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Conceptualizing Integrative Agricultural Education: Introductory Framework for Integrating Mathematics in Agricultural Curriculum

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Abstract

A curriculum framework to support the integration of academic content to support students' development of 21st century skills including critical thinking and problems solving skills is notably absent from agricultural education. An integrative agricultural education framework is conceptualized through a review of literature in STEM education to establish integrative teaching practices. A focus on the development of students' quantitative reasoning skills through agriculture content hones the focus of the curriculum framework. Quantitative reasoning is the ability to confidently approach unique and complex problems in a real-life context by applying mathematical skill, knowledge, and reasoning. The integrative agricultural education framework developed was used to design an evaluative rubric for teachers, administrators, and curriculum designs to use as a tool for building both integrative teaching and mathematics into agricultural education curriculums intentionally and fluidly.

Keywords: STEM education, Agricultural Education, Quantitative Reasoning, Integrative Agricultural Education

Introduction

Preparing students for work and college is one of the primary goals of agricultural education teachers (Rice & Kitchel, 2017). As technology advances, the skills and knowledge required to be workplace ready continue to change. Specific technical skills and job-specific knowledge have given way to skills needed for creatively solving complex problems, effective communication, team work, and self-regulation. These skills are referred to as 21st century skills that promote student success. The National Research Council (NRC) (2011b) describes these skills further:

> These skills include being able to solve complex problems, to think critically about tasks, to effectively communicate with people from a variety of different cultures and using a variety of different techniques, to work in collaboration with others, to adapt to rapidly changing environments and conditions for preforming tasks, to effectively manage one's work, and to acquire new skills and information on one's own (p.1).

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The NRC report further proposes students must be prepared to see the big picture, be ready to face problems head-on with confidence, understand how to find new information when it is needed to solve problems and be able to work with other people as a team and contribute their skills and knowledge. Employers are seeking individuals who can communicate what they know and what they are doing in a manner that is clear, technically savvy, and appropriate for their audience. Additionally, it is highly desirable for employees to have quantitative reasoning skills (Steen, 2002) and be confident at addressing complex problems that involve complicated calculations and require problem-solving skills. While employers highly desire these skills, they are challenging to learn on the job (National Research Council, 2011b).

The development of 21st century skills, including quantitative reasoning, requires a context that provides focus for critical thinking and interest in problem-solving (Agustin, Agustin, Brunkow, & Thomas, 2012). Agriculture provides a wealth of context that is largely science-based and includes the integration of various forms of technology. Agricultural educators are familiar with utilizing a competency-based teaching approach as the driving force for student learning. Projects are common catalysts for learning in agricultural education. To include 21st century skill development in agricultural education instruction should be an easy transition with the foundational curriculum already established. Agriculture students may develop these skills without much teacher planning. However, with purposeful planning and intentional instruction, students will benefit from having well developed 21st century skills by engaging in opportunities to practice and sharpen these skills both in and out of the classroom. To ensure the purposeful inclusion of teaching practices to strengthen 21st century skills, teachers need tools to help them assess and improve their curriculum and teaching plans.

The goal of this article is to report on the literature used to establish a conceptual framework to guide development and teaching capacity around integrative instruction in agricultural education. The purpose of the article is to detail the emergent nature of the framework as it is intended to inform the discussion around integrative agricultural education (IAE) to refine the constructs of the framework through practice and research.

The discussion begins by framing the need for integrative pedagogy in agricultural education to support the development of students' 21st century skills for career and college readiness. The conceptualization of the integrative agricultural education framework began with a review of empirical research literature focused on integrative teaching practices in STEM (science, technology, engineering, and math) content areas to identify components relevant to instruction in agricultural education. A discussion of agricultural education as context introduces the current research in integrative practices in the field. The focus of the article will then turn to a single STEM-related concept, quantitative reasoning. Steen's (2002, 2004) concept of quantitative reasoning will be summarized to operationalize quantitative reasoning within agricultural education. The triangulated synthesis of empirical research in integrative teaching, constructs of quantitative reasoning, and current structure of in-school agricultural education will form the foundation for the conceptual framework for integrative agricultural education. A brief conclusion will provide an introduction to a piloted evaluation rubric and implications of the use of the tool and innovative curriculum concept.

Process of Review

A systematic review (Creamer, Simmons, and Yu, 2015) was conducted to develop a framework for integrative education with a specific connection to STEM education. Education databases ERIC and Education Research Complete were used for the search. The search was limited to literature and research in peer-reviewed publications published between 2000 and 2016.

This time frame ensured current research and literature that would be addressing this rather new approach in education. The search parameters used in the database search were: science, technology, engineering, and math education or STEM education. A total of 32 articles matched the initial parameters. A quick review of each article eliminated all but twelve articles for lack of inclusion of STEM education as a foundational aspect of the article or research. Two additional resources (Bybee, 2013; Wells, 2015) were hand-picked from recommendations of experts in the STEM education field. The literature resources were coded for themes focused on determining common characteristics of STEM education that were identified in the literature.

Review of Literature on Integrative Teaching

The goal of the literature review was to identify characteristics common to STEM education. The purpose of operationalizing STEM education was to use the characteristics and principles identified as the basis for the conceptual framework of integrative agricultural education.

Synthesis of literature revealed five characteristics of STEM education: (1) Instruction integrates two or more subject areas within a context; (2) Students' work should be practical and/or authentic; (3) Intentionally target critical thinking and problem-solving skill development; (4) Learning is student-centered; (5) Technology is regularly used (Asunda, 2012; Berlin & White, 2012; Bybee, 2013; Ejiwale, 2012; Foutz, et al., 2011; Hansen & Gonzalez, 2014; Kennedy & Odell, 2014; Laboy-Rush, 2011; Moye, Dugger, & Stark-Weather, 2014; Sahin & Top, 2015; Sanders, 2009; Stone, 2011; Wells, 2015; Zollman, 2012). Following is a brief discussion of each characteristic to better understand the elements used as guidance to develop the proposed integrative agricultural education framework.

Integrative Instruction

STEM education aims to teach concepts from two or more subject areas during the same instructional unit (Laboy-Rush, 2011; Sanders, 2009; Wells, 2015; Zollman, 2012) with the intention of demonstrating the connection between subjects (Sanders, 2009; Wells, 2015). Often, students miss the connections on their own thus it is an important factor of integration to make the connections obvious for students (Agustin et al., 2012). While some propose integrative STEM education intertwines multiple STEM subjects through the design process (Sanders, 2009), others provide an integrative approach through themes (Foutz et al., 2011; Hansen & Gonzalez, 2014; Sahin & Top, 2015). As a rule of thumb, the integrative nature of STEM education is about the context that drives the teaching and learning.

Context makes a recall of concepts more likely in the future (Driscoll, 2005; Hmelo-Silver, 2004; Steen, 2002) and helps establish transfer to other situations. Learning in context makes knowledge easier to apply in unique instances, and students understand how to use their knowledge in situations to come (Carpenter, 1986; Laboy-Rush, 2011, Wiggins, 2006). Within the context, students can think through problems in a way that makes sense to them (Koedinger & Nathan, 2004; Nathan, Kintsch, & Young, 1992; Moore & Carlson, 2012). As students construct their meanings, abstract concepts also begin to make sense because the context provides meaning and makes the concept useful (Nathan et al., 1992).

Authenticity

In integrative education, students learn by doing (Moye, Dugger, & Stark-Weather, 2014) in realistic or authentic situations that provide much of the same benefit as learning in context. What sets authenticity apart from context is how the presentation of the context to the students and how teaching and learning are focused on doing the math, science, and engineering in situations that are real or seem realistic to the students. When teachers plan for a context that is realistic, students are more engaged and see the relevance in the work they are doing (Shinn et al., 2003).

Authenticity is not about only doing hands-on activities, although that could be an option. To have authenticity, the activities and problems students work on and think about are always within the context of a real situation (Saunders, 2009; Zollman, 2012). Authentic problems are open-ended, do not provide a single path to the solution, and do not necessarily point the student toward the exact concept that will be needed before they dive into the work (Foutz et al., 2011; Laboy-Rush, 2011; National Council of Teachers of Mathematics [NCTM], 2000). Authentic activities are messy by their very nature (Chin & Chia, 2004).

Critical Thinking & Problem Solving

Kennedy and Odell (2014) consider STEM education the nexus between scientific inquiry and engineering design which has students asking questions and investigating ways to formulate and construct solutions. Critical thinking and problem-solving skills carry students through the inquiry and investigation of working in contexts they may not be familiar. With each new context used to present integrated academic concepts, students need time to learn about the context before working on the solution. Despite not being engaged with STEM content area learning initially, students are applying critical thinking and problem-solving techniques to explore the context, become familiar with the situation, and learn what they may need to know to work toward a solution (McCormick, 2004). With constant opportunities to practice critical thinking and problem solving, students develop a habit of mind rather than thinking of the process as a hurdle to jump in order to get to an answer; making critical thinking and problem solving "a lifelong ability to be ever refined and polished" (Cromwell, 1992, p. 41).

Student-Centered Learning

Student-centered instruction uses a student's prior knowledge as a starting point and focuses learning on students' interests and strengths (Laboy-Rush, 2011; Turner, 2011). STEM education uses authentic contexts to pique students' interest. In a well-planned learning situation, teachers can provide students with a need-to-know moment as they think through projects and problems looking for a viable solution (Ejiwale, 2012). While students are focused on learning about the context and begin to formulate designs for a solution, creative planning can draw students to a point where they discover they need to learn a STEM concept to move forward or to make the process easier (Hansen & Gonzalez, 2014; Wells, 2015). Providing students with scaffolding resources or activities build academic knowledge needed to move forward and find or design viable solutions (Hansen & Gonzales, 2014; Laboy-Rush, 2011).

Student-centered learning also opens the door for creativity and intuition to guide students' work toward solutions. Context may help some students work through their confusion because they can make sense of the situation from prior experiences or knowledge (Koedinger & Nathan, 2004; Nathan et al., 1992; Moore & Carlson, 2012). Reflecting on the context and determining what is known and what is needed, significantly moves students toward self-learning and metacognition (Turner, 2011; Zollman, 2012). Teachers need to be intentional about what concepts they want students to learn and plan authentic activities, projects, and problems that aim at those marks (Laboy-Rush, 2011, Turner, 2011; Wells, 2015).

Technology

Use of technology as a principle for defining STEM education is challenging. It would seem at first that technology means students are trained to use cutting-edge computer-based and electronic technologies (Kennedy & Odell, 2014). For others, use of technology means using technology to aid in the learning process through the use of computers, calculators, and similar educationally valuable tools (Ejiwale, 2012; Hansen & Gonzalez, 2014; Sahin & Top, 2015). These are all acceptable uses of technology and would certainly give students an advantage later in life because technology changes at such a rapid pace and is commonly used in most all settings. Looking past strictly computer-based technology makes use of technology in STEM education much more interesting. For some professions, tools of the trade and systems that provide assistance in the face of a problem are considered technology (Hansen & Gonzalez, 2014; Sanders, 2009; Wells, 2015; Zollman, 2014). It is these types of technologies that can be integrated into the context of agricultural education curriculum.

STEM education is learning by doing. Students learn skills that help them assess problems realistically and understand how to use what they know to begin working toward a solution. The path to that solution may be unique to the person designing the solution, but creativity and intuition are representative of STEM education. Always working in an authentic context, students learn abstract math and science concepts that are made meaningful when needed to apply technology to arrive at a solution. Connections are intentionally presented to students through careful teacher planning thus making connections obvious to students. Through authentic context, critical thinking and careful integration of two or more subject concepts, students develop a broad web of interconnected nodes of knowledge that through continued practice become transferable, real, and relevant to students.

Quantitative Reasoning

In 1983, the U.S. Government published *A Nation at Risk* which detailed the shortfalls of the education system to produce students that were science, math and technology literate (Gardner, Larsen, & Baker, 1983). Recommendations from this report were abundant, however, of particular concern is that quantitative reasoning is the realization that students needed to be able to "apply math in everyday situations and estimate, approximate, measure and test the accuracy of their calculations" (Gardner et al., 1983). Quantitative reasoning (QR) is often synonymous with quantitative literacy (QL) and numeracy (Steen, 2004; Wilkins, 2000) however QR takes the use of math skills, and mathematical knowledge to the next level by asking students to apply mathematical thinking to reason through instances when math skills alone may fail them (Cobb, 1997).

Quantitative reasoning is defined concisely in a combination of features proposed by Steen (2004) and Wilkins (2000): (1) Real-world engagement, (2) Application of math in unique situations, (3) Flexible understanding of math, (4) Understanding of the nature and history of the development of math, (5) A positive disposition toward math, (6) Ability to reason mathematically. In the National Council of Teachers of Mathematics (NCTM) (2000) standards for school mathematics, each of the six QL features are represented with common themes of logical reasoning and seeking out solutions to ill-structured problems. Explaining *why* rather than simply following procedures turns the focus of QL to reasoning. With reasoning as the focal point of mathematical teaching and learning, QR comes into focus.

Quantitative reasoning is being able to recognize and use math in real life situations. Quantitative reasoning skills are active in unique situations to make progress toward a solution more logical. Specific math skills and knowledge are not necessities of QR. However, the ability to understand what variables are present and understanding how to apply mathematical knowledge is QR. Applying intuition and critical thinking in situations involving numbers to arrive at a logical and viable solution are QR skills at work. Quantitative reasoning provides the flexibility of mathematical skill or knowledge learned in one context to be applied in a unique situation. Application of the skill or knowledge is still possible even when some features of the situation are slightly altered from the original in which it was learned. Having the confidence to tackle unfamiliar situations that involve numbers and math is also characteristic QR (Wilkins, 2000). It is important to point out that QR is not math (Steen, 2004) rather the understanding and ability to use math in tandem with real contexts (Steen, 1997). However, the foundation of QR is mathematical concepts (Cobb, 1997).

Quantitative reasoning requires a context to work in and for students to have a foundation of math concepts to develop QR skill. Often these math concepts are taught at an abstract level in math classes. In the perfect world of math class, students learn how mathematical relationships cultivate theorems and definitions. In general, these abstract mathematical ideas will hold true in the real world with some variation for real-life imperfections. Ironically, imperfections are what make authentic problems interesting and harder to solve (Gal, 1997; Steen 2004). Imperfections are needed to prompt students to recognize the need for critical thinking, but traditional math classes do not usually offer imperfect situations. Thus, the dilemma arises in identifying a contextual outlet to practice QR skills in interesting and problem-laden contexts.

Agricultural Education as Context for Learning Academic Content

Context plays an important role in both STEM education and in the development of QR skills (Agustin et al, 2012). Context brings interest, meaning, and applicability to the learning process. A broad-based context that is relevant to students and requires active participation by doing, mentally and physically, during learning would provide the most effective stage for STEM education that supports QR skill development. Agricultural education is typically a hands-on, project-driven curriculum that covers a wide variety of agriculture and agriculture-related topics by utilizing local resources and industries making the course material real and relevant to students (Blum, 1996).

Agricultural education is often nested in the career and technical education (CTE) department in many schools. Agricultural education focuses on vocational training as well as teaching agricultural literacy (Committee on Agricultural Education in Secondary Schools Board on Agriculture National Research Council, 1988). Students that are literate in any subject area, be it math, science, or another academic area, can see what they have learned in their everyday life and understand how it plays a role in the world around them (Bybee, 2013). When students are agriculturally literate, they have an appreciation for agriculture and understand general concepts and practices associated with agriculture industries (Phipps et al., 2008).

To address the goal of vocational training, The National Council for Agricultural Education (The Council) (2015) provides an extensive list of standards for career clusters associated with the agriculture, food, and natural resources (AFNR) industry. In most agricultural education classes, hands-on activities and experiential learning are mainstays of instruction that support the career cluster standards (Blum, 1996). Science is integrated into the curriculum through several course options, and engineering concepts are found in a few courses, namely agricultural mechanics (Stubbs & Myers, 2015). Agricultural education programs are taking on the challenge of preparing students' 21st century skills through the vision of The Council's AFNR career cluster standards and incorporation of science and engineering. Intentionally focusing on developing these 21st century skills across curriculums will hone students' skills set in a broad-based manner for a comprehensive experience (Bray, Green, & Kay, 2010). As agricultural education teachers have a history of using open-ended and student-centered instruction (Blum, 1996), they continue to be strong leaders in developing students' abilities to be life-long learners.

Mathematics in Agricultural Education

In 2008, seminal research was conducted in more than 200 career and technical education (CTE) classroom programs, the CTE-in-Math curriculum was developed and deployed in several CTE programs (Stone, Alfeld, & Pearson, 2008). This significant attempt at math integration in CTE courses suggests that students in the experimental groups did perform better on standards-based math tests without seeing a deficit in the career and technical education concepts learned. Stone, Alfeld, and Pearson's (2008) Math-in-CTE model began by providing students with fully embedded mathematical examples. The teachers collaborated with mathematics teachers to identify math concepts that were present in the skills and competencies taught in career and technical education. With the math concepts identified, teachers gave students examples of the math within the CTE content. Next, students were given explicit math problems that related to the context but were no longer embedded. Finally, students practiced with academic mathematical concepts that did not include the context of the initial CTE material. The Math-in-CTE model (Stone et al., 2008) used the authentic nature of career and technical education to anchor mathematical concepts to make them real and relevant. The Math-in-CTE set a strong precedence for integrating academics in agriculture. The next step to improving on the Math-in-CTE model is developing students' mathematical thinking and reasoning as they work on embedded mathematics within the context.

Conceptualizing Integrative Agricultural Education

Curriculum brings order and purpose to what is considered the essential skills and knowledge that should be taught to students (Walker, 2003). Content and purpose drive curriculum design. Content provides a focus for what is taught while the purpose of the curriculum is the reason for teaching the content (Walker, 2003). The purpose can be broad-based or specific. The purpose of integrative agricultural education, as it is proposed here, is to provide an integration of agriculture and core academic content, particularly, mathematics, so that the content areas are so intertwined the content topics rely on one another to make sense through the real and relevant application of the knowledge and skill. To put a finer point on that purpose, specific goals and objectives for the curriculum overall provide guidance as teachers and designers use the IAE framework for developing their curriculum (see Table 1). These goals come from the juxtaposition of the goals of agricultural education, quantitative reasoning, and STEM education previously discussed.

Table 1

The Goals and Objectives of Integrative Agricultural Education

Goals of Integrative Agricultural Education	Objectives of Integrative Agricultural Education
meet agricultural education and academic standards	agriculture content is intentionally and regularly infused with academic content (integrative)
produce students that are agriculturally literate and literate in core subject areas	only academic concepts that are naturally present in the agriculture concepts are included in a lesson (context)
develop students' 21st century skills	learning by doing is fundamental (experiences and critical thinking)
	authentic problems initiate meaningful knowledge and skill building (collaborative problem solving)

These objectives bring together the characteristics of STEM education, agricultural education, and the learning environment needed for developing quantitative reasoning.

Meeting Standards Through Context

For nearly two decades, researchers have investigated the effectiveness of academic integration in CTE and agricultural education (Shinn et al, 2003; Stone et al, 2008; Young et al, 2008; Parr, Edwards & Leising, 2009; Anderson & Anderson, 2012; Stubbs & Myers, 2015). Curriculums have been developed to integrate math, science, and STEM area content with the intention of infusing agriculture curriculum with only the academic content that is naturally occurring. Young, et al. (2009) honed in on students in agricultural education courses that participated in the Math-in-CTE project conducted by Stone et al. in 2008. The study revealed that academic integration did not diminish the students' learning about agriculture.

In a recent study asked students participating in an integrative STEM agricultural education course about the connections they noticed between their agriculture and academic classes (Stubbs & Myers, 2015). These students reported enjoying the activities they did in agriculture class and did notice that what they were learning in other classes was made useful during the agricultural activities. The connections students made were solidified and made meaningful through the agriculture activities that made the academic concepts real and relevant. Teachers tend to agree, believing that by teaching STEM concepts in agriculture, students make connections between scientific principles and agriculture thus better-preparing students to met learning standards in their science courses (Thompson & Balschweid, 2000).

Through integration students' develop a better understanding of the useful connections of their academic learning and a real context such as agriculture, and teachers believe their efforts to provide integrative learning opportunities are beneficial to students (Stubbs & Myers 2015). Integration of academic concepts can take on many forms. For example, to integrate many science and math concepts while also developing welding skills, the student may be asked to redesign a common but handy garden tool. Alongside the knowledge and skills they learn about welding, the student will also need to employ academic concepts to determine a better design for the garden tool and determine how to make the improvements with the material on hand. If planned well and with appropriate constraints on the challenge, students will be able to use their knowledge of math and science concepts as they are needed to solve real-world problems. The practice of applying math and science concepts provides an excellent opportunity to use the context of agriculture to teach academic content knowledge and skill while upholding the welding competency objectives of the agriculture course.

Building Literacy Through Experiences

Mathematics literacy is defined as being able to identify what is learned in everyday life and understanding the role that knowledge plays in the world (Ojose, 2011). Demonstrating confidence, or a "productive disposition" (Madison, 2014), when engaging in situations that involve using what has been learned is a mark of literacy (Bybee, 2013). Thus, to develop literacy students need opportunities to learn, develop, and practice their literacy skills in an authentic, experience-based environment. Authenticity and student-centered instruction in IAE provides the needed opportunities for students to improve and practice their agricultural and academic content literacy.

Authenticity in Agricultural Education. Students in CTE, learn by doing (Bray et al., 2010). Projects in the lab, shop, or green house provide students with learning activities through practical application as does the opportunity for problem-based learning and field experience. In these authentic situations, students are applying what they know and learning to make decisions that often have immediate results (Blum, 1996). Agricultural education incorporates Supervised Agriculture Experiences (SAE) and FFA sponsored Career Development Events (CDE) with classroom and laboratory instruction as part of the three componet model (Shoulders & Toland, 2017). Both are work based learning experiences that put students in an environment that applies their agricultural and academic knowledge to real experiences (Shin et al., 2003; Stone, 2011). Real work experience is integration in a truly authentic setting (Stubbs & Myers, 2015).

In agricultural education, students traditionally work on projects (Blum, 1996). Using what they learn to make or create something is common practice. CTE also strives to remain on the cutting edge of industry and technology as it works to train students for future career paths (Bray et al., 2010). By working in the context of agriculture and carefully planning for fluid integration of academic concepts, skills and knowledge are made real, relevant, and needed by students (Stone, 2011). Through use of tools and resources that are genuine and represented in the agriculture industry, students gain experience with these authentic artifacts related to agriculture and the agricultural industry.

Student Centered Learning in Agricultural Education. Anderson and Anderson (2012) suggest nearly every high school student enrolls in at least one CTE course during their high school career. That brings a wide variety of students, experiences, and ability levels to CTE and agriculture courses in particular. Some experiences come from formal education such as laboratory activities in a greenhouse, while others come within the context through informal learning during a student's SAE project activity. It is through these experiences that students bring prior knowledge of how the world works, how things work together, and in opposition of one another. The community based practices of agricultural education bring an additional level of experience that students can connect within the classroom. It is important for agriculture teachers to relate new agriculture concepts to students' diverse prior knowledge and experiences. The emphasis on prior knowledge and experiences builds utility and interest in formal concepts that help broaden personal experiences. As is the typical practice of agriculture teachers, through hands-on activities and use of students' prior knowledge to approach problems in a way that makes sense to them, students develop a well-rounded and insightful understanding of how and why agriculture shapes the world around them.

Agricultural education teachers in Virginia pointed out that when teaching math to their agriculture students, "mentioning mathematics turned the students off of the lessons at hand" (Anderson & Anderson, 2012, p. 14). To combat this, the teachers took a different route to teaching math, the surprise approach. They integrated the math concepts into their curriculum but chose not to tell students they were practicing math skills until after they had completed the instrucitonal activity. These teachers provided instruction that met the students' needs and provided a scaffold approach in creative ways to promote student learning. These teachers took a different path to meeting the learning objectives. Students can be given the same opportunity while working on many of the hands on activities and projects in agriculture by applying their prior knowledge and intuition in creative ways to find solutions to problems and complete projects.

Often the activities in agriculture courses have clear outcomes but getting to that outcome is the challenge for students. A common woodworking project will result in students building a toolbox using various traditional and modern tools and methods. How students apply their skills in mathematics such as measuring lengths of the wood pieces and angles to ensure square corners as well as proper use of hand tools to complete the project is a strength of project-based learning. Learning with this approach gives students the opportunity to apply their intuition and creativity while applying competencies and knowledge to arrive at a solution that results in a toolbox of the approprate size for it's intended use that also has square corners for strength and endurance over time. It is in the intentional development of the project that teachers create learning opportunities that integrate academic concepts in the challenge of completing the project. Step by step instructions are replaced with clear details that help guide students through the project but require students to explore ideas and apply academic knowledge to meet constraints provided through carefull and purposeful planning.

Critical Thinking & Problem Solving in Agricultural Education. Students learn habits of mind (Costa & Kallick, 2008) by working within the context but not on only one task (Soden, 2013). Through vocational and literacy training in agriculture, students gain knowledge, competencies, and thinking skills that compliment the competencies (Soden, 2013). As students work through problems that develop their understanding of agriculture and build their skill abilities toward work competencies, problem solving is no longer a generic activity tied to only one context. Instead, students learn many skills within the agriculture context, each one slightly different and in need of a new heirarchy for solving problems. Students have to consider when and how to apply each skill to new problems and projects in agriculture. This problem solving process developes critical thinking and further drives home the authenticity of what is learned and how it is applied in the real world.

To develop 21st century skills a real-world context is needed to provide focus for critical thinking and interest in problem solving. Agriculture provides a wealth of context that is science based and includes technology in several forms. Agricultural education teachers are also familiar with managing competencies as a driving force for student learning. Projects are common catalysts for learning in agricultural education. To include 21st century skill development in agricultural education should be an easy transition with the foundation already laid in current curriculum materials. To a great extent, these skills are developed in agriculture students without much planning on behalf of the teacher. However, with purposeful planning and intentional instruction, students may benefit more from having strongly developed 21st century skills through well-planned opportunities to practice and sharpen these skills both in and out of the classroom.

FFA Career Development Events (CDE) and Supervised Agricultural Experiences (SAE) are well established in agricultural education. Sullivan and Downey (2015) suggested competition that allow students to flex their cognitive and interpersonal skill sets help to promote ownership of those skills and give students a sense of the interdisciplinary tasks that can be accomplished as a result of developing 21st century skills. Working outside of the classroom in the community or with industry leaders in the community also provides experience for students to use and further develop their 21st century skills along with the growing academic or subject based knowledge (Sullivan & Downey, 2015). Agricultural education programs are often designed around local resources, be that people or industries. Including these resources with the intention of also developing students 21st century skills is a practice that could prove to have a lifelong value for students in agricultural courses.

Teaching for 21st Century Skills in Agricultural Education

In a National Research Council (NRC) workshop in 2011 (NRC, 2011b), 21st century skills were grouped into three skill clusters: (a) cognitive, (b) interpersonal, and (c) intrapersonal skills. The cognitive cluster of the 21st century skills is characterized by non-routine problem solving, systems thinking, and critical thinking. The interpersonal skills cluster is characterized by skills needed to work productively with others and to clearly communicate knowledge when sharing with others. Intrapersonal skills are characterized by goal setting, coping with challenges, and self-regulation. These skills are described as the skills needed during problem solving while the focus remains on how an individual handles their own thoughts, progress, and emotions that relate to solving problems.

Learning 21st century skills may best be accomplished and provide the most lifelong benefit to students if they are developed by high school graduation (NRC, 2011b). The National Research Council (2011b) reports that 21st century skills and non-cognitive skills combine to be significant determinants of employment status and earnings more than an individual's educational level. This suggests understanding general information in a content area, being able to apply what is known, and communicating that understanding are seen as more important than a person's strict knowledge or domain specific skill set. Practice of the 21st century skills within in a context makes the process of problem solving and critical thinking more automated which in turn makes transfer to other situations easier (NRC, 2011b).

Implications of Integrative Agricultural Education

The proposed framework for integrative agricultural education guides teachers interested in integrating core academics in agricultural education with a focus on mathematics that will support students' development of quantitative reasoning. The IAE framework introduces the ideas of STEM education to agriculture. The framework suggests teachers intentionally plan to include mathematics that is useful and directly related to the content that is routinely covered in their courses. Agricultural education is a strong context for integration and inclusion of applicable and useful mathematics skills. The intention is not to teach math concepts in this curriculum but to support students' abstract understanding of mathematics with contextual experiences that make the mathematics come alive. As students build a stronger, more flexible understanding of how and why mathematics works, they build their quantitative reasoning skills. As students build these skills, they also improve their problem solving and critical thinking skills through mathematical reasoning. Developing a curriculum that supports QR skill growth is done through hands-on projects, big idea problem solving, and relevant experiences that directly involve students. This requirement makes agricultural education the ideal learning environment for students to improve their QR skills. Additionally, agriculture teachers can lead the charge on STEM education, honing the innovative techniques and providing exemplars for best practices in the field of STEM education.

Tools for Teachers

A curriculum tool is only useful if it can be applied. The IEA framework is reduced to an 18- question rubric in Table 2, intended to be used as guidance in the planning and implementation of IAE. The rubric should be used by teachers to evaluate their current curriculum for integration and integration of mathematics. The rubric may also be used by teachers to demonstrate how to administrators and other stakeholders how they are integrating mathematics into their program content. Recall, that integration of mathematics should only occur in the event the mathematics is needed and useful in the context of the agriculture content. It is implied that mathematics likely occurred in all agriculture content. However, it may not be obvious without consultation with a mathematics teacher who is interested in collaborating. Integration of mathematics may be made more rigorous and grade level appropriate with help from colleagues.

Until collaboration becomes a mainstay in education; agriculture teachers can use the IAE rubric to aid in identifying aspects of their curriculum that may include math. Once identified, the rubric will help guide in the process of providing activities and resources to students that will provide practice in mathematical thinking, open-ended problem solving, asking critical questions of the context and the values involved well as considering why the mathematics was useful and how the concept could b applied in other situations. Working to integrate mathematics into agricultural education is not an easy process. The rubric was designed to provide teachers a roadmap as they begin to consider intentionally integrating mathematics. As teachers try their hand in these initial stages, the discourse among teachers can also be guided by the questions in the rubric to provide better focus on the support and training that is needed to improve the practice of integrative agricultural education.

Table 2

Integrative Agricultural Education Curriculum Rubric

The criteria below are elements that are expected to be present in an integrative agricultural education program. Determine how well each criteria is met using the following scale:				
0 - not applicable/inadequate 1 - developing 2 - proficient 3 - advanced				
Integration				
Is the lesson problem or project based?	0	1	2	3
Were connections between agriculture topics and math topics obvious?	0	1	2	3
Were authentic resources used?	0	1	2	3
Were students encouraged to ask critical questions about the topic or the mathematics?	0	1	2	3
Was scaffolding support provided for math concepts?	0	1	2	3
Were at least two subject areas covered in the lesson (agriculture + *n*)?	0	1	2	3
Student-Centered				
Were students sharing ideas in groups?	0	1	2	3
Were students asked to reflect on their learning either in writing or orally?	0	1	2	3
Were activities offered with multiple methods or variations for ability levels?	0	1	2	3

Table 2 (continued)

Integrative Agricultural Education Curriculum Rubric

The criteria below are elements that are expected to be present in an integrative agricultural education program. Determine how well each criteria is met using the following scale:				
0 - not applicable/inadequate 1 - developing 2 - proficient 3 - advanced				
Were students asked to relate the learning to their own experiences?	0	1	2	3
Did the teacher model mathematical thinking?	0	1	2	3
Were students asked to seek out more information that related to the topic?	0	1	2	3
Were students encouraged to consider alternative processes/solutions/consequences related to the topic?	0	1	2	3
Quantitative Reasoning				
Were math concepts included in the lesson?	0	1	2	3
If so, how many instances?				
Were the math activities appropriate and accurate?	0	1	2	3
Was the math needed or beneficial?	0	1	2	3
Were students encouraged to use mathematical language during discussions/presentations?	0	1	2	3
Were students encouraged to use mathematical thinking during discussions/presentations?	0	1	2	3

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