR education in which future research and practice could align. Results indicated STEM in AFNR serves a range of populations, science and math are well represented, engineering is poorly represented, and mechanisms through which STEM learning occurs are often inadequately described. We recommend a collaborative and interdisciplinary future for STEM and AFNR education because both communities are pursuing common aims.

Keywords: agriculture; education; engineering; mathematics; science; STEM; technology

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Introduction

Once again, the education community has embraced a slogan without really taking the time to clarify what the term might mean when applied beyond a general label. When most individuals use the term STEM, they mean whatever they meant in the past. So STEM is usually interpreted to

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mean science or math. Seldom does it refer to technology or engineering, and this is an issue that must be remedied. (Bybee, 2010, p. 30)

The United States is facing a shortfall in people trained in the science, technology, engineering, and mathematics (STEM) fields (Maltese & Tai, 2011; National Academy of Engineering [NAE] & National Research Council [NRC], 2014). Progress and prosperity within the United States, as well as its global competitiveness, cannot remain strong if young people are not STEM-literate and well prepared to enter the workforce of STEM professionals. With changes in technology and advancements in agriculture, STEM-literacy is increasingly important in the 21st century to help agriculture producers make informed decisions and attract more youth to careers in agriculture, food, and natural resources (AFNR). However, what does STEM-literate mean? Even the acronym "STEM" is not clear (Bybee, 2010).

The AFNR-education community is not immune to this critique. For example, Research Priority Area three of the American Association for Agricultural Education (AAAE) National Research Agenda (Stripling & Ricketts, 2016) focuses on a sufficient scientific and professional workforce that addresses the challenges of the 21st century. One of the five research priority questions in this area asks: "What are effective models for science, technology, engineering, and math (STEM) integration in school-based agricultural education curriculum?" (p. 31). The accompanying review of literature, however, only discusses teaching of science and math in AFNR contexts. The absence of engineering is in contrast to recent framing of STEM education regarding integrated learning experiences in which the practices of science and engineering are brought to bear on real-world, interdisciplinary challenges (NAE & NRC, 2014; NGSS Lead States, 2013). It is encouraging that AAAE Research Priority Area six asks: "What methods, models, and programs are effective in preparing people to solve complex, interdisciplinary problems (e.g., Climate change, food security, sustainability, water conservation, etc.)?" and asserts that "agricultural educators . . . are uniquely positioned" to address this challenge (Andenoro, Baker, Stedman, & Weeks, 2016, p. 59). However, this is not part of the discussion of models for STEM integration in Priority Area three. The real-world, interdisciplinary nature of AFNR makes it a prime context for modern STEM education, and the AFNR-education community brings a wealth of experience, particularly in the areas of science (e.g., McKim, Velez, Lambert, & Balschweid, 2017; Velez, Lambert, & Elliott, 2015) and math (e.g., Stone, Alfeld & Pearson, 2008; Stripling & Roberts, 2013). However, further advancing STEM education in AFNR contexts requires systematic efforts to understand what models are effective and how learning occurs.

AFNR educators and education researchers are not alone in this pursuit. Efforts outside of traditional agricultural education contexts, such as the proliferation of school gardens as a venue for STEM learning (Risso, 2018), the AgBot competition (Gerrish & Gerrish, 2018), and the turn to urban gardening techniques as a component of community-based STEM programs for urban youth (Green Bronx Machine, 2018), indicate that the time may be ripe for increased collaboration between researchers and practitioners in AFNR education and the broader STEM-education community. However, collaboration requires addressing three fundamental questions that prompted this study: (a) What does previous work tell us about how STEM learning in AFNR occurs?, (b) What are the entry points to collaboration between AFNR and STEM education communities?, and (c) Are we collectively ready to move into this new collaborative, interdisciplinary space?

Efforts to advance robust, research-supported, theoretically driven models for STEM in AFNR education require synthesis across multiple studies. Calls for the use of meta-analytic techniques in educational research, in which statistical analysis of existing studies allows for identification of larger scale trends and relationships, are not new (e.g., Glass, 1976). Recent examples of meta-analyses in undergraduate education contexts have demonstrated the effectiveness of active learning over lecture format for STEM students (Freeman et al., 2014) and gains in critical-thinking skills for college students (Huber & Kuncel, 2016). Meta-analyses are rare in agricultural education research (a search of prominent journals yielded few examples); however, this approach has been promoted as a promising practice for improving research in career and technical education (Gordon, McClain, Kim, & Maldonado, 2010; Oh-Young, Gordon, Xing, & Filler, 2018). Such techniques require a level of consistency in the literature that the field currently lacks. A cursory review of STEM in AFNR education literature yields myriad conceptualizations, justifications, and operationalizations for STEM education. The range of operational definitions and models for STEM education has profound implications for attempts to aggregate data, compare findings across studies, and build connections with the broader STEM-education community. To date, there has been little research focused on developing a common language for work in this arena, and we identified no literature review or synthesis articles for STEM in AFNR education. We addressed this gap by conducting a systematic review of the STEM in AFNR education literature. Through describing characteristics and identifying themes in previously published articles, we developed a framework to help situate research programs and educational interventions in the larger context and provide common ground regarding operationalizing models for STEM education in AFNR-related work. Further, our findings offer a foundation from which to illuminate entry points for collaboration between STEM and AFNR education, a critical first step in achieving a shared goal to prepare learners to address complex, interdisciplinary problems.

Visioning for STEM Education Research and Practice

Previous efforts to define, describe, and provide visions for STEM education research and practice can provide guidance for what to look for in the STEM in AFNR literature. Throughout education, STEM efforts have focused on six areas: (a) achievement of various demographic groups, (b) international mathematics and science test performance, (c) foreign student enrollments in postsecondary STEM degrees, (d) global STEM education attainment, (e) STEM teacher quality, and (f) the STEM labor supply (Gonzalez & Kuenzi, 2012). These efforts to understand STEM student achievement and workforce issues have created shifts in models for implementing STEM education. As Bybee articulated in 2013, STEM definitions range from each of the four STEM subjects being its own silo to real-world, interdisciplinary approaches. Visions for STEM education have moved toward the latter in recent years. In the 2011 publication, *Successful K-12 STEM Education,* the National Research Council set STEM education goals with a strong emphasis on science and mathematics, and this focus was carried over into subsequent work identifying indicators of success (NRC, 2013). The seminal document, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012), provided an approach that integrated content knowledge with the practices of science and engineering. The inclusion of engineering design principles, emphasis on concepts that cut across subjects, and reduction of content standards to "core ideas" marked a departure from previous frameworks for K-12 science education, e.g., American Association for the Advancement of Science (AAAS, 1993) and NRC (1996). In addition, the use of this framework to develop performance expectations integrating all three dimensions, i.e., science and engineering practices, core content ideas, and concepts that cut across multiple subjects, necessitated a vision for learning episodes that more accurately mimicked the ways science and engineering are "practiced and experienced in the real world" (NGSS Lead States, 2013, Conceptual Shifts, p. 1). Increased collaboration among teachers in different content areas may be a path forward to implementing such interdisciplinary, integrated STEM education (Roehrig, Moore, Wang, & Park, 2012).

As these models for implementing STEM education have evolved toward more integrated approaches, recent empirical research and synthesis efforts have also suggested new directions and areas of emphasis for STEM education research. A study of self-identified "STEM schools" reported that key instructional elements included personalization of learning, problem-based learning, rigorous learning, and career, technology, and life skills; STEM disciplinary outcomes, however, were not emphasized (LaForce et al., 2016). There is a need for research that articulates exactly how to accomplish integrative STEM education (NAE & NRC, 2014) and consideration of research designs that account for learning beyond the formal classroom (Dierking & Falk, 2016; NRC, 2015). The report *STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research* (NAE & NRC, 2014) recommended researchers "document the curriculum, program, or other intervention in greater detail, with particular attention to the nature of the integration and how it was supported" (p. 9) and develop "clearly articulated hypotheses about the mechanisms by which integrated STEM education supports learning, thinking, interest, identity, and persistence" (p. 10). Kelley and Knowles (2016) provided an example of such an attempt by grounding their conceptual model for integrated STEM learning in situated learning theory. Dierking and Falk (2016) presented a synthesis of six key, cross-cutting principles from the *2020 Vision: The Next Generation of STEM Learning Research* project. Within this set are calls to "frame STEM learning research within the broader social-cultural-political contexts of the needs and concerns of the larger global society" and to consider "learning as a lifelong process that occurs across settings . . ., situations . . . and time frames" (p. 4). These ideas are echoed in the views of STEM educators and administrators who emphasized interdisciplinary connections and "explicit connections between in-school content and out-of-school problems or contexts" (Holmlund, Lesseig & Slavit, 2018, p. 11). Furthermore, in non-formal settings, research in STEM programs should "explore how STEM learning ecosystems work" (NRC, 2015, p. 3), considering the interconnected contexts in which learning occurs. In higher education, there is a growing need for researchers to understand STEM teaching practices at a large scale, particularly related to teaching diverse student populations and understanding "faculty beliefs about teaching" (AAAS, 2013, p. 44).

The larger STEM education backdrop allows for consideration of the role STEM education research and practices in AFNR educational contexts plays in implementing this vision. Claims that teaching STEM in AFNR educational contexts offers an opportunity to simultaneously strengthen STEM education through contextualized learning, expanding the STEM pipeline, and strengthening student preparedness for careers in AFNR are prevalent, e.g., Mercier (2015) and STEM Food & Ag Council (2014), but efforts to substantiate these claims require synthesis of research findings in a meaningful way. The context and target audience for interventions, goals for teaching STEM, frameworks, and models for STEM education and/or integration, and operationalization of STEM in research (Dierking & Falk, 2016; NAE & NRC, 2014; NRC, 2015) need to be documented systematically within this body of literature.

Purpose of the Study

The purpose of this study was to articulate the state of the field for STEM in AFNR education to inform future research, innovations in practice, and interdisciplinary collaborations. Through a systematic review of the existing peer-reviewed literature, we addressed the following research question: *How did researchers and practitioners frame STEM education in existing peer-reviewed articles addressing AFNR education published from 2010 to 2017?* To answer this research question, we addressed the following objectives for each article in the systematic review.

Objective 1. Identify trends in the characteristics and type of research used.
Objective 2. Describe instructional approaches used.
Objective 3. Determine what STEM subjects were addressed.
Objective 4. Distinguish the relationship between STEM subjects.
Objective 5. Distinguish the relationship between AFNR education and STEM learning.

Objective 6. Determine how research and teaching of STEM was justified.
Objective 7. Describe the primary focus or objective.
Objective 8. Identify how STEM was operationalized in the intervention and/or research design.

Methods

Review Approach/ Framework

We conducted a systematic review (Borenstein, Hedges, Higgin, & Rothstein, 2009; Gough, Thomas, & Oliver, 2012) to synthesize and develop a framework of the STEM in AFNR education literature. We systematically employed document analysis guided by the objectives to identify emergent themes that allowed for development of a framework for the topic. Borenstein et al. (2009) defined a systematic review as the process of synthesizing results by constructing a thematic story to fit the literature base (Oh-Young et al., 2018). Following recommendations of Borenstein et al. (2009), our systematic review included listing the search criteria, explaining methodologies for how the studies were evaluated and analyzed, and describing the characteristics of the studies in a summary table.

Search Strategy and Inclusion Criteria

The lead researcher, Scherer, utilized the EBSCO search engine to simultaneously search the education databases ERIC and Education Research Complete; the platform automatically removes duplicates. The search was limited to peer-reviewed journals published in English between 2010 and 2017. We selected 2010 as the start date because it was the first year in which the term "STEM" appeared in the *Journal of Agricultural Education*. A Boolean search string was used to search for the occurrence of these terms in the title, abstract, or subject/keyword: ("STEM" OR "science, technology, engineering, and math" OR "science, technology, engineering, and mathematics") AND ("agricultur*" OR "food" OR "natural resources"). The database search resulted in 123 unique publications. As an additional measure, a web-based search of titles of articles in prominent AFNR education journals for instances of STEM or "science, technology, engineering, and math*" during the same period yielded 13 additional peer-reviewed articles. The journals included in this component are also indexed in the databases utilized. Journals searched were the *Journal of Agricultural Education*, the *Journal of Food Science Education*, *Natural Science Education* (formerly the *Journal of Natural Resources & Life Sciences Education*), the *North American Colleges and Teachers of Agriculture Journal*, the *Journal of Extension*, and the *Career and Technical Education Research Journal*. The lead researcher systematically reviewed abstracts of the 136 articles to determine if they met four criteria for inclusion in the study: (a) at least one instance of STEM or "science, technology, engineering, and math (or mathematics)" used in an educational context, (b) addresses AFNR context or content, (c) intervention or study has some connection to instruction, and (d) represented a U.S. educational context. The systematic review yielded 52 articles relevant for inclusion in this study.

Analysis Techniques and Trustworthiness of the Study

The entire research team conducted qualitative analysis based on the constant comparative method (Lincoln & Guba, 1985) and content analysis techniques (Patton, 2002). In the first stage of analysis, conducted in 2017, there were 38 articles from 2010 to 2016 that met the inclusion criteria. We randomly divided the articles among the five members of the research team, and each initially coded a subset of the articles based on the targeted areas of interest. We debriefed the process, refined the research objectives, and systematically reviewed all 38 articles.

To identify trends in the characteristics and type of research used, objective one, we identified the type of article, target participants for the study or intervention, and the context or topic for the article. Coding for the type of article followed the classification outlined by St. John & McNeal (2015). This framework includes "practitioner wisdom" articles in which educators describe their own successes, "expert opinion" articles, "case studies" that include educational research but focus on a single course or intervention, and "cohort studies" in which research is conducted across courses or institutions. Additionally, we added emergent codes for historical quasi-experimental research studies. For research objectives two through eight, we conducted open coding on each article using the objectives as sensitizing constructs (Patton, 2002). For the purposes of this study, we defined STEM "subjects" as the broad fields of science, technology, engineering, and math.

Once we completed the systematic review, we compiled these articles into a table. In the second stage, we further analyzed codes for research objectives four through eight to identify themes. First, following Lincoln and Guba (1985), individual researchers synthesized codes within the target objectives to develop emergent themes. Then, we debriefed the themes, collectively interrogating the evidence for the themes and reaching consensus on the initial list and conducted focused coding using the themes. To ensure consistency, each team member used the established themes to analyze the same two randomly selected articles, resulting in a 72% interrater agreement. We then discussed discrepancies and further refined theme descriptions for clarity. Next, each team member analyzed a new set of three randomly selected articles with a resulting 85% interrater agreement. One member of the research team revisited each article to ensure alignment with the final emergent themes and raised questions about articles that were difficult to code with the entire team. We then summarized the themes by categorizing and describing the emergent themes of STEM in AFNR. Finally, we added 14 articles published in 2017 to the study and analyzed them using the same methods, resulting in a final dataset of 52 articles that span 2010-2017.

Throughout our analysis, we employed additional techniques for establishing trustworthiness in qualitative research, as described by Lincoln and Guba (1985). Debriefing sessions allowed for perspective triangulation and sensitivity to negative cases, contributing to the credibility of the study. We established an audit trail and provided our coding in the Appendix to address confirmability. We described our search criteria, methods of analysis, and provided direct quotations from the articles to establish dependability. The lead researcher oversaw the entire process as an additional measure to ensure consistency in coding (Oh-Young et al., 2018).

Reflexivity and Research Team Stance

This project grew out of a research collaboration among members of the Enhancing STEM through Agricultural Education Special Interest Group of AAAE to address the question of effective models for STEM education in school-based agricultural education (SBAE). The research team included researchers in AFNR education with a range of expertise and experience in STEM education. Scherer is a current Extension and teacher educator whose research focuses on models for integration of science and agriculture in formal and non-formal educational settings. McKim is a former SBAE teacher and current postsecondary leadership and teacher educator whose research focuses on teaching STEM within the context of AFNR. Wang is a teacher educator focusing on STEM integration, inquiry-based instruction, and experiential learning in science and agricultural education, with specific interest in the cognitive bases of STEM learning. DiBenedetto is a teacher educator with experience in inquiry-based instruction whose research focuses heavily on teaching and learning, career readiness, and the utilization of STEM in the AFNR curriculum. Robinson has conducted research related to development of quantitative reasoning in the context of integrative agricultural education. Collectively, we represent a diverse team with prior teaching experience in both SBAE and secondary STEM working to enhance STEM education in AFNR contexts. This diversity in perspective and collective expertise fostered reflexivity throughout the study, contributing to trustworthiness (Lincoln & Guba, 1985).

Results

Our analysis revealed trends, gaps, and emergent themes in articles addressing research and practice for STEM in AFNR education. Findings from our systematic review for all research objectives are summarized in Tables 1 and 2, and discussed for each research objective. Full details of our findings for each article are provided as a reference in the Appendix.

Table 1

Summary of Selected Characteristics, Instructional Approaches, and STEM Subjects of STEM in AFNR Education Literature

Code	Description	#[b]	%[c]
Type of article (in order of increasing strength of evidence)[a]			
Practitioner wisdom	Educator described their own experiences and/or successes.	12	23
Expert opinion	Author with relevant expertise described experiences and/or interventions.	4	8
Case study	Educational research that focused on a single course or intervention.	17	33
Historical	Historical research.	1	2
Cohort study	Educational research conducted across courses or institutions.	15	29
Quasi-experimental	Educational research with a quasi-experimental design.	3	6
Instructional approach (in order of decreasing occurrence in the articles reviewed)			
Unspecified	No instructional approach specified.	20	38
Multiple	More than one instructional approach was discussed.	8	15
Problem-based	Approach in which learners engaged with a real-world problem, design challenge, or project that is AFNR related.	8	15
Hands-on	No specific model was employed but included a mention of hands-on activities.	7	13
Experiential	An experiential learning approach was described.	3	6
Inquiry	Inquiry-based learning was described.	3	6
Competition	Youth participation in and/or training for competitions.	2	4
Design challenge	Engineering design challenge was described.	1	2
STEM subjects utilized (in order of decreasing occurrence in the articles reviewed)			
S	Science only.	15	29
S,T,E,M	Science, technology, engineering, and math.	14	27
S,M	Science and math.	7	13
S,T	Science and technology.	6	12
S,T,E	Science, technology, and engineering.	3	6
S,E	Science and engineering.	3	6
M	Math only.	2	4
T,E	Technology and engineering.	1	2
S,E,M	Science, engineering, and math.	1	2

[a] Labels follow those recommended by St. John & McNeal (2015) with the addition of quasi-experimental and historical.
[b] # = number of articles.
[c] % = percent of articles based on a total of 52.

Table 2

Summary of Emergent Themes Identified Through Systematic Review of STEM in AFNR Education Literature

Emergent Theme	Description	Representative Quote	#	%
Relationship between STEM Subjects[a]				
Interrelated STEM Subjects	Two or more STEM subjects were discussed in combination within the context of AFNR.	"ChickQuest allows students to apply scientific and mathematical concepts to something real and familiar" (Horton, Krieger & Halasa, 2013, Goals, para. 5)	20	57
Disciplinary Silos	No relationship between STEM subjects articulated.	"instrument asked teachers to report their perception of the importance of each of the STEM areas, and their confidence in integrating each of the STEM areas" (Smith, Rayfield, & McKim, 2015, p. 187)	8	23
Real-World Problem Solving	STEM is an integrated approach used to address complex problems.	"youth were taught about worldwide food insecurity and the importance of aquaculture. They were then asked to create a prototype of a fish food distribution system" (Horton & House, 2015)	7	20
Relationship between AFNR and STEM				
Applied STEM	AFNR education is an appropriate context for STEM learning.	"agricultural education can take scientific topics to higher levels, emphasize scientific concepts…potentially supporting a STEM curriculum" (Despain, North, Warnick, & Baggaley, 2016, p. 195)	29	56
STEM is Naturally Occurring	STEM learning happens as students engage in AFNR education.	"[preparing] preservice agricultural education teachers for teaching mathematics found naturally within the agricultural education curricula" (Stripling & Roberts, 2013, p. 74)	18	35
STEM is External	STEM learning outcomes can be incorporated into AFNR education.	"[Curriculum for Agricultural Science Education] is intended to integrate core academics and Science, Technology, Engineering, and Math (STEM) into agricultural education programs" (Velez, Lambert, & Elliott, 2015, p. 204)	5	10
Primary Justification for STEM in AFNR[b]				
STEM Learning	STEM learning outcomes can be achieved or enhanced through AFNR education.	"promise for helping elementary students explore the four core subjects: science, mathematics, language arts, and social studies, while teaching … about the origin and production of food crops" (Graves, Hugher & Balgopal, 2016, p. 193)	29	56
Recruitment	More professionals are needed in STEM and/or AFNR.	"it is imperative to place a culturally sensitive historical narrative of science before students, as it can help to bolster their interest in STEM courses and eventually [in] careers" (Akins, 2013, p. 20)	13	25
Career Readiness	STEM learning is needed for success within professional careers.	"to more fully prepare our nation's students to enter the globally competitive workforce, STEM integration allows students to make connections between the abstract concepts learned in core subject classrooms and real-world situations" (Wooten, Rayfield, & Moore, 2013, p. 31)	8	15

Table 2

Summary of Emergent Themes Identified Through Systematic Review of STEM in AFNR Education Literature Continued

Problem Solving	STEM learning is needed to solve complex problems.	"students [in STEM programs] as leaders and agents who can collaborate…to respond with solutions and innovative strategies to help Native communities adjust to the impacts of a changing climate" (Sorenson, 2011, para. 5)	4	8
Interdisciplinary Connections	AFNR and STEM learning are mutually reinforcing.	"[youth participants] create understanding of the value of aquaculture as a sustainable practice for addressing food security" (Horton & House, 2015, para. 3)	1	2
Article Focus[b]				
STEM Program or Curriculum	Evaluating or describing a program or curriculum to engage students in STEM.	"how elementary teachers at a STEM-centric elementary school perceived and integrated the Edible Plants Curriculum (EPC) into their existing curriculum" (Graves, Hugher, & Balgopal, 2016, p. 194)	33	63
Teacher Practices and Characteristics	Identifying or describing characteristics and approaches of STEM among AFNR educators.	"better understand how faculty facilitate learning in introductory courses in animal science, food science, and plant science" (Balschweid, Knobloch, & Hains, 2014, p. 163)	9	17
Student Career Choice	Evaluating STEM career choice.	"scientific reasoning scores . . . to predict students' likelihood to indicate plans to pursue a career in agriculture, STEM or plan to attend college" (DiBenedetto, Easterly, & Myers, 2015, p. 108)	4	8
Perceptions of STEM	Interested in how individuals conceptualize STEM.	"explore and describe teacher perceptions of STEM and STEM integration" (Stubbs & Myers, 2016, p. 89)	3	6
Emergent STEM	STEM was not the initial focus, however, STEM emerged through data collection.	"participants emphasized science and technology as a curriculum and school focus highlighting how agricultural science courses enhanced this focus" (Henry, Talbert, & Morris, 2014, p. 94)	3	6
Standardized Testing	Evaluating results from standardized assessments of STEM knowledge.	"compare[d] 11th grade science achievement test scores of students enrolled in the agricultural and natural resources cluster with those enrolled in STEM and [other] clusters " (Israel, Myers, Lamm, & Galindo-Gonzalez, 2012, p. 3)	2	4
Operationalization of STEM in Research[b]				
Single Subject	One STEM subject within the intervention and/or research design.	"investigate[d] the relationships between mathematics ability, personal mathematics efficacy, mathematics teaching efficacy, personal teaching efficacy, and background characteristics" (Stripling & Roberts, 2013, p. 73)	17	33
Two or More Subjects	Two or more STEM subjects within the intervention and/or research design.	"Please list all STEM (science, technology, engineering, and mathematics) concepts that you believe to be associated with junior livestock projects" (part of survey instrument, Wooten, Rayfield, & Moore, 2013, p. 34)	11	21

Table 2

Summary of Emergent Themes Identified Through Systematic Review of STEM in AFNR Education Literature Continued

Unspecified Subjects	Intervention and/or research design involves an undescribed subset of science, technology, engineering, and/or mathematics.	"Definitions of STEM careers and agriculture careers were not operationalized for the teachers and students in this study" (DiBenedetto, Easterly, & Myers, 2015, p. 108).	7	13
n/a	Not research or STEM was emergent in the study.		19	37

= number of articles; % = percentage of articles
[a] Only the 35 articles that addressed more than one STEM subject were analyzed for this category. Percentages are reported relative to this total count of 35.
[b] Some articles were categorized in more than one theme (see Appendix), thus the total percentages for these categories are greater than 100.

Objective 1. Identify trends in the characteristics and type of research used

STEM in AFNR education is being investigated through research and described by practitioners in formal and non-formal settings addressing a variety of AFNR topics (Table 1). Roughly one-third of the articles were practitioner or expert accounts of promising educational programs, experiences, or strategies that did not include any data. Of the reviewed research articles, approximately one-half were cohort (data collection across courses or institutions) or quasi-experimental studies, which could potentially position the field for future meta-analyses. Participants for the educational interventional and research articles represented a wide range of ages and settings, including middle and high school students (31%), 4-H and FFA participants (10%), general K-12 students (8%), postsecondary students (17%), preservice agriculture teachers (8%), general in-service K-12 teachers (6%), and in-service secondary agriculture teachers (2%). The topical focus for the articles included, but was not limited to, subjects typically covered in school-based agricultural education. Topics included: life science; biology; food, e.g., food safety, food supplies, and food science; agricultural technologies, such as biogeochemical simulation and biotechnologies; animal science; environmental issues, including climate change; and plant science, e.g., medicinal plants. Notably, STEM is being addressed through AFNR topics in formal and non-formal settings in both traditional agricultural education (55%), i.e., 4-H and formal agriculture courses at the secondary and postsecondary levels, and other settings (45%) including elementary, secondary, and postsecondary science contexts.

Objective 2. Describe instructional approaches used

A range of instructional approaches were named or described in the articles (Table 1), but few were described very thoroughly, limiting analysis to identifying the approach. Of note, the instructional approach was not specified, multiple approaches were listed without particular emphasis, or "hands-on" was mentioned but not based on an established model in the majority (67%) of the articles, including six that reported on a STEM program or curriculum. Of the approaches that were clearly named, problem-based learning was most frequent (15%) with the remaining four each representing less than 10% of the articles in the study.

Objective 3. Determine what STEM subjects were addressed

Of the 52 articles, 33% highlighted a single STEM subject with no integration of a second. Science was the most common (29%), and no studies focused solely on technology or engineering (Table 1). In these cases, mention of STEM primarily served to situate the article in a larger context. The second most frequent type of article (27%) utilized all four STEM subjects in some way, typically with some effort to integrate the subjects. The remainder of the studies utilized more than one STEM subject in the research design or educational intervention in various combinations (Table 1).

Objective 4. Distinguish the relationship between STEM subjects

Our analysis of the 35 articles that addressed more than one STEM subject revealed three different ways that authors discussed the relationship between the subjects of science, technology, engineering, and math (Table 2). STEM subjects were interrelated in some way in the majority of articles (57%); however, a clear articulation of how they were integrated within a learning episode was typically not described. In 23% of the articles, no effort was made to combine subjects. In these articles, each area of STEM was most commonly intentionally considered individually with respect to agriculture content (e.g., Smith, Rayfield, & McKim, 2015) or the article focused on STEM degree or career contexts (e.g., Mars & Hart, 2017) within traditional disciplinary boundaries. Finally, 20% of the articles utilized an integrated approach in which the learners encountered STEM through addressing complex, real-world, interdisciplinary, AFNR-related problems.

Objective 5. Distinguish the relationship between AFNR education and STEM learning

The relationship between AFNR and STEM, while in some cases applied to a single learning episode or unit, was often expressed at a curricular or programmatic level. In our analysis, "STEM" referred to the related content in that particular article. For example, if an article only discussed science, the relationship between science and AFNR was coded.

Three themes emerged that describe these relationships (Table 2). More than one-half of the articles (56%) framed AFNR as an appropriate context for STEM learning. In this Applied STEM theme, the curricular and/or instructional emphasis was on the STEM content or outcomes for students, e.g., science content standards, and AFNR was framed as a context in which to support STEM learning. The articles in this theme were in a wide range of instructional contexts both within and outside of traditional agricultural education. Contexts included, for example, elementary school gardens, secondary agriculture programs, and youth livestock clubs. An additional 10% of the articles more explicitly framed STEM content as external to AFNR and emphasized adding STEM disciplinary content, including learning standards, to AFNR-learning episodes or curricula. In contrast, approximately one-third (35%) of the articles emphasized student learning of AFNR content with STEM outcomes a product of engaging in AFNR-learning episodes, or STEM is Naturally Occurring. This theme included articles in which this relationship was assumed, articles that framed AFNR degrees or careers as STEM, and articles that explicitly sought alignment with STEM standards/content. The defining characteristic for the theme STEM is Naturally Occurring is that the intent was not to alter the AFNR content but illuminate the STEM concepts already present. The majority (78%) of articles in which STEM is Naturally Occurring or External represented traditional AFNR educational contexts.

Objective 6. Determine how research and teaching of STEM was justified

From our analysis, five themes emerged that illustrated why STEM education in AFNR should be pursued (Table 2). Each theme is described below. These justifications were typically articulated in the introduction to the article as the context or motivation for the study or intervention. STEM learning, the most common justification for STEM education in AFNR (56% of articles), was articulated regarding a primary need to support student learning of STEM concepts, e.g., science standards, through an AFNR-related intervention. Two themes framed STEM learning for more specific purposes: STEM knowledge and skills as critical for career readiness in a broad range of fields (15%) and complex problem-solving related to AFNR challenges (8%). Additionally, 25% of the articles highlighted the need for additional professionals in STEM or AFNR, citing recruitment as a justification for the study or intervention. Finally, one article (2%) described AFNR and STEM knowledge as mutually reinforcing; therefore, STEM learning was predicted to enhance and support student learning of AFNR content.

Objective 7. Describe the primary focus or objective

We identified six themes for the focus of the articles (Table 2), determined by examining the main topic of the new information presented. The majority of articles (63%) described or evaluated a STEM program or curriculum. All of the practitioner and expert opinion articles were included in this theme, along with 17 empirical studies that presented data related to program or curriculum implementation. Seventeen percent of the articles examined teacher practices and characteristics, addressing topics such as professional development for educators, best-practices related to STEM teaching, or self-efficacy for teaching STEM subjects, typically, but not exclusively independent of a particular intervention. An additional set of the research articles reported on investigations focused outside the context of specific STEM-related curricula, activities, and/or courses. These articles included influences on student career choice or interest (8%), teacher or learner perceptions of STEM (6%), and standardized testing as the primary tool for understanding course or program-level student outcomes (4%). Finally, three articles (6%) reported on qualitative studies in which STEM was not part of the initial research objectives but emerged from participants.

Objective 8. Identify how STEM is operationalized in the intervention and/or research design

Three themes emerged from the analysis of the 33 articles that reported findings from research studies designed to understand some aspect of STEM (Table 2). Articles were categorized in more than one theme if STEM was operationalized differently in separate constructs or objectives. Of the 33 articles, approximately half (52%) reported on research focused on one subject, 33% addressed two or more subjects, and 21% used STEM as an acronym but did not fully operationalize it in the research context. For articles reporting research on a single subject, although STEM was discussed more broadly in other portions of the article, the majority of the studies were focused on science or, to a lesser extent, math, and it is noteworthy that engineering and technology were largely absent. When multiple subjects were included in the research, they were typically discussed or listed separately, with a lack of emphasis on integration other than that the subjects were connected to AFNR.

Discussion, Implications, and Recommendations

We conducted a systematic review of STEM in AFNR education literature, yielding a summary of existing approaches to STEM education and research in this area. The analysis was limited to articles that met our search criteria. Although consistent with standards for conducting systematic reviews (Borenstein et al., 2009), the selection technique did not include non-peer-reviewed practitioner pieces (e.g., *The Agricultural Education Magazine*) or peer-reviewed articles lacking the selected verbiage in the title or abstract. These limitations notwithstanding, our analysis provided an informative review of STEM in AFNR-education literature.

We have demonstrated that STEM is being addressed through AFNR topics in a variety of educational contexts not limited to traditional AFNR-education spaces. Target learners range along a continuum from elementary through graduate students. While not surprising, the fact that articles address all of these stages offers opportunities to further investigate how AFNR-related learning experiences may accumulate over time, potentially supporting research-based knowledge progressions and/or insights into how to scaffold learning longitudinally.

Our analysis revealed a key deficit in the articles regarding the depth of descriptions of instructional approaches. Efforts to understand how learning occurs in this space and to further support educators in these efforts rely on theoretically and empirically supported frameworks and models. These efforts can be developed through detailed accounts of what has happened in real-world settings (NAE & NRC, 2014). In our study, problem-based learning was the most frequently named approach, consistent with previous work on STEM schools (Kelley & Knowles, 2016). Case studies of learning environments that connect STEM in AFNR could further reveal key practices that lead to powerful outcomes for learners and provide the basis for a framework that can be evaluated, revised, and extended through additional research (NAE & NRC, 2014). In the absence of such a teaching framework, scholars and practitioners are left to disparate, rather than complementary, efforts.

Efforts to address AFNR and science are frequently reported in the articles in our review, reflecting alignment between AFNR and this core area of the curriculum. The addition of engineering practices to the K-12 science curriculum (NRC, 2012) represents a new opportunity for interdisciplinary research to address the gap that we revealed regarding the paucity of articles that addressed engineering in AFNR and to capitalize on grant funding opportunities increasingly supporting engineering education interventions and evaluation (Gonzalez & Kuenzi, 2012). Researchers are encouraged to expand the focus from science and mathematics to more holistic analyses of STEM learning that include foci in engineering design and technology. Learning experiences within the Power, Structural, and Technical Systems pathway of school-based AFNR education and 4-H Maker and robotics programs offer potential contexts in which learning about engineering design and technology could occur in AFNR.

For articles that addressed multiple subjects, we identified an overemphasis on partial STEM (i.e., science and/or mathematics) and a need for authors to fully describe the nature of the integration, as recommended by the NAE & NRC (2014). The manner in which STEM subjects are integrated, if at all, has implications for research and teaching in that the way learners engage with various STEM subjects in relation to each other influences expected outcomes (NAE & NRC, 2014). Furthermore, few of the articles in our study aligned with an interdisciplinary understanding of STEM, in which STEM was seen as a unified approach, rather than four distinct disciplinary silos (Bybee, 2010).

The prevalence of articles in our review in traditional AFNR education contexts (e.g., preservice AFNR educators, and secondary school AFNR programs) that conceptualized STEM content as either naturally occurring within AFNR or completely external to AFNR belies a need to consistently define the relationship between STEM and AFNR in these contexts. In addition, neither description implied a need to improve the way AFNR content is taught in traditional education settings. Studies suggesting STEM is naturally occurring within AFNR curriculum may inculcate an idle mindset to achieving STEM aims within AFNR - i.e., “if it naturally exists, I do not need to change anything.” As an alternative, studies conceptualizing STEM as an external “add-on” to AFNR content implied disciplinary silos, failing to recognize, or educate others about, the interconnectedness of STEM and AFNR. To address this challenge, we recommend adopting a mutual understanding of the relationship between STEM and AFNR. Consistency in defining the relationship between STEM and AFNR may help AFNR educators and researchers communicate a role in broader STEM education aims. To position AFNR education to address student preparedness for increasingly interdisciplinary careers and challenges (NGSS Lead States, 2013), we recommend a common understanding in which AFNR and STEM are seen as complex systems of knowledge and skills with numerous overlapping ideas, concepts, and abilities. Within this understanding, teaching STEM through AFNR contexts is not an added experience but rather a required component to preparing students to learn about, address challenges within, and be successfully employed in AFNR. If adopted, this common understanding would reinforce the essential nature of addressing STEM within AFNR learning contexts as well as the tremendous opportunities to reinforce and extend STEM-learning contexts through applications in AFNR.

Review of the knowledge gained through this work provided essential recommendations for STEM in AFNR education research and practice. First, we recommend that future contributors to STEM in AFNR education (i.e., via research or practice) use the findings of this systematic review to better coordinate efforts to understand, and advance, STEM in AFNR education. From a research perspective, using the themes we identified to describe the justification, instructional approach, research approach, focus, and STEM/AFNR relationships will allow the body of research regarding STEM in AFNR to move forward in a more organized and focused manner as well as provide terminology that links AFNR-education research to the broader STEM-education literature. Furthermore, we encourage researchers to critically review the operationalization of each characteristic to ensure alignment within their work. In addition to recommending application of the findings, we recommend scholarship that utilizes a complete and interdisciplinary perspective of STEM.

For practitioners, the summary from the systematic review provides options to clarify why, what, and how STEM content can be taught within the context of AFNR curriculum. We recommend that agricultural education faculty utilize the summary of our findings as a foundation to initiate meaningful learning experiences for preservice teachers that connect the knowledge gained through this study to daily curricula. This connection could be achieved by engaging preservice educators in transforming the identified justifications into experiences that increase student motivation, including interest approaches and motivational sets, research foci into learning outcomes, and operationalizations into methods for teaching. These efforts can support early career educators to think pragmatically about teaching STEM within AFNR. Additionally, developers of professional learning experiences for in-service educators can leverage our findings by having educators use the emergent themes in Table 2 to critically reflect on their practice. Methods, activities, and learning outcomes used in their curricula can be strengthened through clearer articulation of the purpose of teaching STEM in AFNR and the relationships among the various disciplines represented.

Conclusions

Recommendations for the future of STEM education emphasize interdisciplinary STEM-learning experiences that will prepare individuals to solve complex problems (NGSS Lead States, 2013). This interdisciplinary vision provides an opportunity to more closely align the research and practice of STEM education with AFNR education and foster collaboration. At the beginning of this article, we posed three fundamental questions that, if answered, may lead to increased collaboration between AFNR and STEM education communities. We revisit those questions here through our concluding remarks.

What does previous work tell us about how STEM learning in AFNR occurs?

Key findings revealed STEM in AFNR serves a wide range of populations, spanning formal and non-formal educational settings. Science and math are well represented, with a notable deficit in the areas of engineering and technology. Mechanisms through which STEM learning occurs are often poorly described, but there is an emergent area of focus on integrative approaches to STEM education in AFNR educational contexts.

What are the entry points to collaboration between AFNR and STEM education communities?

Reviewing the literature shed light on the pursuit of common aims (e.g., increased problem-solving capacity, improved teacher quality, career readiness, and STEM learning supporting student success) within STEM and AFNR education (Bybee, 2010; Gonzalez & Kuenzi, 2012). The prevalence of STEM learning as a justification indicated supporting STEM learning outcomes is a promising area for new collaborative efforts. Additionally, as STEM education moves toward emphasizing the role of human and societal issues (NGSS Lead States, 2013), work framing AFNR as a context for STEM education (applied STEM theme) may serve as promising practices for STEM education researchers and practitioners. Finally, comprehensive descriptions of STEM in

AFNR education programs provide a starting point for additional research focused on how AFNR education supports student learning as recommended by the NAE & NRC (2014). Detailed investigations of these interventions would be of value to both communities.

Are we collectively ready to move into this new collaborative, interdisciplinary space?

The pursuit of STEM outcomes can occur through either separate, distinct efforts or through a coordinated relationship between subjects. Taking a page from the evolved nature of STEM education, we recommend a collaborative and interdisciplinary future for STEM and AFNR education. To catalyze this collaboration, we systematically reviewed existing STEM in AFNR education literature to provide a synopsis where we believe future research and practice can begin to align. By taking “the time to clarify what [STEM] might mean when applied beyond a general label” (Bybee, 2010, p. 30), we intended to provide a brighter future for the students, teachers, and stakeholders of STEM and AFNR education and move the AFNR education profession a step forward toward a new collaborative, interdisciplinary space.

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Appendix

Characteristics and Themes for Peer-reviewed STEM in AFNR Education Literature

Article	Type of article	Participants[a]	Context/ Topic	Instructional approach[b]	STEM subjects	STEM relationship[b]	AFNR/STEM relationship[b]	Justification[b]	Article focus[b]	Oper. Def. of STEM[b]
Akins, 2013	expert	MS/ HS	Ag careers	-	S,T,E,M	Interrelated	Applied	Recruitment	STEM program or curriculum	-
Balschweid et al., 2014	cohort	u-grad	Life science course	-	S,T,E,M	Disciplinary silos	Naturally occurring	Recruitment	Teacher practices & characteristics	Single
Birney et al., 2017	case	MS teachers	Harbor restoration	hands-on	S	n/a	Applied	STEM Learning	Teacher practices & characteristics	Single
Brandt et al., 2017	cohort	ES	Ag literacy	-	S,T,E,M	Interrelated	External	STEM Learning	STEM program or curriculum	2 or more
Campbell et al., 2014	pract-itioner	ES	Ag awareness day	hands-on	S	n/a	Applied	STEM Learning	STEM program or curriculum	-
Campbell et al., 2015	pract-itioner	ES	Ag day program	hands-on	S,M	Interrelated	Applied	STEM Learning	STEM program or curriculum	-
Chumbley et al., 2015	cohort	HS	Ag science	-	S	n/a	Applied	Recruitment	Perceptions of STEM	Single
Costas et al., 2017	case	HS	Soil microbiology	inquiry	S,T	Real-world	Naturally occurring	STEM Learning	STEM program or curriculum	Single
de Koff, 2017	expert	K-12	Drones in Extension	multiple	S,T,E,M	Interrelated	Naturally occurring	STEM Learning	STEM program or curriculum	-
Despain et al., 2016	cohort	HS	Ag biology	-	S	n/a	Applied	STEM Learning	Standardized testing	Single
DiBenedetto et al., 2015	case	HS	Ag in general	inquiry	S	n/a	Applied	Recruitment	Student career choice	Single + unspecified
Dodd et al., 2015	pract-itioner	4-H	Food challenge	competition	S,M	Interrelated	Naturally occurring	STEM Learning	STEM program or curriculum	-
Foutz et al., 2011	case	MS/ HS	Ag engineering	problem-based	S,M	Interrelated	Applied	STEM Learning	STEM program or curriculum	2 or more
Graves et al., 2016	case	ES	School garden	problem-based	S,M	Interrelated	Applied	STEM Learning	STEM program or curriculum	2 or more
Gupta et al., 2017	case	ES	Food science workshop	hands-on	S	n/a	Applied	Recruitment	STEM program or curriculum	Single
Hacker et al., 2017	cohort	MS	Vertical farming	design challenge	T,E	Real-world	Applied	Problem Solving	STEM prog/curric, Teach pract & char	Single

Haynes et al., 2014	cohort	Pre-service	Ag ed curriculum	-	S,M	Interrelated	External	STEM Learning	Teacher practices & characteristics	2 or more
Henry et al., 2014	case	HS	General ag courses	-	S,T	Interrelated	Applied	Recruitment	Emergent STEM	N/A
Hilby et al., 2014	case	Pre-service	Math ability	-	M	n/a	Applied	STEM Learning	Teacher practices & characteristics	Single
Horton & House, 2015	cohort	K-12	Fish farm challenge	problem-based	S,E	Real-world	Naturally occurring	Inter- disciplinary	STEM program or curriculum	2 or more
Horton et al., 2013	case	ES	ChickQuest curriculum	problem-based	S,E,M	Interrelated	Applied	STEM Learning	STEM program or curriculum	Single
Israel et al, 2012	quasi-exp	HS	CTE programs	-	S	n/a	Naturally occurring	STEM Learning	Standardized testing	Single
Johnson, 2017	pract-itioner	K-12 teacher	Beef industry	multiple	S,T,E,M	Real-world	Applied	STEM Learning	STEM program or curriculum	-
Kahler & Valentine, 2011	pract-itioner	4-H	4-H STEM program	-	S,T,E,M	Interrelated	Naturally occurring	Career readiness	STEM program or curriculum	-
Kellog et al., 2016	case	HS/ u-grad	Medicinal plants	multiple	S	n/a	Applied	STEM Learning	STEM program or curriculum	Single
Ketchledge & Cantu, 2013	pract-itioner	ES	Food products	problem-based	S,E	Interrelated	Applied	STEM Learning	STEM program or curriculum	-
Lant et al., 2016	case	MS	Biogeochemistry	problem-based	S,E	Real-world	Applied	STEM Learning	STEM program or curriculum	2 or more
Mars, 2017	cohort	grad	STEM-based ag ed programs	-	S,T	Interrelated	Naturally occurring	Recruitment	Student career choice	Unspecified
Mars & Hart, 2017	cohort	grad	STEM-based ag ed programs	-	S,T	-	Naturally occurring	Recruitment	Student career choice	Unspecified
McKim et al., 2017	case	u-grad	STEM-based ag ed programs	-	S,T,E,M	Disciplinary silos	Naturally occurring	Recruitment	STEM program or curriculum	Unspecified
Musante, 2011	pract-itioner	u-grad	Biology	-	S	n/a	Applied	Problem Solving	STEM program or curriculum	-
Odera et al., 2015	case	u-grad	FAES internship	experiential	S	n/a	Naturally occurring	STEM Learning + Career ready	STEM program or curriculum	Unspecified
Parker & Lazaros, 2013	pract-itioner	ES	Food safety	hands-on	S,T,E,M	Interrelated	Naturally occurring	STEM Learning	STEM program or curriculum	-
Preble, 2015	pract-itioner	K-12	Apple grafting	hands-on	S,T,E	Interrelated	Naturally occurring	STEM Learning	STEM program or curriculum	-
Reeve, 2015	expert	K-12 teacher	Ag in general	problem-based	S,T,E,M	Real-world	Applied	Problem Solving	STEM program or curriculum	-
Ripberger & Blalock, 2015	cohort	4-H	Biotech, ag, geospatial	competition	S,T	Interrelated	Naturally occurring	Career Readiness	Teacher practices & Characteristics	2 or more

Robinson et al., 2013	cohort	Pre-service	SBAE program	-	S,T	Disciplinary silos	Applied	STEM Learning	Emergent STEM	N/A
Sallee & Peek, 2014	case	4-H	General AFNR	-	S,T,E	Interrelated	Applied	Recruitment	STEM program or curriculum	Single
Schmidt et al., 2012	pract-itioner	K-12	Food	hands-on	S	n/a	Applied	STEM learn., Career ready	STEM program or curriculum	-
Skelton et al., 2014	cohort	MS	Ag in general	multiple	S	n/a	Applied	STEM learn., Recruitment	STEM program or curriculum	Single + unspecified
Smith et al., 2015	cohort	Ag teacher	Ag courses in general	multiple	S,T,E,M	Disciplinary silos	External	STEM learning	Teacher practices & char	2 or more
Smith & Rayfield, 2017	quasi-exp	HS	Intro ag science	experiential	S	n/a	Applied	STEM learning	STEM program or curriculum	Single
Sorensen, 2011	pract-itioner	u-grad	Climate change	multiple	S,T,E	Real-world	Applied	Problem Solving	STEM program or curriculum	-
Stripling & Roberts, 2013	case	Pre-service	Math in ag courses	-	M	n/a	Naturally occurring	Career Readiness	Teacher practices & characteristics	Single
Stubbs & Meyers, 2015	case	HS	SBAE program	multiple	S,T,E,M	Disciplinary silos	External	Career Readiness	Percep of STEM, Teach pract & char	2 or more
Stubbs & Myers, 2016	case	Ag teacher	Perception of STEM integ.	-	S,T,E,M	Interrelated	Naturally occurring	STEM learning	Perceptions of STEM	2 or more
Twenter & Edwards, 2017	historical	-	SBAE facilities	-	S,T,E,M	Disciplinary silos	Naturally occurring	Career Readiness	Emergent STEM	Unspecified
Velez et al., 2015	quasi-exp	HS	CASE curriculum	inquiry	S	n/a	External	STEM learning	STEM program or curriculum	Single
Wagner, 2015	expert	HS	Food science	multiple	S	n/a	Applied	Recruitment	STEM program or curriculum	-
Webb & Curran, 2017	pract-itioner	MS	Coastal habitats	experiential	S,M	Interrelated	Applied	STEM learning	STEM program or curriculum	-
Wooten et al., 2013	cohort	FFA/ 4-H	Livestock	problem-based	S,T,E,M	Interrelated	Applied	Career Readiness	STEM program or curriculum	2 or more
Zahry & Besley, 2017	cohort	HS + u-grad	Perception of ag and NR majors	-	S,M	Disciplinary silos	Naturally occurring	Recruitment	Student career choice	Unspecified

[a]ES = elementary, MS = middle school, HS = high school, Pre-service = pre-service agriculture teachers, u-grad = undergraduate; [b]See Table 2 for description of themes