Journal of Agricultural Education, 59(1), 297-315
https://doi.org/10.5032/jae.2018.01297

STEM Education at the Nexus of the 3-Circle Model

Marshall Swafford[1]

Abstract

The United States economy is requiring employees to have knowledge and skills in science, technology, engineering, and mathematics (STEM). Researchers have identified agriculture, food, and natural resources (AFNR) education as a context in which STEM concepts can be formally taught and highlighted. Additionally, researchers have identified where, within the 3-circle model of agricultural education, students can develop STEM-related career skills. However, a conceptual model illustrating an integrated approach to STEM-AFNR education does not exist. The purpose of this research study was to identify where STEM technical content and employability skills can be explicitly taught, highlighted, and developed, within the current model of agricultural education. Research findings suggest STEM technical content can be explicitly taught and highlighted in curriculum when grounded in the Agriculture, Food and Natural Resources (AFNR) Career Cluster Content Standards. Furthermore, STEM technical content and employability skills are embedded in Supervised Agricultural Experience programs and National FFA Career Development Events. Using the findings as a guide, a conceptual model of STEM-AFNR is suggested along with recommendations for practice and future research.

Keywords: Agricultural education, STEM education, model of agricultural education

Introduction

Currently, 64% of companies have vacancies for STEM positions due to a lack of qualified applicants (Dobbs, Madgavkar, Barton, Labaye, Manika, Lund, & Madhav, 2012). By 2020, the United States economy is expected to require 123 million highly skilled workers, yet at current qualification levels, only 50 million workers will be available to fill the jobs (Gordon, 2009). However, the current model of school-based agricultural education (SBAE) provides a context where students may be exposed to and engaged in activities which support the development of competencies and skills required to fill future jobs. The current SBAE model is comprised of three interconnected components and include classroom/laboratory instruction, Supervised Agricultural Experience (SAE) programs, and leadership development through participation in the FFA. The classroom/laboratory component provides students opportunities to create content-specific knowledge pertaining to agriculture and natural resources through traditional instruction and inquiry-based methods (Phipps, Osborne, Dyer, & Ball, 2008). The SAE component engages students in settings where they apply knowledge and skills learned in the classroom to real-life situations (Phipps et al.). Participation in National FFA Organization sponsored activities provides an intra-curricular setting where students can participate in programs and activities through which communication, leadership, critical thinking, and teamwork skills are developed (Bunshaft, Boyington, Curtis-Fisk, Edwards, Gerstein, & Jacobson, 2015; Phipps et al.).

According to Bunshaft et al. (2015), employers are seeking candidates with more than just discipline-specific competencies or technical skills. Employability skills including communication, teamwork, leadership, along with critical thinking, problem solving, and

[1] Marshall Swafford is an Assistant Professor of Agricultural Education in the Department of Family and Consumer Sciences & Agriculture at Eastern New Mexico University, 1500 South Avenue K, Station 11, Portales, NM 88130, marshall.swafford@enmu.edu

managerial abilities are priorities for hiring managers. Bunshaft et al. suggested experiential learning activities provide opportunities for future employees to develop and apply their skills, increasing the likelihood of obtaining employment after graduation. Although difficult to identify a universal definition of employability skills, most accepted definitions include 1) a set of general skills needed to perform well and remain employed throughout one's career; 2) generic skills which cut across all industries, business types, and job levels and; 3) are divided into three skill sets – academic skills, personal qualities, and higher-order thinking skills (Bunshaft et al., 2015). Unsurprisingly, mathematics and science are common academic skills required by employers (Bunshaft et al., 2015.; Jang, 2016). Within the context of AFNR, Scherer, McKim, Wang, DiBenedetto, and Robinson (2017) identified STEM learning as a need for success within professional careers. However, candidates who possess non-technical skills, in addition to technical competence, are highly sought by 21st century organizations. Written and oral communication, project management, and interpersonal skills are frequently cited as lacking in STEM graduates (Hung-Lian, Lee, & Koh, 2000; Radermacher & Walia, 2013). As technology has advanced, computers have increasingly replaced humans in performing routine tasks (National Research Council, 2011). Thus, workers are required to have the cognitive and social skills needed to solve non-routine problems (Jang, 2016). The National Research Council (2011) identified five 21st century skills needed by prospective STEM employees: adaptability, complex communication skills, non-routine problem-solving skills, self-management/development, and systems thinking. Using workplace characteristics information maintained by the United States Department of Labor, Jang (2016) identified five similar competencies employers sought in STEM candidates, 1) problem-solving skills, 2) social communication skills, 3) technology and engineering skills, 4) system skills, and 5) time, resource, and knowledge management skills. Career and technical education organizations have attempted to identify employability skills needed in STEM careers. Advance CTE: State Leaders Connecting Learning to Work (2008) identified 10 competencies required of future STEM employees and include areas ranging from academic and technical knowledge and skills to problem-solving, critical thinking, and leadership.

Engaging students in active educational programs focused on fostering STEM competencies is vital for students' future employment prospects (Bunshaft et al., 2015; Crawley, Malmqvist, Östlund, & Brodeur, 2007; Jang, 2016). Ferrini-Mundy (2013) was more specific and noted, more hands-on, authentic STEM activities should be provided at the secondary level. Agricultural education has been considered a viable platform for teaching STEM concepts (Smith, Rayfield, & McKim, 2015). In a case study of three Florida high schools, Stubbs and Myers (2015) found students were exposed to a variety of STEM disciplines and careers through interdisciplinary curricula. STEM integration in agricultural education has been researched, however primarily as a vehicle to teach math and science (Boone, Gartin, Boone, & Hughes, 2006; Brister & Swortzel, 2009; Clark, 2013; Conroy, Dailey, & Shelley-Tolbert, 2000; Haynes, Robinson, Edwards, & Key, 2012; Johnson, 1996; Myers & Thompson, 2006; Myers & Washburn, 2008; Parr, Edwards & Leising, 2006, 2009; Ricketts, Duncan, & Peake, 2006; Scales, Terry, & Torres, 2009; Shinn et al., 2003; Stripling & Roberts, 2012; Thompson & Balschweid, 1999; Thompson & Balschweid, 2000; Thoron & Myers; 2012a, 2012b; Warnick, Thompson, & Gummer, 2004). Additionally, Heinert and Barrick (2015) established a framework which aligned agricultural education and STEM disciplinary core ideas with the *Agriculture, Food and Natural Resources (AFNR) Career Cluster Content Standards* (The Council, 2015a), and the *Next Generation Science Standards* (NGSS, 2013). Specifically, regarding future employment, agricultural education has been identified as a foundation for providing career development (Baker, Robinson, & Kolb, 2012; Roberts & Ball, 2009). Furthermore, agricultural education teachers are charged with developing knowledge and skills in their students by creating experiences from which connections can be made to future careers (Arnold, Warner, & Osborne, 2006).

Bunshaft et al. (2015) suggested STEM employability skills may be best developed through engaging students in career focused experiential learning as, "Experiential learning is a practical way for individuals to internalize Employability Skills within the context of a career" (p. 20). Henderson (2008) echoed this notion when it was observed that STEM education has experienced a shift from teacher-centered to student-centered. The Supervised Agricultural Experience (SAE) program found within the contemporary model of agricultural education is an effective medium through which students can further develop the STEM competencies (Smith & Rayfield, 2016) needed for employment in the 21st century. While involved in an SAE, students are able to explore multiple careers and occupations, develop and apply industry-specific and occupational skills, and learn professional workplace behavior (National FFA Organization, 2017). SAE involvement enables students to make management decisions, demonstrate scientific knowledge through research-based SAEs, and plan projects (National FFA Organization, 2017), which have been identified as competencies needed for contemporary STEM careers (Jang, 2016). Regarding technical knowledge, Wooten, Rayfield, and Moore (2013) identified 21 STEM concepts to which students may be exposed or experience while involved in junior livestock projects.

Career Development Events (CDEs), sponsored by the National FFA Organization, have been identified as a successful experiential learning model to engage students in STEM fields (Bunshaft et al., 2015). These events focus on career exploration, development, and preparation. Career Development Events seek to challenge participants to develop skills in critical thinking, decision-making, teamwork, and communication (National FFA Organization, 2017). Lundry, Ramsey, Edwards, and Robinson (2015) found participation in CDEs provided participants knowledge of agricultural careers, and the potential for career preparation. These researchers also identified 24 workplace skills, in addition to content or technical science and mathematics skills, desired by employers seeking qualified candidates for careers in the 21st century.

Conceptual Framework

Experiential learning has served as a foundation for agricultural education (Moore & Krueger, 2005). Within the context of agricultural education, Knobloch (2003) identified four principles of experiential learning including, learning through real-life context, learning by doing, learning through projects, and learning through problem-solving. These tenets align with standards which guide authentic learning and provide a "sound psychological framework for learning" (Retallick & Martin, 2008, p. 29). Baker et al. (2012) attempted to clarify the connection between experiential learning and agricultural education. These researchers concluded experiential learning should "(a) encompass each of the three components of the agricultural education model, (b) require purposeful and planned support from the agricultural education instructor, (c) lead to the development of important meta-cognitive skills, and (d) include curriculum planning and assessment" (p.6).

Dewey (1938) believed there was an inherent connection between education and personal experience and that the impact hinged on the experience quality and its connection to later experiences (Retallick & Martin, 2008). Dewey further described the continuity of experience where "every experience both takes up something from those which have gone before and modifies in some way the quality of those which come after" (p. 35). The project method, as described by Kilpatrick (1918), is purposeful and has utility for learning. Stimson (1915) expanded upon the premise of utility for learning when he explained students were better able to retain abstract concepts when they had the opportunity to apply those concepts in concrete experiences.

Kolb (1984) described experiential learning as a method to examine and strengthen the relationships between education, work, and personal development. The "combination of grasping experience and transforming it" (Kolb, 1984, p. 41) creates knowledge. Kolb (2015) further conceptualized learning as process, which is continuous and grounded experience; and the process of learning requires the resolution of conflicts between opposed modes of adaption to the world. Using these as a foundation, Kolb (2015) based his experiential learning cycle on three additional characteristics:

1. Learning is a holistic process of adaption to the world
2. Learning involves transactions between the person and the environment
3. Learning is the process of creating knowledge (as cited in Smith, 2015).

As a result, Kolb conceptualized the process of the experiential learning cycle. The model includes two sets of dialectically opposed approaches to learning: Active Experimentation (AE) and Reflective Observation (RO) in relation to the perception of information, and Concrete Experience (CE) and Abstract Conceptualism (AC) in relation to information processing. Kolb and Kolb (2013) further defined each mode of learning. Active Experimentation (AE) is "learning by doing", Concrete Experience (CE) is "learning by feeling", Reflective Observation (RO) is "learning by watching", and Abstract Conceptualization (AC) is "learning by thinking" (Kolb & Kolb, 2005, p. 10).

When integrated with the agricultural education model, the model of experiential learning theory (ELT) illustrates the total and comprehensive learning experience of agricultural education (Baker et al., 2012). While McLean and Camp (2000) indicated the SAE component of the model has been traditionally known as the experiential element of the model, Baker et al. (2012) explored the concept that all three components of the model "fit nicely into the experiential learning cycle" (p. 6). These researchers further explained, within the context of the experiential learning cycle, the classroom/laboratory component of the agricultural education model was related to the abstract, while the FFA is more concrete and reflective.

When the agricultural education model is combined with the experiential learning model, a more comprehensive illustration is provided as "Agricultural education has a great advantage in that the entire program is so easily experiential" (Baker et al., 2012, p.6). While these researchers indicated the direct connection between classroom instruction and SAEs is insignificant, this activity allows students to identify an area of interest from which to build a project that can be used to create a synergy enabling both components to inform the other. Most importantly, the interconnectedness of the model aids in the development of *meta-learning* (Baker et al., 2012) which refers to applying learned information to implement a plan by which problems are solved. The resulting *meta-skills* can then be used to support classroom instruction and FFA components, as well (Baker et al., 2012). The conceptualized model of contemporary agricultural education illustrated by Baker et al. (2012) guiding this study is identified in Figure 1.

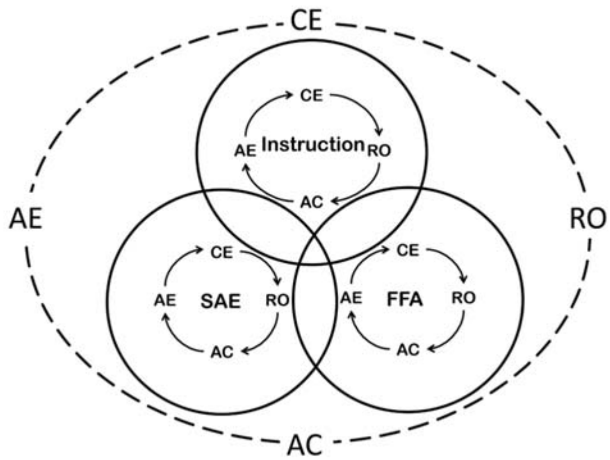

Figure 1. Comprehensive Model for Secondary Agricultural Education. (Baker, Robinson, & Kolb, 2012, p. 9). Reprinted with permission.

Purpose of the Study

Scherer et al. (2017) indicated a need for establishing a framework for connecting AFNR and STEM learning to lay the foundation from which "research can evaluate, revise, and extend" (p. 506). Furthermore, Scherer, et al. identified a lack of coordination between STEM and AFNR education literature thus, impeding the advancement of both. However, clearly articulating the relationship between STEM and AFNR may assist AFNR education to address student career preparedness in STEM fields. Therefore, the purpose of this study, through systematic analysis of existing documents, was to articulate the interconnectedness of STEM and AFNR education in order to inform research and innovations in practice. To achieve this purpose, the following research questions guided this study:

1. Where do STEM content competencies exist in the Agriculture, Food and Natural Resources (AFNR) Career Cluster Content Standards (The Council, 2015a)?
2. Are STEM career readiness competencies present in National FFA CDEs?
3. Are STEM content competencies embedded in SAEs?

Methods

STEM content competencies included in the classroom and laboratory instruction component of the agricultural education model were identified by analyzing the standards found in the *Agriculture, Food and Natural Resources (AFNR) Career Cluster Example Crosswalks* (The Council, 2015b). The researcher, along with two additional teacher education faculty, determined the existence of STEM content competencies, by systematically reviewing each content standard, along with the associated performance indicators, and sample measurements. Each standard was assessed for STEM competencies guided by the *Common Core Mathematics Standards* (NGA Center/CCSSO, 2010) and the *Next Generation Science Standards* (NGSS, 2013). STEM technical content competencies in each standard were identified using directions outlined in the *Agriculture, Food and Natural Resources (AFNR) Career Cluster Example Crosswalks*, which noted, "for a crosswalk to be established, the content of the cross-walked standard must be explicitly taught in order to attain the related Performance Indicator in the AFNR Content Standards given the stated sample measurements" (p. 1). Inter-rater reliability (Ary, Jacobs, Razavieh, & Sorensen, 2006) was established for all document analyses by comparing individual competencies and reconciling differences through consensus.

To determine the STEM career readiness competencies existing in National FFA CDEs, a document analysis was conducted of the affiliated crosswalk standards found in each CDE handbook. The *STEM Career Cluster: Cluster Knowledge and Skill Statements* (Advance CTE, 2008) served as the framework for this analysis. AFNR Career Cluster Content Standards are identified in a matrix within each CDE handbook. Within the matrix, performance measurement levels, event activities addressing measurements, and related academic standards are identified. The research team assessed each AFNR standard and any affiliated cross-walked standard to determine what STEM career statement was present. To maintain the integrity of the analysis, no attempts were made to identify additional *STEM Career Cluster: Cluster Knowledge and Skill Statements* present in the CDEs.

STEM technical knowledge existing in SAEs was assessed using the affiliated science standards (NGSS, 2013) cross-walked within the *Agriculture, Food and Natural Resources (AFNR) Career Cluster Content Standards* (The Council, 2015a) as established by Heinert and Barrick (2015). STEM technical content competencies in SAEs were identified through document analysis of National FFA proficiency award applications and *A Framework for Agricultural STEM Education: Aligning Ag-STEM Disciplinary Core Ideas with the Agriculture, Food and Natural Resource Standards and the Next Generation Science Standards* (Heinert & Barrick, 2015). For this portion of the study, SAEs were categorized as Animal Systems, Biotechnology Systems, Environmental Service Systems, Food Products and Processing Systems, Natural Resource Systems, Plant Science Systems, and Power, Structural and Technical Systems. As a component of each National FFA Proficiency Award application, the FFA member completing the application must identify which system pathway their SAE most closely aligns. Within the pathway, each applicant must identify five skills, competencies, and/or knowledge affiliated with an AFNR performance indicator and discuss how the performance indicator contributed to the success of their SAE and resulting proficiency award. Using the framework established by Heinert and Barrick, the research team identified the disciplinary core idea affiliated with each AFNR performance indicator FFA members can reference when discussing its contribution to their SAE. Once the Disciplinary Core Ideas were identified for each SAE pathway, the research team utilized the framework to identify with which, if any, Next Generation Science Standard was affiliated.

Findings

The focus of Objective 1 was to identify STEM content competencies currently embedded in the *Agriculture, Food and Natural Resources (AFNR) Career Cluster Content Standards* (The Council, 2015a). Displayed in Table 1, are the eight content pathways, and STEM content areas explicitly taught within each pathway. At least one STEM content area competency is taught in all pathways, with content representing all areas of STEM present in the Environmental Service Systems Pathway.

Table 1

Technical STEM Content Explicitly Taught in AFNR Career Cluster Pathways

AFNR Cluster Pathway	Explicitly Taught STEM Content
Agribusiness Systems	Math
Animal Systems	Science, Engineering, Math
Biotechnology Systems	Science, Engineering
Environmental Service Systems	Science, Technology, Engineering, Math
Food Products and Processing Systems	Engineering
Natural Resource Systems	Science, Math
Plant Systems	Science, Math
Power, Structural and Technical Systems	Science, Engineering

Objective 2 sought to identify STEM career readiness competencies present in National FFA CDEs. The *STEM Career Cluster: Cluster Knowledge and Skill Statements* (Advance CTE, 2008) are, when applicable, cross-walked in the matrix within each handbook as they relate to AFNR Career Cluster Content Standards performance measurement levels. Per CDE, STEM career readiness competencies existed at a mean frequency of 1.94 (*SD* = 1.51). Agricultural Communications, Agricultural Sales, Farm and Business Management, Food Science and Technology, and the Marketing Plan CDEs did not include STEM career readiness cross-walked standards. The Environmental and Natural Resources CDE included five STEM career readiness cross-walked standards. A visual representation of these findings can be found in Table 2.

Table 2

Existence of STEM Career Cluster: Cluster Knowledge and Skill Statements in National FFA Career Development Events

National FFA Career Development Events	STEM Career Cluster Knowledge & Skill Statements									
	SCC 01	SCC 02	SCC 03	SCC 04	SCC 05	SCC 06	SCC 07	SCC 08	SCC 09	SCC 10
Ag Mechanics				x	x					
Agronomy	x			x						
Dairy Cattle	x			x	x					
Environmental & Natural Resources	x	x	x	x		x				
Floriculture				x						
Forestry	x	x	x							
Horse Evaluation	x			x	x					
Livestock	x			x	x					
Meats Evaluation	x			x	x					
Milk Quality	x									
Nursery / Landscape		x	x	x						
Poultry	x			x	x					
Vet. Science	x			x	x					

Note. SCC01 = Academic Foundations; SCC02 = Communications; SCC03 = Problem-Solving and Critical Thinking; SCC04 = Information Technology Applications; SCC05 = [Organizational] Systems; SCC06 = Safety, Health, and Environmental; SCC07 = Leadership and Teamwork; SCC08 = Ethics and Legal Responsibilities; SCC09 = Employability and Career Development; SCC10 = Technical Skills (Advance CTE, 2008).

Objective 3 was to identify STEM technical content competencies in SAEs. Establishing STEM competencies embedded in SAEs was accomplished by identifying Next Generation Science Standards (NGSS, 2013) cross-walked with Agriculture, Food and Natural Resources (AFNR) Career Cluster Content Standards (The Council, 2015a) Performance Indicators used by FFA members when describing their SAEs within National FFA Proficiency Award applications. Using the Agriculture, Food and Natural Resources (AFNR) Career Cluster Content Standards (The Council, 2015a) as a guide, SAEs were categorized as Animal Systems, Biotechnology Systems, Environmental Service Systems, Food Products and Processing Systems, Natural Resource Systems, Plant Science Systems, and Power, Structural and Technical Systems. As identified by Heinert and Barrick (2015), the Agriculture, Food and Natural Resources (AFNR) Career Cluster Content Standards (The Council, 2015a) include systems pathways with inherent STEM concepts, which include performance indicators associated with disciplinary core ideas. Heinert and Barrick identified multiple performance indicators which affiliate with multiple disciplinary core ideas. Table 3 summarizes the number of performance indicators and disciplinary core ideas found within each system pathway (Heinert & Barrick, 2015).

Table 3

Number of Performance Indicators and Disciplinary Core Ideas within each Agriculture, Food and Natural Resources (AFNR) Career Cluster Content Standards (The Council, 2015a)

AFNR Content Standard System Pathway	Performance Indicators	Disciplinary Core Ideas
Animal Systems	17	20
Biotechnology Systems	11	14
Environmental Service Systems	16	20
Food Products and Processing Systems	10	23
Natural Resource Systems	13	24
Plant Systems	12	22
Power, Structural and Technical Systems	18	20

Heinert and Barrick (2015) identified 63 of the 143 AFNR disciplinary core ideas were associated with *Next Generation Science Standards* (NGSS, 2013). Forty (28%) disciplinary core ideas were associated with life science, 14 (10%) with physical science, eight (6%) with earth and space science, and six (4%) with engineering, technology, and applications of science. It should be noted, six ANFR disciplinary core ideas were associated with more than one *Next Generation Science Standard* (NGSS, 2013) performance expectation. Table 4 outlines the specific AFNR disciplinary core ideas, as identified by Heinert and Barrick, proficiency award applicants may include in their applications and the affiliated *Next Generation Science Standards* (NGSS, 2013) performance expectation.

Table 4

AFNR Disciplinary Core Ideas Associated with Next Generation Science Standard Performance Expectations (NGSS, 2013)

AFNR Pathway/Disciplinary Core Idea	NGSS Performance Expectation
Animal Systems	
Anatomy and physiology of animals	LS
Animal Nutrition	LS
Genetics	LS
Management practices for livestock and animals	LS
Animal behavior and management systems	LS
Animal production systems	ETS

Table 4 (continued)

AFNR Disciplinary Core Ideas Associated with Next Generation Science Standard Performance Expectations (NGSS, 2013)

AFNR Pathway/Disciplinary Core Idea	NGSS Performance Expectation

Global significance of animal agriculture	LS, ESS, ETS
Innovations and applied technologies within animal systems	PS
Veterinary technology	PS
Taxonomy and classification	LS
Energy and its transformation in animal systems	LS
Domestication and evolution of species and breeds	LS
Biodiversity and humans	LS
Data analysis and probability	LS
Biotechnology Systems	
Genetics	LS
Chemical reactions	PS
Ethical and cultural issues in biotechnology	LS, ETS
Biofuels	PS
Macromolecules	LS
World food systems	LS
World population	LS
Environmental Service Systems	
Wildlife management	LS
Ecosystem	LS
Humans and the environment	LS, ETS
Land use management at different levels	ESS
Ecology: earth's systems and cycles	LS
Sustainability of human systems	LS
Global environmental phenomenon & trends	ESS
Innovations & applied technologies within environmental service systems	PS, LS
Environmental technologies	PS
Climate change	ESS
Data analysis, quantitative reasoning and calculation	LS

Table 4 (continued)

AFNR Disciplinary Core Ideas Associated with Next Generation Science Standard Performance Expectations (NGSS, 2013)

AFNR Pathway/Disciplinary Core Idea	NGSS Performance Expectation
Food Products and Processing Systems	
Chemistry of food	LS

Food security	ETS
Sustainable food production across the globe	LS
Genetically modified foods and biotechnology	LS
Natural Resource Systems	
Biodiversity	LS
Natural resource management	ESS
Wildlife habitat	LS
Use of natural resources	ESS
Sustainability	ETS
Interaction of humans and natural resources	LS, ESS
Ecosystem and energy transfer	LS
Forestry and timber systems	LS
Energy	PS
Cycles of matter	LS
Innovations and applied technologies within natural resource systems	PS, ESS
Climate change	ESS
Economics of resource utilization	ESS
Data analysis, quantitative reasoning and calculation	LS
Plant Science Systems	
Anatomy and physiology of plants	LS
Genetics	LS
Plant reproduction	LS
Environmental effects on plants	LS
Growth and development of organisms	LS
Biodiversity	LS
Innovations and applied technologies within plant systems	PS
Hormones	LS
Energy conversion	PS

Table 4 (continued)

AFNR Disciplinary Core Ideas Associated with Next Generation Science Standard Performance Expectations (NGSS, 2013)

AFNR Pathway/Disciplinary Core Idea	NGSS Performance Expectation
Power, Structural and Technical Systems	
Sources of power	PS
Innovations and applied technologies within power, structural and technical systems	PS

Metallurgy	PS
Forces	PS

Note. ESS = Earth & Space Science; ETS = Engineering, Technology, & Applications of Science; LS = Life Science; PS = Physical Science (NGSS, 2013).

Conclusions

Supported by the findings of this study, AFNR and STEM are complex systems of knowledge and skills with overlapping ideas, concepts and abilities (Scherer et al., 2017). The *Agriculture, Food and Natural Resources (AFNR) Career Cluster Content Standards* (The Council, 2015a) are replete with STEM content and competencies. While technical STEM content is present in all pathways, it should be clearly noted, the identification of STEM knowledge and skills were limited to content that can be explicitly taught within curriculum grounded in the standards. Except for Agribusiness Systems, competencies within at least two STEM content areas can be explicitly taught within the remaining pathway standards. The most common areas, falling under STEM, in the standards are science and math. Engineering and technology are present, but to a lesser degree. The Environmental Service Systems Pathway serves as a broad foundation to develop curriculum to explicitly teach technical content in all areas falling under the STEM framework. Nevertheless, agricultural education serves as an effective context in which to teach and reinforce STEM technical content.

It is well known and documented, experiential learning activities engage students in authentic scenarios which support deeper and more complete content knowledge acquisition and application (Smith, 2015). Furthermore, experiential learning methods can be used to teach employability skills more effectively (Bunshaft et al., 2015). The findings from this study support the position of Wooten et al. (2013) who concluded STEM concepts exist in SAEs. Not only is STEM technical knowledge present in SAEs but, STEM-based employability. As the SAE program is inherently experiential, engaged participation in SAEs provides an effective medium to support STEM content knowledge acquisition and skill development in secondary AFNR students.

Bunshaft et al. (2015) indicated the National FFA Organization's CDE program is an excellent career focused experiential learning model for developing STEM-based employability skills. The findings further support the conclusions of Bunshaft et al. and Lundry et al. (2015) that participation in CDEs exposes students to workplace competencies needed in the 21st century. The inclusion of team activities within the current CDE model provides, yet, another medium to engage students in scenarios which support effective workplace employability competencies. It should be further noted, while CDEs may not implicitly develop STEM content and competency knowledge, they do create an environment where participants are required to apply STEM content knowledge.

The findings from this study suggest STEM and AFNR education are not separate, standalone concepts. By its very nature, a comprehensive education in agriculture, food, and natural resources exposes students to and engages them in learning environments which support the development of content knowledge and skills required by contemporary and future STEM-based agriculture careers. Therefore, based upon the findings from this study, a modification to the current model of Agricultural Education (Phipps & Osborne, 1988) to include STEM education is proposed. The proposed model is illustrated in Figure 2.

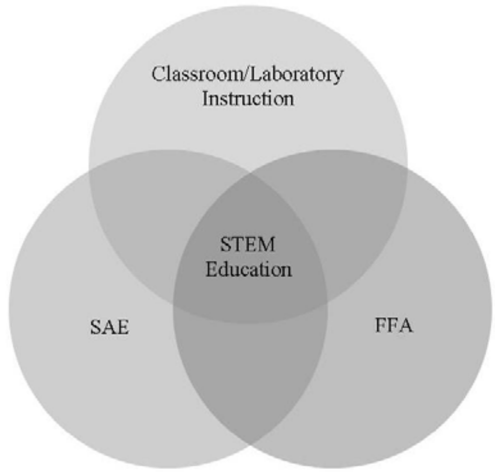

Figure 2. Agricultural STEM Education Model

Discussion

As the agricultural education profession promotes its place in the education fabric of the United States, as well as the global economy, the active enhancement of STEM education is imperative. It is clear, to be a successful member of today's professional workforce, STEM knowledge and workplace employability skills are required. STEM education is naturally inherent to the standards by which agricultural education curriculum is developed and implemented. As the agricultural education profession self-evaluates, the concept of STEM education should be viewed as an integral component and not a concept viewed as separate, with the potential to be infused. Through examination of the vast STEM-AFNR paradigm, the agricultural education profession shoulders the responsibility to support future teachers and students by conducting methodologically sound research to explore the most effective methods by which the future workforce may be prepared.

The proposed model herein was not conceptualized for perpetuity. Rather, it is to be used as a foundation to support future research with the expectation that agricultural education scholars will continue to produce findings supporting STEM-AFNR education. It is my desire that the quality research produced by scholars will inform the profession in a manner which supports the conceptualization of a more comprehensive model to guide the academic preparation of future generations of STEM-AFNR students and professionals.

Recommendations for Practice

Based upon the findings and conclusions of this study, several recommendations are proposed. As the profession continues to solidify its place in education, teacher preparation faculty are encouraged to support the concept of the interconnected nature of STEM-AFNR principles. These professionals are encouraged to continue to incorporate effective methods to teach and highlight STEM concepts within the context of agricultural education.

As CDEs and SAEs are key components and sub-components within the agricultural education model, SBAE teachers are encouraged to continue implementing those elements into comprehensive agricultural education programs. Teacher educators should continue to support well-rounded SBAE programs by incorporating effective instructional strategies regarding implementation of SAEs and additional FFA activities in preservice teacher education programs. STEM career readiness skills are present in National FFA CDEs. However, while not all STEM career standards are specifically noted in the CDE Handbook content standards matrices, the CDEs do require the skills necessary for future employment. It is further suggested to more deeply assess the STEM career readiness competencies and technical content existing within the specific CDEs.

Agricultural education provides an effective context in which to teach and enhance STEM concepts. Therefore, SBAE teachers along with college and university AFNR faculty should continue to promote the effective context agricultural education provides to teach STEM technical knowledge and career readiness skills to the general public and non-AFNR teachers, faculty, and education administrators.

Recommendations for Research

Future research studies should assess the efficacy for teaching STEM concepts in agriculture by incorporating the science, technology, engineering, and math standards cross-walked in the existing *Agriculture, Food and Natural Resources (AFNR) Career Cluster Content Standards* (The Council, 2015a). Implementing the cross-walked standards may provide insight into specific needs for which inservice teachers require additional support. To support this, future research should be conducted to determine the specific content topics which are not only explicitly taught, but those topics which can be highlighted within the existing *Agriculture, Food and Natural Resources (AFNR) Career Cluster Content Standards* (The Council, 2015a).

As agricultural education can be viewed as a context for teaching abstract STEM concepts (Myers & Dyer, 2004), little research exists documenting the best methods to deliver this content (Stone, 2011). However, Smith (2015) indicated grounding agricultural education in experiential learning theory along with differentiated instruction through cognitive sequencing, meeting the challenge to teach STEM concepts more effectively in agricultural education may be realized. Education researchers should continue to investigate effective teaching methods, both formal and informal, by which STEM concepts can be explicitly taught and highlighted. Findings from this research are recommended for implementation to better prepare preservice teachers to effectively employ those strategies within AFNR curriculum.

References

Ary, D., Jacobs, Razavieh, A., & Sorenson, C. (2006). *Introduction to research in education* (7th ed.) Belmont, CA: Thomson Wadsworth.

Advance CTE. (2008). *Science, technology, engineering and mathematics career cluster: Cluster knowledge and skill statements.* Silver Spring, MD: Advance CTE: State Leaders Connecting Learning to Work.

Arnold, S., Warner, W. J., & Osborne, E. W. (2006). Experiential learning in secondary agricultural education classrooms. *Journal of Southern Agricultural Education Research. 56*, 30-39.

Baker, M. A., Robinson, J. S., & Kolb, D. A. (2012). Aligning Kolb's experiential learning theory with a comprehensive agricultural education model. *Journal of Agricultural Education, 54*(4), 1-16. doi: 10.5032/jae.2012.04001

Boone, H. N., Gartin, S. A., Boone, D. A., & Hughes, J. E. (2006). Modernizing the agricultural education curriculum: An analysis of agricultural education teachers' attitudes, knowledge, and understanding of biotechnology. *Journal of Agricultural Education, 47*(1), 78-89. doi: 10.5032/jae.2006.01078

Brister, M. H., & Swortzel, K. A. (2009). *A comparison of attitudes of agriscience teachers, counselors, and administrators toward science integration with student attitudes toward agriscience programs*. Paper presented at the American Association for Agricultural Education Research Conference, Louisville, KY.

Bunshaft, A., Boyington, D., Curtis-Fisk, J., Edwards, T., Gerstein, A., & Jacobson, C. (2015). *Focus on employability skills points to experiential learning.* A publication by STEMconnector's STEM Innovation Task Force.

Clark, A. R. (2013). *Effects of integrating mathematical concepts into an animal science curriculum* (Master's thesis, Utah State University). Retrieved from http://digitalcommons.usu.edu/etd/1950/

Conroy, C. A., Dailey, A. L., & Shelley-Tolbert, C. A. (2000). The move to agriscience and its impact on teacher education in agriculture. *Journal of Agricultural Education*, *41*(4), 51-61. doi: 10.5032/jae.2000.04051

Crawley, E., Malmqvist, J., Östlund, S., & Brodeur, D. (2007). *Rethinking engineering education: The CDIO approach*. New York: Springer.

Dewey, J. (1938). *Education and experience*. New York, NY: Simon and Schuster.

Dobbs, R., Madgavkar, A., Barton, D., Labaye, E., Manika, J., Lund, S., & Madhav, S. (2012). *The world at work: Jobs, pay and skills for 3.5 billion people.* McKinsey Global Institute.

Ferrini-Mundy, J. (2013). STEM education: The administration's proposed reorganization. Presented to the *Committee on Science, Space, and Technology, U.S. House of Representatives.* Washington, DC.

Gordon, E. (2009). The global talent crisis. *The Futurist, 43*(4), 34-39.

Haynes, J. C., Robinson, J. S., Edwards, M. C., & Key, J. P. (2012). Assessing the effect of using a science-enhanced curriculum to improve agriculture students' science scores: A causal comparative study. *Journal of Agricultural Education*, *53*(2), 15-27. doi: 10.5032/jae.2012.02015

Heinert, S., & Barrick, R. K. (2015). *A framework for agricultural STEM education.* Retrieved from http://aec.ifas.ufl.edu/docs/AGSTEM.pdf

Henderson, C. (2008). Promoting instructional change in new faculty: An evaluation of the physics and astronomy new faculty workshop. *American Journal of Physics, 76*(2), 179-187.

Hung-Lian, T., Lee, S., & Koh, S. (2000). Educational gaps as perceived by IS educators: A survey of knowledge and skill requirements. *The Journal of Computer Information Systems, 41*(2), 76.

Jang, H. (2016). Identifying 21st century STEM competencies using workplace data. *Journal of Science Education and Technology, 25*(2), 284-301.

Johnson, D. M. (1996). Science credit for agriculture: Perceived support, preferred implementation methods, and teacher science course work. *Journal of Agricultural Education, 37*(1), 22-30. doi: 10.5032/jae.1996.01022

Kilpatrick, W. H. (1918). The project method. *Teachers College Record, 19*(4), 319-335.

Knobloch, N. A. (2003). Is experiential learning authentic? *Journal of Agricultural Education, 44*(4), 22–34. doi: 10.5032/jae.2003.04022

Kolb D. (1984). *Experiential learning as the science of learning and development*. Englewood Cliffs, NJ: Prentice Hall.

Kolb, A. Y., & Kolb, D. A. (2005). *The Kolb Learning Style Inventory version 3.1 2005 technical specifications.* Philadelphia, PA: HayGroup. Retrieved from http://learningfromexperience.com/media/2010/08/tech_spec_lsi.pdf

Kolb, A. Y., & Kolb, D. A. (2013). *Kolb Learning Style Inventory workbook version 3.2.* Philadelphia, PA: HayGroup.

Kolb, D. A. (2015). *Experiential learning: Experience as the source of learning and development* (2nd ed.). Upper Saddle River, NJ: Pearson Education, Inc.

Lundry, J., Ramsey, J. W., Edwards, M. C., & Robinson, J. S. (2015). Benefits of career development events as perceived by school-based, agricultural education teachers. *Journal of Agricultural Education, 56*(1). 43-57. doi: 10.5032/jae.2015.01043

McLean, R. C., & Camp, W. G. (2000). An examination of selected agricultural teacher education programs in the United States. *Journal of Agricultural Education, 41*(2), 23–35. doi: 10.5032/jae.2000.02023

Moore, E. A., & Krueger, D. (2005). Contributions of agricultural education to the goals of education, the economy, and priorities for the future. In *Agricultural Education and the FFA: Remarkable achievements, challenges, and opportunities in an ever-changing global society.* White paper commissioned by the National Council for Agricultural Education.

Myers, B. E., & Dyer, J. E. (2004). Agriculture teacher education programs: A synthesis of the literature. *Journal of Agricultural Education, 45*(3), 44-52. doi: 10.5032/jae.2004.03044

Myers, B. E., & Thompson, G. W. (2006). Integrating academics into agriculture programs: A delphi study to determine perceptions of the national agriscience teacher ambassador academy participants. *Journal of Agricultural Education, 47*(4), 77-88. doi: 10.5032/jae.2006.04044

Myers, B. E., & Washburn, S. G. (2008). Integrating science in the agriculture curriculum: agriculture teacher perceptions of the opportunities, barriers, and impact on student enrollment. *Journal of Agricultural Education, 49*(2), 27-37. doi: 10.5032/jae.2008.02027

National FFA Organization. (2017). *Supervised agricultural experiences.* Retrieved from: https://www.ffa.org/about/supervised-agricultural-experiences

National Governors Association Center for Best Practices, Council of Chief State School Officers. (2010). *Common core state standards (mathematics)*. Washington, DC: National Governors Association Center for Best Practices, Council of Chief State School Officers.

National Research Council. (2011). *Assessing 21st century skills: Summary of a workshop.* Washington, DC: The National Academics Press.

NGSS Lead States. (2013). *Next generation science standards: For states, by states.* Washington, DC: The National Academies Press.

Parr, B. A., Edwards, M. C., & Leising, J. G. (2006). Effects of a math-enhanced curriculum and instructional approach on the mathematics achievement of agricultural power and technology students: An experimental study. *Journal of Agricultural Education*, *47*(3), 81-93. doi: 10.5032/jae.2006.03081

Parr, B., Edwards, M. C., & Leising, J. G. (2009). Selected effects of a curriculum integration intervention on the mathematics performance of secondary students enrolled in an agricultural power and technology course: An experimental study. *Journal of Agricultural Education*, *50*(1), 57-69. doi: 10.5032/jae.2006.01057

Phipps, L. J., & Osborne, E. W. (1988). *Handbook on agricultural education in public schools* (5th ed.). Danville, IL: The Interstate Printers & Publishers, Inc.

Phipps, L. J., Osborne, E. W., Dyer, J. E., & Ball, A. (2008). *Handbook on agricultural education in public schools* (6th ed.). Clifton Park, NY: Delmar.

Radermacher, A., & Walia, G. (2013). Gaps between industry expectations and the abilities of graduates. Paper presented at the *Proceeding of the 44th ACM technical symposium on Computer Science Education*.

Retallick, M. S., & Martin, R. (2008). Fifteen-year enrollment trends related to the three components of comprehensive agricultural education programs. *Journal of Agricultural Education, 49*(1), 28-38. doi: 10.5032/jae.2008.01028

Ricketts, J. C., Duncan, D. W., & Peake, J. B. (2006). Science achievement of high school students in complete programs of agriscience education. *Journal of Agricultural Education, 47*(2), 48-55. doi: 10.5032/jae.2006.02048

Roberts, T. G., & Ball, A. L. (2009). Secondary agricultural science as content and context for teaching. *Journal of Agricultural Education, 50*(1), 81-91. doi: 10.5032/jae.2009.01081

Scales, J., Terry Jr, R., & Torres, R. M. (2009). Are teachers ready to integrate science concepts into secondary agriculture programs? *Journal of Agricultural Education, 50*(2), 102-113. doi: 10.5032/jae.2009.02102

Scherer, H., McKim, A., Wang, H., DiBenedetto, C., & Robinson, K. (2017). Making sense of the buzz: Providing a taxonomy of "STEM" in agriculture, food, and natural resource education. Presented at the *National AAAE Research Conference,* San Luis Obispo, CA.

Shinn, G.C., Briers, G.E., Christiansen, J.E., Edwards, M.C., Harlin, J.F., Lawver, D.E., et al. (2003). *Improving student achievement in mathematics: An important role for secondary agricultural education in the 21st century.* Monograph, National Council for Agricultural Education. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/summary doi: 10.1.1.130.5829

Smith, K. L. (2015). *A quasi-experimental examination of the effects of cognitive sequencing on STEM concept integration in agricultural education* (Unpublished doctoral dissertation). Texas A & M University, College Station, TX.

Smith, K. L., & Rayfield, J. (2016). An early historical examination of the educational intent of Supervised Agricultural Experiences (SAEs) and project-based learning in agricultural education. *Journal of Agricultural Education, 57(*2). 146-160. doi: 10.5032/jae.2016.02146

Smith, K. L., Rayfield, J., & McKim, B. R. (2015). Effective practices in STEM integration: Describing teacher perception and instruction use. Journal of Agricultural Education, 54(4). doi: 10.5032/jae.2015.04

Stimson, R. W. (1915). The Massachusetts home project plan of vocational agricultural education. *The School Review*, 474-478.

Stripling, C. T., & Roberts, T. G. (2012). Preservice agricultural education teachers' mathematics ability. *Journal of Agricultural Education, 53*(3), 28-41. doi: 10.5032/jae.2012.03028

Stone III, J. R. (2011, May). *Delivering STEM education through career and technical education.* Retrieved from http://www7.nationalacademies.org/bose/STEM_Schools_Workshop_Paper_Stone.pdf.

Stubbs, E. A., & Myers, B. E. (2016). Part of what we do: Teacher perceptions of STEM Successful STEM Education in K-12 Schools. *Journal of Agricultural Education, 57*(3), 87-100. doi:10.5032/jae.2016.03087

The Council for Agricultural Education. (2015a). *Agriculture, food and natural resources (AFNR) career cluster content standards*. Indianapolis, IN: The Council for Agricultural Education.

The Council for Agricultural Education. (2015b). *Agriculture, food and natural resources (AFNR) career cluster example crosswalks*. Indianapolis, IN: The Council for Agricultural Education.

Thompson, G. W., & Balschweid, M. M. (1999). Attitudes of Oregon agricultural science and technology teachers toward integrating science. *Journal of Agricultural Education*, *40*(2), 21-29. doi: 10.5032/jae.1999.02021

Thompson, G. W., & Balschweid, M. M. (2000). Integrating science into agriculture programs: Implications for addressing state standards and teacher preparation programs. *Journal of Agricultural Education, 41*(2), 73-80. doi: 10.5032/jae.2000.02073

Thoron, A. C., & Myers, B. E. (2012a). Effects of inquiry–based agriscience instruction and subject matter–based instruction on student argumentation skills. *Journal of Agricultural Education, 53*(2), 58-69. doi: 10.5032/jae.2012.02058

Thoron, A. C., & Myers, B. E. (2012b). Effects of inquiry–based agriscience instruction on student scientific reasoning. *Journal of Agricultural Education*, *53*(4), 156-170. doi: 10.5032/jae.2012.04156

Warnick, B. K., Thompson, G. W., & Gummer, E. S. (2004). Perceptions of science teachers regarding the integration of science into the agricultural education curriculum. *Journal of Agricultural Education, 45*(1), 62-73. doi: 10.5032/jae.2004.02073

Wooten, K., Rayfield, J., & Moore, L. L. (2013). Identifying STEM concepts associated with junior livestock projects. *Journal of Agricultural Education, 54*(4), 31-44. doi: 10.5032/jae.2013.04031