A Case Study of Integrative Agricultural Education: Integrating Mathematics to Develop Students Quantitative Reasoning

Kelly Robinson

Dissertation submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Doctor of Philosophy
in
Agricultural, Leadership, and Community Education

Donna Westfall-Rudd

Tiffany Drape

Jeremy Ernst

Hannah Scherer

April 12, 2017

Blacksburg, VA

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

A Case Study of Integrative Agricultural Education: Integrating Mathematics to Develop Students Quantitative Reasoning

Kelly Robinson

Abstract (Academic)

Preparing students to be life-long learners that are career and college ready is a goal of agricultural education. Changing expectations of education have pointed to agriculture educators as potential leaders in the STEM education movement. Literature related to STEM education in agricultural education is lacking in guidance for teachers, administrators, and curriculum developers in integrating academic content related to STEM content areas. A review of STEM education literature coupled with the framework of quantitative reasoning, lead to a conceptualization of a framework for integrative agricultural education. This framework was implemented through a case study to investigate collaborative efforts in curriculum development in agricultural education with a specific focus on integrating mathematics to develop students' quantitative reasoning skills. Teacher characteristics were identified that seemed to support implementation of integrative agricultural education practices. Teaching and planning strategies were also identified in the case study. Recommendations suggest support of collaboration between agriculture and mathematics teachers would best support curriculum design and aid in the quality of instruction that follows.

A Case Study of Integrative Agricultural Education: Integrating Mathematics to Develop Students Quantitative Reasoning

Kelly Robinson

General Audience Abstract

Agricultural education teachers work to prepare students to be life-long learners that are career and college ready. STEM education has become vogue in education. As expectations change about what students should learn and how they learn it, agriculture educators have potential to be leaders in the STEM movement. STEM education in agricultural education is lacking in guidance for teachers, administrators, and curriculum developers in integrating academic content related to STEM content areas. This dissertation presents a conceptualization of a framework for integrative agricultural education that combines elements characteristic of STEM education coupled with the concept of quantitative reasoning. The framework was used to research collaborative efforts in curriculum development in agricultural education with a specific focus on integrating mathematics to develop students' quantitative reasoning skills. Results provide teacher characteristics that seemed to support implementation of integrative agricultural education practices. Teaching and planning strategies were also identified that lead to recommendations suggesting support of collaboration between agriculture and mathematics teachers would best support curriculum design and aid in the quality of instruction that follows.

Table of Contents

List of Tables

List of Figures

Introduction

Agricultural education teachers report attempts of integration in science, math, and STEM content areas (Blum, 1996; Stubbs & Myers, 2015; The National Council for Agricultural Education, 2015) but also expressed a desire to have more training in integrating academic concepts (Anderson & Anderson, 2012; Balschweid & Thompson, 2002; Thompson & Balschweid, 2000). These and other agricultural education teachers have also expressed a desire to have an academically integrated agricultural education curriculum that can be implemented in their classrooms (Anderson & Anderson, 2012; Asunda, 2012; Balschweid & Thompson, 2002). Stone (2008) set forth the framework for Math-in-CTE which provided a building block to begin formulating a framework that pulls together specific aspects of integrative teaching practices and focusing on math integration in agricultural education. A curriculum framework based on recent literature related to integrative instructional practices would update Stone's (2008) Math-in-CTE model and connect pedagogy to STEM education practices which are strong in integrating science, technology, engineering, and mathematics.

Agriculture educators are in a position to support students' academic literacy while preparing them to be life-long learners and critical thinkers. Federal funding calls for a balance between academic integration and career and college readiness in career and technical education (Phipps et al., 2008). The National Council of Teachers of Mathematics (NCTM) lays the foundation for standards in math education grounded in application in a context (1989, 2000). Combining the governmental goals and the national mathematics standards, opens the door for students to develop quantitative reasoning (QR) skills. Quantitative reasoning is the ability to apply mathematical knowledge to complex situations and reason through the context of the problem confidently and with a mathematical eye (Steen, 1997, 2004). Quantitative reasoning also falls within the skill set described as 21st century skills (Partnership for 21st Century

Learning, 2015). The National Research Council (2011) suggests that 21st century skills are best learned in a broad context to practice complex problem solving and critical thinking.

While agriculture educators are approached to include STEM content in their curriculum to support students' 21st century skill development and academic knowledge, there is a notable lack of support on what a STEM infused curriculum should look like in agricultural education (Scherer, et al., 2017). Teachers reportedly requested an integrative curriculum in agricultural education they could use in their classrooms (Anderson & Anderson, 2012; Asunda, 2012; Balschweid & Thompson, 2002). The first manuscript includes a conceptualized curriculum framework for integrative agricultural education (IAE). This is not the classroom ready curriculum teachers requested but a significant start on the development of that curriculum.

The IAE framework provided guidance to a case study agriculture teacher and me during collaborative curriculum development in an Introduction to Animal Sciences course. The instructional unit developed was designed to integrate mathematics in agriculture with the goal of improving students' QR skills. Video recordings, teacher reflections, and a final interview with the case study teacher provided insight on strategies used during implementation of the IAE lessons and activities. Strategies during the collaboration and barriers to quality collaboration were revealed through audio recordings and journaling, as well as comments made during the final interview. These findings are reported in the second manuscript along with implications of the findings and how the case study may inform the next steps in further developing the IAE framework proposed in this document.

References

Anderson, R. & Anderson, S. (2012). Emerging themes in integrating mathematics into agricultural education: A qualitative study of star teachers in Virginia. *Journal of Career and Technical Education, 27*(2), 8-19.

Asunda, P. (2012). Standards for technology literacy and STEM education delivery through career and technical education programs. *Journal of Technology Education, 23*(2). Retrieved from https://scholar.lib.vt.edu/ejournals/JTE/v23n2/asunda.html

Balschweid, M.A. & Thompson, G.W. (2002). Integrating science in agricultural education: Attitudes of Indiana agricultural science and business teachers. *Journal of Agricultural Education*, 43(2), 1-10.

Blum, A. (1996). *Teaching and learning in agriculture: A guide for agricultural educators.* Rome: FAO.

The National Council for Agricultural Education. (2015). Agriculture, food and natural resources (AFNR) career cluster content standards. Retrieved from: https://www.ffa.org/SiteCollectionDocuments/council_afnr_career_cluster_content_standards.pdf

National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation standards for school mathematics.* Reston, Va.: The Council.

National Council of Teachers of Mathematics (2000). *Principles and Standards for School Mathematics*. Reston, Va.: The National Council of Teachers of Mathematics, Inc.

National Research Council. (2011). *Assessing 21st century skill: Summery of a workshop*. J.A. Koenig, rapporteur. Committee on the Assessment of 21st Century Skills. Board on Testing and Assessment, Division of Behavioral and Social Sciences and Education. Washington D.C.: The National Academies Press.

The Partnership for 21st Century Learning. (2015). *Framework for 21st century learning*. Retrieved from: http://www.p21.org/our-work/p21-framework

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

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

Steen, L. A. (2004). *Achieving quantitative literacy: An urgent challenge for higher education*. Washington, D.C.: The Mathematical Association of America

Steen, L. A. (Ed.). (1997). Preface: The new literacy. In L. A. Steen (Ed.), *Why numbers count: quantitative literacy for tomorrow's America* (pp. xv -xxviii). New York: College Entrance Examination Board.

Stone, J. R., Alfeld, C., & Pearson, D. (2008). Rigor and relevance: Enhancing high school students' math skills through career and technical education. *American Educational Research Association, 45*(3), 767-795.

Stubbs, E., & Myers, B. (2015). Multiple case study of STEM in school-based agricultural education. *Journal of Agricultural Education, 56*(2), 188-203.

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

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

Kelly Robinson

Abstract

A curriculum framework to support 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 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.

Preparing students for work and college is one of the goals of agricultural education. 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 often 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).

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 are able to communicate what they know and what they are doing in a manner that is clear, technically savvy, and appropriate for their audience. Additionally, employees with quantitative reasoning skills (Steen, 2002), those that approach complex problems that involve complicated calculations and require problem solving with confidence are highly desired. While these skills are highly desired by employers, it is suggested that these skills 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. 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. These skills may be developed by agriculture students without much teacher planning. However, with purposeful planning and intentional instruction, students may benefit more from having well developed 21st century skills by engaging opportunities to practice and sharpen these skills both in and out of the classroom.

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) in order 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 development of students' 21st century skills for career and college readiness, a common goal in most career and technical education programs. 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 of the practice relevant to instruction in agricultural education. A discussion of agricultural education as context follows to introduce 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 in an effort to operationalize quantitative reasoning within the field of agricultural education. The triangulated synthesis of empirical research in integrative teaching, construct of quantitative reasoning and current structure of in-school agricultural education will conclude the article to form the foundation for the conceptual framework for integrative agricultural education. A brief conclusion will provide 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 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 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 identifiy characteristics common to STEM education. The purpose of operationalizing STEM education was to use the characteritisics and principles indentified as the basis for the conceptual framework of integrative agricultural education.

Synthesis of litature revealed five characterisitics 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 used regularly (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). The 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; Heibert & Lefevre, 1986). 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 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 are able to 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 own meanings, abstract concepts also begin to make sense because the context provides meaning and makes the concept useful (Nathan et al., 1992).

Authenticity

In intergrative education, students learn by doing (Moye, Dugger, & Stark-Weather, 2014) and doing in situations that are realistic or authentic provide much of the same benefit as learning in context. What sets authenticity apart from context is how the context is presented to the students and how teaching and learning are focused on doing 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 with in 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 neccessarly 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 acitivies 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 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, student develop a habit of mind rather 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 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 are able to 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 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 are able to 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 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 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).

STEM education is learning by doing. Students learn skills that help them assess problems in a realistic manner 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 intutuion 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* that detailed the short falls 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 with respect to 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 understanding, use of math skills, and mathematical knowledge to the next level by asking students to use mathematical thinking to reason through instances when math skills 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 in order 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 within 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. 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.

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 other academic area, are able to 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 regularly integrated into the curriculum through several course options and engineering concepts can be 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 some 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 the 2008, seminal research 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, suggest that students in the experimental groups did perform better on standards based math tests without seeing a defect in the career and technical education concepts learned. Young, Edwards, and Leising (2009) reported agriculture students enrolled in agricultural power and technology courses that included the Math-in-CTE model showed improved math achievement.

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, students were given examples of the math within the CTE content being introduced. Stepping back from the context, 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 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 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 to develop their own curriculum (Table 2). These goals come from the juxtaposition of the goals of agricultural education, quantitative reasoning, and STEM education as each has been previously discussed. 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 3 decades, researchers have investigated the effectiveness of academic integration in CTE and agricultural education. 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

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)

occuring. Young, Edwards, and Leising (2009) honed in on students in agricultural education courses that participated in the Math-in-CTE project conducted by Stone, Alfeld, and Pearson in 2008. The study revealed that students' math scores improved after concluding the math infused course and additionally noted that students' learning about agriculture was not diminshed by the academic integration in context.

In a recent study of students participating in an integrative STEM agricultural education course, students were asked 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).

Agricultural education courses obviously have context well in hand. Through integration students' seem to improve their scores related to academic standards, 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. Integration of academic concepts can take on many forms. For example, to integrate many science and math concepts while also developing welding skills, 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 employe academic concepts to determine a better design for the garden tool and deteremine how to make the improvements with the material on hand. If planned well and with appropriate constraints on the challenge, math and science concepts will become need-to-know. This 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

Literacy is defined as being able to identify what is learned within everyday life and understanding the role that knowledge plays in the world. 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). 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 while others come with context through informal learning. 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 with in the classroom. It is important for agriculture teachers to relate new agriculture concepts to students' diverse prior knowledge and experiences. This builds meaning and interest into formal concepts that help broaden personal experiences. As is 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 Virgina pointed out teaching math to their agriculture students often turned the students off (Anderson & Anderson, 2012). To combat this, the teachers took a different route to teaching math; the surprise attack. They integrated the math concepts into their curriculum but chose not to tell students they were practicing math skills until after the fact. 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 and knowledge 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. 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 by working within the context but not on only one task (Soden, 1994). Through vocational and literacy training in agriculture, students gain knowledge, competencies and thinking skills that compliment the competencies (Soden, 1994). 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 largely science based and often 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 likely 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 that competitions 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 workshop in 2011, 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 (National Research Council, 2011). The National Research Council (2011) 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 would seem to suggest that 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 within in the context makes the process of problem solving and critical thinking more automated which in turn makes transfer to other situations easier (National Research Council, 2011).

Implications of IAE

The proposed framework for integrative agricultural education provides guidance for 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 mathematics 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 curriculum that supports QR skill growth is done through hands-on projects, big idea problem solving, and relevant experiences that students are directly involved in. 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 is only useful if it can be applied. The framework was reduced to a 19-question rubric (Appendix), intended to be used as guidance in planning and implementation of IAE. The rubric should be used by teachers to evaluate their current curriculum for integration and for integration of mathematics. 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 was 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 collaborting. 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, as well as considering why the mathematics was useful and how the concept could be 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.

Conclusion

Agricultural education teachers are expected to provide support for their students' academic learning as well as prepare them for careers and college. The broad-based foundation of agriculture lends itself to learning through in-class projects and hands-on experiences that are unique to agricultural education through FFA. In the context of agriculture, science is readily identified and in many cases, intentionally introduced to students. The same intention should be applied to mathematics concepts that are embedded in many aspects, if not all, of agriculture. Planning curriculum with intention and following the guidelines for integrative agricultural education provided in this article opens a new window of opportunity for students to build confidence, transferable knowledge, and flexible processing skills in mathematics for application in all facets of their life now and in the future.

References

Agustin, M. Z., Agustin, M., Brunkow, P., & Thomas, S. (2012). Developing quantitative reasoning: Will taking traditional math courses suffice? An empirical study. *Journal of General Eduation, 61*, 305-313.

Anderson, R. & Anderson, S. (2012). Emerging themes in integrating mathematics into agricultural education: A qualitative study of star teachers in Virginia. *Journal of Career and Technical Education, 27*(2), 8-19.

Asunda, P. (2012). Standards for technology literacy and STEM education delivery through career and technical education programs. *Journal of Technology Education, 23*(2). Retrieved from https://scholar.lib.vt.edu/ejournals/JTE/v23n2/asunda.html

Berlin, D. F., & White, A. L. (2012). A longitudinal look at attitudes and perceptions related to the integration of mathematics, science, and technology education. *School Science and Mathematics*, 112(1), 20-30. doi:10.1111/j.1949-8594.2011.00111.x

Blum, A. (1996). *Teaching and learning in agriculture: A guide for agricultural educators.* Rome: FAO.

Bray, J., Green, K., & Kay, K. (2010). *Up to the challenge: The role of career and technical education and 21st century skills in college and career readiness.* Retrieved from Partnership for 21st Century Skills: http://www.p21.org/storage/documents/CTE_Oct2010.pdf

Bybee, R. (2013). *The case for STEM education: Challenges and opportunities.* Arlington, VA: National Science Teachers Association.

Carpenter, T. (1986). Conceptual knowledge as a foundation for procedural knowledge. In J. Hiebert (Ed.), *Conceptual and Procedural Knowledge: The Case of Mathematics.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Chin, C., & Chia, L.-G. (2004). Problem-based learning: Using students' questions to drive knowledge construction. *Wiley InterScience*. doi:10.1002/sce.10144

Cobb, G.W. (1997). Mere literacy is not enough. Steen, L. A. (Ed.). *Why numbers count: quantitative literacy for tomorrow's America* (pp. 75 – 90). New York: College Entrance Examination Board.

Committee on Agricultural Education in Secondary Schools Board on Agriculture National Research Council. (1988). *Understanding agriculture: New directions for education.* Washington, D.C.: National Academy Press.

Creamer, E.G., Simmons, D.R., & Yu, R. (2015). *Using mixed methods to conduct a meta-synthesis of the literature: Moving from words to numbers*. Paper presented at the Conference on Higher Education Pedagogy, Blacksburg, VA. Retrieved from http://www.cider.vt.edu/conference/proceedings/2015ConferenceProceedings.pdf

Cromwell, L. (1992). Assessing critical thinking. *New Directions for Community Colleges, 77*(Spring), 37-50.

Driscoll, M. P. (2005). *Psychology of learning for instruction.* Boston, MA: Pearson Education, Inc.

Foutz, T., Navarro, M., Bill, R., Thompson, S., Miller, K., & Riddleberger, D. (2011). Using the discipline of agricultural engineering to integrate math and science. *Journal of STEM Education, 12*(1&2), 24-32.

Gal, I. (1997). Numeracy: Imperatives of a forgotten goal. Steen, L. A. (Ed.). *Why numbers count: quantitative literacy for tomorrow's America* (pp. 36 -44). New York: College Entrance Examination Board.

Gardner, D. P., Larsen, Y. W., & Baker, W. (1983). A nation at risk: The imperative for educational reform. *Washington, DC: US Government Printing Office*.

Hiebert, J., & Lefevre, P. (1986). Conceptual and procedural knowledge in mathematics: An introductory analysis. In J. Hiebert (Ed.), *Conceptual and procedural knowledge: The case of mathematics* (pp. 1-27). Hillsdale, NJ: Lawrence Erlbaum Associates.

Hmelo-Silver, C. E. (2004). Problem-based learning: what and how do students learn? *Educational Psychology Review, 16*(3), 235-266.

Kennedy, T., & Odell, M. (2014). Engaging students in STEM education. *Science Education International, 25*(3), 246-258.

Koedinger, K. R., & Nathan, M. J. (2004). The Real Story Behind Story Problems: Effects of Representations on Quantitative Reasoning. *Journal of the Learning Sciences, 13*(2), 129-164.

Laboy-Rush, D. (2011). Integrating STEM education through project based learning. Retrieved from http://www.rondout.k12.ny.us/common/pages/DisplayFile.aspx?itemId=16466975

Madison, B.L. (2014). How does one design or evaluate a course in quantitative reasoning? *Numeracy*, 7(2), article 3.

McCormick, R. (2004). Issues of learning and knowledge in technology education. *International Journal of Technology and Design Education, 14*, 21-44.

Moore, K., & Carlson, M. (2012). Students' images of problem contexts when solving applied problems. *The Journal of Mathematical Behavior, 31*, 48-59.

Moye, J., Dugger, W., & Stark-Weather, K. (2014). “Learning by doing” research introduction. Retrieved from http://iteea.org/39126.aspx

Nathan, M. J., Kintsch, W., & Young, E. (1992). A Theory of Algebra-Word-Problem Comprehension and Its Implications for the Design of Learning Environments. *Cognition and Instruction, 9*(4), 329-389.

National Research Council. (2011). *Adding it up: Helping children learn mathematics*. Washington, D.C.: National Academy Press.

National Research Council. (2011b). *Assessing 21st century skill: Summery of a workshop*. J.A. Koenig, rapporteur. Committee on the Assessment of 21st Century Skills. Board on Testing and Assessment, Division of Behavioral and Social Sciences and Education. Washington D.C.: The National Academies Press.

The National Council for Agricultural Education. (2015). Agriculture, food and natural resources (AFNR) career cluster content standards. Retrieved from: https://www.ffa.org/SiteCollectionDocuments/council_afnr_career_cluster_content_standards.pdf

National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation standards for school mathematics.* Reston, Va.: The Council.

National Council of Teachers of Mathematics (2000). *Principles and Standards for School Mathematics*. Reston, Va.: The National Council of Teachers of Mathematics, Inc.

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

Sahin, A., & Top, N. (2015). STEM students on the stage (SOS): Promoting student voice and choice in STEM education through an interdisciplinary, standards-focused, project based learning approach. *Journal of STEM Education, 16*(3), 24-33.

Sanders, M. (2009). STEM, STEM education, STEMmania. *The Technology Teacher, December/January*, 20-26.

Shinn, G., Christainsen, J., Harlin, J., Lindner, J., Murphy, T., Edwards, M., . . . Lawver, D. (2003). *Improving student achievement in mathematics: An important role for secondary agricultural education in the 21st century* (Vol. Unpublished). College Station, TX: Texas A&M University.

Soden, R. (1994). *Teaching problem solving in vocational education.* London: Routledge.

Stubbs, E., & Myers, B. (2015). Multiple case study of STEM in school-based agricultural education. *Journal of Agricultural Education, 56*(2), 188-203.

Steen, L. A. (2002). Quantitative Literacy: Why numeracy matters for schools and colleges. *FOCUS*, 22(2), 8-9.

Steen, L. A. (2004). *Achieving quantitative literacy: An urgent challenge for higher education*. Washington, D.C.: The Mathematical Association of America

Steen, L. A. (Ed.). (1997). Preface: The new literacy. In L. A. Steen (Ed.), *Why numbers count: quantitative literacy for tomorrow's America* (pp. xv -xxviii). New York: College Entrance Examination Board.

Stone, J. I. (2011). Delivering STEM education through career and technical education schools and programs. Retrieved from http://sites.nationalacademies.org/cs/groups/dbassesite/documents/webpage/dbasse_072641.pdf

Stone, J. R., Alfeld, C., & Pearson, D. (2008). Rigor and relevance: Enhancing high school students' math skills through career and technical education. *American Educational Research Association, 45*(3), 767-795.

Sullivan, S.C. & Downey, J. A. (2015). Shifting educational paradigms: From traditional to competency-based education for diverse learners. *American Secondary Education*, 43(3), 4-19.

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

Turner, S. L. (2011). Student-centered instruction: Integrating the learning sciences to support elementary and middle school learners. *Preventing School Failure, 55*(3), 123-131.

Walker, D.F. (2003). *Fundamentals of curriculum: Passion and professionalism* (2nd edition). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Wells, J. (2015). *A technology education perspective on the potential of STEM education.* Blacksburg, VA: Virginia Polytechnic Institute and State University.

Wiggins, G., & McTighe, J. (2006). *Understanding by Design* (2nd ed.). Upper Saddle River, NJ: Pearson Education, Inc.

Wilkins, J. L. M. (2000). Preparing for the 21st century: The status of quantitative literacy in the United States. *School Science and Mathematics*, 100(8), 405-418.

Young, R., Edwards, M., & Leising, J. (2009). Does a math-enhanced curriculum and instructional approach diminish students' attainment of technical skills? A year-long experimental study in agricultural power and technology. *Journal of Agricultural Education, 50*(1), 116-126.

Zollman, A. (2012). Learning in STEM literacy: STEM literacy for learning. *School Science and Mathematics, 112*(1), 12-19.

Launching the Conversation of Integrative Agricultural Education: A Case Study Integrating Math in Ag Ed to Develop Students' Quantitative Reasoning

Kelly Robinson

Abstract

The goals of education have shifted from learning to know information to learning to be about to apply what is learned. Federal funding in agricultural education has promoted integration of academics in context for over two decades. The National Council of Teachers of Mathematics (NCTM) supports learning and applying mathematics in context. Combining these expectations is being attempted in agricultural education classroom but there are questions that remain on how to improve curriculum development and teaching practices in integrative agricultural education. This case study investigated integration of mathematics in an Introduction to Animal Science class with a veteran agricultural education teacher through video analysis of teaching episodes, audio recording of collaborative work sessions, document analysis of lesson plans, and a culminating interview. A conceptual framework for integrative agricultural education (IAE) was used to guide and evaluate the collaborative curriculum development.

The foundational results of the case study suggest that specific teacher characteristics have an impact on implementing IAE. Student-centered instruction is seen as a viable approach to teaching IAE in practice. However, development of lessons and activities may be most effective through collaborative efforts between agriculture and mathematics teachers who are guided through well-facilitated and supported collaborative work to build both an integrative curriculum and teachers' content knowledge and quantitative reasoning skills.

In 1983, the U.S. Government published A Nation at Risk that detailed the short falls of the education system to produce students that were science, math and technology literate (Gardner, Larsen, & Baker, 1983). A year later, the Carl D. Perkins Vocational Education Act became a federal mandate to incorporate academics into agricultural education (Phipps et al., 2008). With the extension of the Perkins Act in 1990, curriculum and instructional focus in agricultural education began to shift from career development and competencies needed in agriculture and agriculture related careers to the importance of integrating academics in a meaningful way. The National Council of Teachers of Mathematics (NCTM) (1989, 2000) provided a foundation to lay the ground work toward integrating context into math curriculum. The NCTM standards are based on the idea that math is not a series of facts to be memorized but concepts and skills to be mastered and used to investigate, reason, and apply in context. NCTM suggests that all students should be given the opportunity to see math at work and to use it in ways that are relevant and relatable to their lives.

Combine the call for science, math, and technology literate students from A Nation at Risk together with NCTM's math standards and mix them with the Perkins Act; an interesting educational triangle is bidding to help students meet the requirements of secondary education standards and prepare students for the workforce. The National Research Council (2011) summarizes 21st century skills as skills needed for solving complex problems in innovative and creative manners, effective communication, team work, and self-regulation. The NRC report seems to suggest that 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. Nonetheless, context is needed to practice problem solving and critical thinking skills. Critical thinking is domain specific and requires context.

Agriculture provides a wealth of context that is largely science based and often includes technology. Competencies are the driving force for learning and projects are common catalysts for meeting competencies in agricultural education. When students are able to put what they know to use in new or complex situations with confidence, 21st century skills are demonstrated. Common requests of employers are to have employees that have a variety of reasoning skills, can make decisions and provide creative solutions to complex problems while having the confidence to face situations that involve numbers and numerical problem solving head-on (Partnership for 21st Century Learning, 2015).

Developing confidence and capabilities to understand and use mathematical skills and knowledge through mathematical thinking and reasoning is a fundamental characteristic of quantitative reasoning (Steen, 1997, 2004). Quantitative reasoning (QR) is often synonymous with quantitative literacy (QL) and numeracy (Steen, 2004; Wilkins, 2000) however QR takes understanding, use of math skills, and mathematical knowledge to the next level by asking students to use mathematical thinking to reason through instances when math skills 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. Through integration of academics in a contextually interesting curriculum, such as agricultural education, students' quantitative reasoning skill development can be supported to raise students' science, math, and technology literacy to a new level.

Purpose

This single case embedded design study, provided foundational strategies and insight into a teachers' implementation of an integrative agricultural education curriculum unit. The intent of the designed curriculum is to integrate mathematics with the intent of developing students' QR skills. The intention of the research is not to definitively identify the design elements and pedagogical strategies of integrative agricultural education. Rather, the findings will begin the discussion about preparing teachers to provide intentional integrative instruction in agricultural education. The IAE lesson rubric that resulted from the study can be a guide to teachers, administrators, and curriculum developers to build an integrative agricultural education curriculum.

Research Questions

The research questions target a single agricultural education teacher's approach to developing and implementing an integrative agricultural education curriculum focused on mathematics integration to develop students' quantitative reasoning skills.

1. What teacher characteristics and habits play a role in integrating mathematics instruction into agricultural education courses?
2. What decisions and strategies do agricultural education teachers use to guide instruction when implementing an integrated agricultural education course?
3. What decisions and strategies do agricultural education teachers use to incorporate elements of quantitative reasoning skill in an integrated agricultural education course?
4. What strategies are employed by an agriculture education teacher and math teacher during the process of collaborative curriculum development?

Method

Research Design

An instrumental case study identifies an exceptional case within a practice and exploits the experience of the case participant to highlight the intricate details of the system (Stake, 1995). Ms. Martin was identified as an exceptional case because of her involvement in a grant program offered to agricultural education teachers interested in developing an innovative idea for their in-school program. Ms. Martin expressed an interest in integrating mathematics in the curriculum she wanted to develop for beef quality assurance certification. A single unit of curriculum for Introduction to Animal Science was developed to use for the purpose this study. Ms. Martin implemented the lessons that were collaboratively designed to include integrative practices and mathematics into the beef quality assurance (BQA) material.

Care was taken to gather information from many sources of data, an iterative approach to data analysis provided triangulation and bolstered connections to the data and different perspectives of the evaluation of the integrative curriculum were used in the methodology. Multiple perspectives can and should be represented in case study (Stake, 1995; Yin, 2009). It is in the multiple units of analysis that the holistic view of the integrative teaching approach comes to be better understood (Yin, 2009). Pragmatic research looks for the method or methods that work best to reach answers to the research questions (Creswell & Plano Clark, 2011). A pragmatic approach uses varied methods and types of data and methods to ensure the lived experience is captured. This variety of data and analysis ensured multiple perspectives of the case study. By combining several units of analysis, inductive and deductive thinking lead to better understanding of what strategies worked and when adaptions were made in teaching an integrative agricultural education unit (Creswell & Plano Clark, 2011; Yin, 2009). To identify themes and categories, constant comparative analysis (Corbin & Strauss, 2005) was used. To improve trustworthiness, I used memoing, bracketing, and researcher reflection throughout the coding and analysis process (Marshall & Rossman, 2011). Video recordings were used as an approach to capture the full berth of the teaching taking place in the classroom setting. As teaching is a dynamic practice with many decisions made at hand and adjustments and interactions practiced through professionalism and student need, video recording was a tool that allowed an in-depth investigation of the technique and content employed in the integrative lessons.

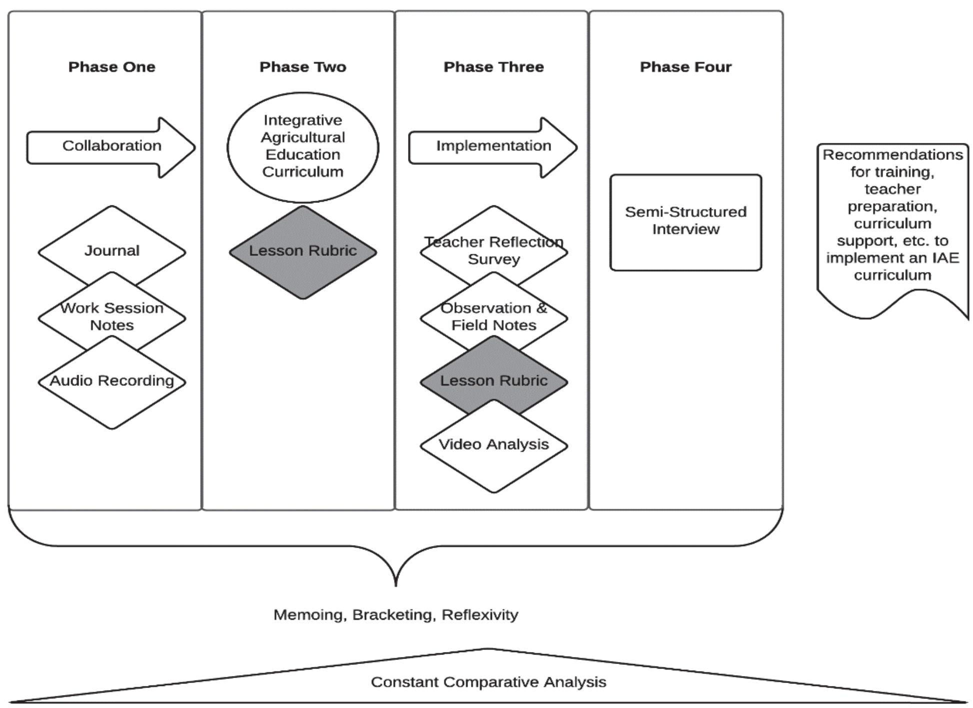
The research was conducted in four stages (Figure 1). The first phase was collaboration to develop a more integrative curriculum. Work sessions were recorded and partially transcribed to highlight moments of collaboration. A reflective journal was used to capture immediate and lingering insights about the collaboration from my own perspective as a collaborator on the curriculum development. Journal also allowed me to memo and reflect about my own subjectivity in the process. This document was coded with an iterative qualitative method.

The lessons that resulted from the collaboration were evaluated using a rubric developed for the purpose of this study (Appendix). The rubric was aligned with the elements of the IAE framework. To further identify specific elements of IAE present in the curriculum, document analysis on the written lesson plans produced an extensive table that cross referenced specific components of the lesson with the elements included in the operational definition of integrative education, quantitative reasoning, and IAE. Further suggestions for math integration were offered to Ms. Martin to extend the collaboration efforts to develop a well-developed integrative unit of lessons. Unfortunately, scheduling conflicts prevented further work sessions.

In the third phase of data collection, implemented lessons were video recorded and analyzed in four passes to identify different aspects of the lessons and the methods Ms. Martin used in her delivery. Ms. Martin provided a reflection on her teaching as an additional element of collection. In person observations also provided a point of analysis during implementation.

Figure 1

Four Stages of Research, Analysis, and Research Artifacts



Identifying the data. The data should reveal information about strategies used, content covered, and teaching techniques used by the teacher while implementing IAE. This collection of information can only be derived from teaching episodes contained on the video recordings (Pirie, 1996). Thus, the use of video affords multiple viewings of the same instructional occurrences to collect several aspects, levels, and intricacies of the strategies and habits presented by the practicing teacher. It is in the video that the data is collected from the teaching episodes.

To identify this data, four categories directly associated with the research question were used as an initial coding schema. The first viewing of the video and coding pass collected the setting, educational content in the lesson, general description of participants involved during the teaching episode, and organization of the lesson. The organization of the lesson was fashioned after the lesson mapping strategy used in The TIMSS videotape classroom study (Stigler et al., 1999). This strategy was found effective and reflects a grounding to the data that suggests creditability (Charmaz, 2014). The second pass investigates the segments of the lesson more intensely. With a third pass providing further details related to the strategies and habits identified in the second pass. The final pass will compare the delivered lesson with the planned lesson to identify instructional decisions and the role those changes play in the teaching process. With each pass, video segments were tagged for later review to use as stimulated recall in the final interview with the teacher. Stimulated recall is a method for research that identifies moments in teaching episodes that reflect teacher decisions and seeks to gain descriptions of those decisions from the teacher by watching the video tape to stimulate recall of the moment during teaching (Calderhead, 1981).

The final phase of data collection was a semi-structured interview with Ms. Martin. During the interview stimulated recall (Calderhead, 1981) was used as an approach to trigger a more thorough discussion of the teaching episode that was identified as significant. The interview provided an opportunity to member check the initial interpretation of the teaching episodes.

Rationale for the Case Study Design

Of interest for this study were the decisions she made about implementing an innovative curriculum that was different from the curriculum with which she was highly familiar. An instrumental case study acknowledges a need for a general understanding or insight that can come from considering a particular case. Stake (1995) describes a case as "a specific, complex, functioning thing" (p. 2). Case study findings can be generalizable to theoretical propositions but not to general populations (Yin, 2009). In this case, findings were generalized to improving the integrative agricultural education curriculum framework to provide a stronger foundation for integrative teaching methods in agricultural education.

Researcher Subjectivity

In qualitative research, it is impossible to completely separate oneself from the research completely (Corbin & Strauss, 2005). In this case study, the researcher plays the role of collaborating curriculum developer and researcher. Therefore, there is a challenge to remain subjective when approaching data analysis and interpreting findings. As a secondary mathematics teacher with ten years of classroom teaching experience I bring to the curriculum development a specific knowledge in the field of math education. Initially addressing assumptions and determining positionality prior to the initiation of the study provides those that review this study with a reflection of my vested interest and background related to this study.

Conceptual Framework

A conceptualized framework for Integrative Agricultural Education (IAE) brings together the goals and objectives of agricultural education, quantitative reasoning, and STEM education. Architecturally, IAE is built on the foundation of developing students' 21st century skills which include strong quantitative reasoning (QR) while meeting the academic standards and competencies for agricultural education set forth by The National Council of Agricultural Education (2015) as well the mathematics standards designed by the National Council of Teachers of Mathematics (2000). The teaching and learning pillars for IAE include: (a) intentional instruction of mathematics, (b) integration of math concepts naturally present in the agriculture context, (c) inclusion of student experiences that provide opportunity for critical thinking, and (d) student engagement in authentic problems and/or projects that prompt collaborative problem solving (Robinson, 2017).

Under the guidance of the pillars of IAE, curriculum developers and teachers should identify mathematics that is needed and supports the required agriculture content. Activities and instruction developed for IAE should include experiences that provide students with active engagement with both the agriculture and mathematics content. Problems and projects should drive the learning process to promote critical thinking and problem solving both as an individual and through communication and planning in collaborative groups. The IAE framework provided guidance in the development of the customized curriculum in agricultural education for this study. The framework guided the intent of integrating core academic content, specifically mathematics, to improve students' quantitative reasoning. Table 3 illustrates the connections between the goals and objectives of Integrative Agricultural Education.

Table 2

Goals and Objectives of Integrative Agricultural Education Framework

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)

Significance of the Study

In Steen's *Why Numbers Count* (1997), he notes that QR development in school is not likely until colleges begin producing quantitatively literate adults. Shortly after, in 2000, NCTM math standards became a jumping off point for schools to make teaching and learning in math a more context-oriented practice. Within a few years, the fields of science and technology followed suit with standards that suggested literacy development was important for school-aged students. As the science, technology, engineering and math (STEM) movement has come into vogue, literacy in the STEM fields in school has sparked interest for including a philosophy of learning by doing for school-age students. STEM education is aimed at teaching, in context, math, science, and engineering concepts through integrative instruction with a focus on technology use as a vehicle to drive development of a tool (system or artifact) in the process of learning. Integrative STEM education is a lofty goal. Focusing teachers' and students' attention on working toward only one STEM subject could prove as a stepping stone toward including the remaining STEM subjects innovatively at a secondary level.

Not meant to be a stand-alone course (Steen, 1997), QR needs context to bring relevance and meaning to using mathematics, critical thinking and problem solving. Stone (2011) describes two ways to view bringing context and QR together. One method is to bring the context to the math. This is done by providing problems that seem realistic to students in math class. The second method for bringing context and QR together is with a contextual approach. Stone and colleagues (2008) used a contextual approach to integrate mathematics into several Career and Technical Education (CTE) courses. Using the Math-in-CTE framework, CTE teachers delivered math enhanced lessons that provided instruction of math concepts that were embedded in the CTE content taught during the course. Through collaboration with a cooperative math teacher, the CTE teacher identified math concepts that were naturally present in the CTE content for the course. The Math-in-CTE framework had teachers introduce the CTE content, informally assess students' math awareness, provide guided instruction on the math concepts in the CTE lesson while bridging the math and CTE vocabulary, then return to the context of the CTE lesson to work more problems that relate to the embedded math concept. After checking for understanding of both the math and the CTE concepts, traditional math examples were assigned and students were asked to demonstrate their understanding of the CTE and math concept on a classroom assessment. Empirical data from this study demonstrates that fluid integration of math into CTE context does significantly improve math achievement on standardized math tests. While this does not provide evidence of QR skill improvement, the groundwork for integration into CTE context is supported by evidence of improved mathematical ability. With evidence that math can be successfully integrated into CTE context and support that context encourages QR development (Agustin, Agustin, Brunkow, & Thomas, 2012; Boose, 2014; Koedinger & Nathan, 2004; Kruse & Drews, 2013; Lobato & Siebert, 2002; Moore & Carlson, 2012; Nathan, Kintsch, & Young, 1992), it would seem Steen's (1997) conjecture to integrate math into vocational training for middle and high school students is correct. CTE, specifically agricultural education, would be an ideal curriculum to begin developing secondary students' QR skills.

Results

Integrative Agricultural Education Rubric

A 19-question rubric was designed and applied to four extensive written lesson plans related to the curriculum development Ms. Martin was required to do for the grant program in which she was involved. The rubric was also applied to five instructional activities implemented by Ms. Martin during the project. The IAE rubric was designed guided by the conceptual

Table 3

IAE Rubric Scores for Written Integrative Lesson Plans

	Importance of BQA	Getting Fruity	Read Carefully: Medication Labels	Handle with Care
Problem/Project Based	0	0	0	0
Ag-Math Connections	3	3	0	2
Critical Questions	0	0	0	0
Authentic Resources	0	3	3	3
Scaffolding for Math	0	3	0	0
Two + subjects	1	2	0	0
Sharing Ideas in Groups	3	3	3	3
Reflect on Learning	1	1	0	2
Variations for Ability	0	0	0	0
Related experiences	1	0	0	0
Model mathematical thinking	0	0	0	0
Seek information	0	2	0	2
Consider alternatives	1	0	2	2
Math included	1	2	0	0
Appropriate Math	1	3	0	3
Need/beneficial math	1	1	0	2
Mathematical language	1	2	0	0
Mathematical thinking	1	2	0	1

Note. Scale 0 (none) – 3 (excellent)

framework for IAE (Appendix). The questions are scored 0 to 3. A zero score would relate to criteria not meet or not present in the lesson. The rubric was applied to two written lesson plans by the research team as well as two former agricultural education teachers to verify consistent use of the rubric and clarity of the criteria explanations. Some clarification on criteria explanation was recommended and adjusted prior to application of the rubric to the implemented activities.

Table 4

Break-out Rubric Scores for IAE Components

	Importance of BQA	Getting Fruity	Read Carefully: Medication Labels	Handle with Care
Integration	0.3	1.7	1.0	1.0
Student centered	1.0	1.0	0.8	1.5
Math/QR	1.0	2.0	0.0	1.0
Average Rubric Score	0.8	1.5	0.4	1.1

Note. Scale 0 (none) – 3 (excellent)

The resulting rubric scores on the written lesson plans are illustrated in table 3. Table 4 provides breakout scores for integration, student centered learning, and quantitative reasoning components of the rubric as well as an average rubric score for each lesson plan. These lesson plans are the result of the grant program to introduce an innovative idea into agriculture programs in which Ms. Martin was involved. Preparing lessons that reflected the innovation was a requirement of the grant program. In Ms. Martin's case, the innovation was providing students with BQA training, practice with mathematics in the agriculture context, and purchasing a mobile working chute for students to receive BQA certification testing on site. Ms. Martin prepared four extensive lessons prior to the beginning of this project. These lessons covered four major aspects of BQA certification and attempted to include mathematics in several activities in the lessons.

Collaboration

In this section, I present the results of analysis of collaborative work done between Ms. Martin and me which includes audio recordings of the limited number of work sessions we were able to organize, my own reflective journaling, field notes, and interview. The following categories were identified and will be discussed here: (a) collaboration strategies and (b) barriers to collaboration. Two themes for collaboration strategies were: (a) goals for collaboration are needed and (b) brining an expertise to collaboration. Barriers to collaboration were numerous with four themes developing: (a) uncertainties about math expectations, (b) lack of structured time to collaborate, (c) no tradition of collaboration, and (d) differences between content area teaching and duties.

Collaboration strategies revolved around needing goals and expertise that collaborating teachers bring to the table during the efforts. In my own reflections following work sessions, it was clear that the goals I had for integration were very different from the goals that Ms. Martin had for integration. This sentiment became clearer as we continued to work toward inclusion of higher levels of mathematics. In work sessions and very obviously in the interview, Ms. Martin states that her goal for integrating math is to keep the math basic; the ideas and procedures she believed would be needed in everyday life and those skills most prominent in agricultural practices related to BQA. During the first work session, Ms. Martin also shared that having several well-written lesson plans that she could easily submit to her administration on a weekly basis would be a beneficial outcome of the collaboration.

Barriers to collaboration were a far more significant discussion in several contexts. Ms. Martin is excited about using the pencil strategy and shares that she sees value in the approach. She would like to see the strategy used in other classes as well. During the final interview, she shares her uncertainty in using the strategy however saying, “I’m not the math department. I’m not forcing them to do stuff like that. I don’t know if it is something that is totally in opposition to something the math department teaches.” In this instance, she is unsure about whether her teaching is supporting the math teachers in her school. In other cases, her uncertainty relates to what students have learned in the past. Ms. Martin reflects on working out dosage calculations in class during the interview. She expresses this uncertainty about what mathematics students should know in a colorful way, “I was like, shit, I have to teach them how to do cross multiplication. [laughs] And I do, I have these moments when I’m like, crap, they don’t have that skill yet!”

Lack of a structured time to collaborate with other teachers and having no tradition of collaboration were viewed as barriers to collaboration. These also seemed to be the obstacle that Ms. Martin did not have a solution. Lack of support from school administration seemed to constitute the greatest concern. However, Ms. Martin also expressed that collaboration between agriculture teachers is not a common practice either, “So, it’s not like we don’t get along or anything. It’s just the way it is. CTE has never done things like that.”

Ms. Martin also contributes some of the lack of collaborative efforts to differences that she perceives between how math teachers and agriculture teachers approach their content area teaching and the duties that go along with their respective teaching assignments. Ms. Martin states that during workdays that are provided by her school system to work with other teachers in her department, the time is spent organizing FFA events or sharing changes to pertinent laws and changes to government regulations that effect what and how they present the content they teach in their agriculture courses. She sees this as a very different use of the time than what the math department teachers are able to do with their common workday time. Ms. Martin also points out during work sessions and again during the interview, that she believes she plans differently from other teachers. She however makes it clear that while she “would never dare infuse [her] style” on others but that does not mean that she is not will to help other teachers whenever she can.

Instructional activities

Five instructional activities were identified during the duration of the project. Each implemented activity had a clear introduction, a conclusion, and included concept development expectations. Two activities were math-laden, one activity included math but was not planned with that effort in mind, and two activities were not integrative in nature. Table 5 details the scores for each activity and each rubric question. Table 6 provides breakout scores for integration, student centered learning, and quantitative reasoning components of the rubric as well as an average rubric score for each implemented activity. See appendix for rubric and additional explanation for scoring criteria. A brief description of each activity follows.

Words into Math. The math laden activities were called Math into Words and Calculating Dosages. In the Math into Words activity, Ms. Martin introduced the activity with the opening line, “How many of you guys hate math?” She went on to collect reasons why students “hate math” and lead them toward not being certain about what operations should be used when reading math problems. Ms. Martin turned students’ attention to the types of problems they see on high-stakes standardized tests to make the connection to reading word problems stronger for her students. She then provided a rapid-fire set of questions about which words relate to mathematical operations that students should be familiar with. In this rapid-fire

Table 5

IAE rubric scores for implemented activities

	Intentional Math Laden Lesson		Math Included Lesson	Intentional Ag Lesson	
	Math into Words	Calculating Dosages	Wilbur	Breeds	Chute Design
Problem/Project Based	0	0	2	0	2
Ag-Math Connections	2	1	1	0	0
Critical Questions	0	0	0	1	1
Authentic Resources	0	3	3	3	1
Scaffolding for Math	3	2	1	0	0
Two + subjects	2	1	1	0	0
Sharing Ideas in Groups	2	3	1	2	0
Reflect on Learning	0	0	2	0	1
Variations for Ability	0	0	0	0	0
Related experiences	1	0	0	1	1
Model mathematical thinking	2	1	0	0	0
Seek information	1	0	2	3	3
Consider alternatives	0	1	0	0	2
Math included	3	1	2	0	0
Appropriate Math	3	1	1	0	0
Need/beneficial math	1	1	1	0	0
mathematical language	3	1	0	0	0
mathematical thinking	1	0	0	0	0

Note. Scale 0 (none) – 3 (excellent)

Table 6

Break-out Rubric Scores for IAE Components in Implemented Activities

	Intentional Math Laden Lesson		Math Included Lesson	Intentional Math Laden Lesson	
	Math into Words	Calculating Dosages	Wilbur	Breeds	Chute Design
Integration	0.7	1.3	2.0	1.3	1.3
Student centered	0.7	0.7	0.8	1.0	1.2
Math/QR	2.3	1.0	0.8	0.0	0.0
Average Rubric Score	1.3	0.9	0.9	0.6	0.6

Note. Scale 0 (none) – 3 (excellent)

questioning, Ms. Martin did not get a lot of answers from the students because the answers are not immediately recalled. She made it clear that it is important to know how to translate words into math and that in the agriculture industry, as with most industries, there are words that need to be translated into math as well. A quick review of several herd management words began to make this connection obvious to students. With the ground work laid for the activity, Ms. Martin provided students with a graphic organizer with a word bank of terms for students to organize into categories that relate to mathematical operations. As students worked, Ms. Martin provided some one on one help, usually as she is monitored students' progress but before they asked for help. Twice she made open announcements to the class following a student question to give hints about terms that seem to be confusing. Students could work with other students at their table and could use their phones to look up words if needed but Ms. Martin did request that student try to get through the words they knew first. The answers on the graphic organizer were reviewed as a class. This had Ms. Martin reading from the projection of the answer key to students with some commentary about a few of the terms as she read. The next activity in the activity was using the pencil strategy that was provided to students in an earlier activity combined with the review of translated words into math. Ms. Martin projected a word problem about a farmer calculating how much medication to purchase for herd vaccinations onto the board. The pencil strategy is a literacy comprehension strategy that provides steps to identifying keywords in the word problem followed by simple steps to transition to the math related to the keywords. Ms. Martin lead this discussion, asking students to provide answers that relate to each step of the strategy as she marks the keywords on the board over the word problem being projected. Before beginning the mathematical calculations, Ms. Martin took a moment to visibly check over the problem to make sure she had not missed anything (interview). She picked up again, asking the class to provide her with the next pieces of information needed to solve the problem until they come to a reasonable solution. Ms. Martin finished the problem with a quick explanation about how knowing the total medication needed for the herd needed to be taken a step further when purchasing the medication to make sure an appropriate amount, not too large a bottle, is purchased because the storage life on the medication is limited.

Calculating Dosages. This activity began with a very brief introduction that does not contain concepts but instead provided a good amount of direction for students to follow to get through the activity. There were 12 questions written on the whiteboard and Ms. Martin handed out copies of medication labels to students. To prevent cheating, Ms. Martin said in class, and later mentioned, that each student started the activity by writing their birthday on their paper to be used as the vaccination date for calculations that came throughout the activity. The questions are direct and related to the information students found on the medication label provided. Students were told they could work with other students at their table. Ms. Martin was present in the room, walked around, and checked students' progress as they worked. She provided one-on-one help most often. She also made several class announcements with helpful hints and words of encouragement after she answered individual student's questions. As she monitored progress, she had students pause during their work and directed their attention to the board and on her. At the board, she explained how to calculate the medication dosage for one of the five calves she provided in the third question. She asked the class questions as she worked and waited for responses which she recognized as she continued to work. She wrote the equation first, said she needed to divide to solve, and then wrote the simplified equation under the original. After a few questions from students, the solving process was reduced to simply dividing. Ms. Martin instructed students to return to work on the rest of the questions. As students completed the assignment, Ms. Martin collected papers as she reviewed the answers to the questions just in time for class to end.

Wilbur's Record Keeping. This activity was intended to provide students a good review of record keeping procedures, dosage calculations, and medication storage requirements. The introduction of the activity provided students background information on Wilbur the pig and directions for completing the worksheet of questions that guided students through Wilbur's life. Students were expected to use the internet to find medication labels that were needed throughout the pig's health care routine and use information from those labels to answer questions about dosage, storage, withdrawal times, and similar details needed in the record keeping process that was previously introduced. Students were once again provided the offer to work with other students at their table. Ms. Martin circulated throughout the room, helped students one-on-one as they asked and occasionally, as she noticed they were not making progress, helped without being called upon. After some individual questions, Ms. Martin made class announcements about helpful hints or procedures that were needed. Several times, she reminded students that they would need to do a little math to calculate the dosages but almost always saying "you'll just cross multiple." The internet access was lost during the activity which prevented students from looking up the labels they needed. While the access was down, Ms. Martin provided some information about the medications needed from memory or by looking up the label for herself on her own phone. One of the questions on the worksheet required students to calculate a dosage from a concentrated medication. This problem was a challenge for several students. Ms. Martin called students' attention to the board and on her, as she began to work the concentration problem on the board for demonstration. She explained as she worked and solicited help with calculations from students. She got a value that she was not happy with and tried a different method for solving the equation. Asking again for help from a few students with calculators to speed up the process. Ms. Martin was not successful in completing the problem but did tell students she would check on the process and get back to them. The timeframe of the study ended before we could see Ms. Martin revisit this problem with her students.

Breeds. The Breeds activity was designed to have students gather more information for the cattle breed they chose to make as their cow model, an ongoing project during the BQA unit. The introduction for this activity consisted of several questions posed by Ms. Martin that activated information learned in a prior lesson about climate, location, and human survival needs that helped shape breed characteristics. Ms. Martin provided students with clear directions about the assignment and passed out index cards that were needed for the activity. Students were instructed to use their phones, Chromebooks, or laptops to search the internet for advantageous and disadvantageous characteristics of the breed that students' models were to represent. As students completed their search and listed the characteristics needed on their index card, they turned in their note cards to be graded.

Chute Design. This was the lengthiest complete activity viewed during the timeframe of the study. The introduction to this activity was a reminder to students that they would soon be going to a local farm to do their BQA certification training. Becoming familiar with cattle handling and a working chute would, Ms. Martin suggested, make the training less stressful for students that had not been on a farm or around cattle before. Most of Ms. Martin's students have little to no experience with cattle. Ms. Martin asked students questions about their own experience with herding animals. For many students, their only experience was related to Ms. Martin's pet potbellied pig, Hammy, who visited the classroom regularly. They discussed how moving around Hammy caused him to go in the direction they needed him to and how similar movements around cattle had the same results. This provided a transition to the video on cattle handling techniques. This video was watched from the beginning to the end with a class discussion at the end that related several techniques back to a prior Temple Grandin video that was watched in a previous class period. Ms. Martin then transitioned students to the next video on cattle chute design and the components of a working chute. After each segment of this video, Ms. Martin stopped the video, gave students time to take notes after she made it clear what was important from each segment, then provided a brief discussion of the information covered. She asked questions about the design components. Some questions focused on why they would be important for the cattle and others focused on the importance as a safety measure for the handlers. Ms. Martin stayed aware of the fact that her students were not familiar with cattle in general and tried to relate design components and handling methods to more familiar things her students would likely be familiar. For example, the video introduced students to a squeeze chute. When asked, students were not clear on the purpose of the design element. Ms. Martin recalled Dr. Grandin's suggestion from the previous video that a strong hug could help calm people and animals when they were nervous. She also likened the squeeze chute to a thunder jacket for dogs. Ms. Martin seems satisfied that students understood the purpose of the squeeze chute after these two examples. Once the video was complete, Ms. Martin provided a situation for a local farmer that wanted to design a mobile handline facility for his cattle. In the situation, Ms. Martin provided details about the number of cattle and space available for the facility. She instructed students to use their notes, talk to the other students at the table, and search online to design a handling system that would be appropriate for the farmer.

Planning, Teaching, & Reflection

In this section, I present the results of my analysis of Ms. Martin's teaching episodes, collaborative work sessions between Ms. Martin and me, which also includes my own reflective journaling, lesson plan documents, teacher reflection, and interview. The following categories were identified and will be discussed here: (a) Intentionality and (b) Content.

Intentionality. Intentionality was identified as planning and teaching with the intention of integrating math that is both needed and useful in the required agriculture content. Ms. Martin focused on making the connections between the agriculture and math clear. To help students build a better understanding of math, Ms. Martin supported students' use of intuition, prior knowledge, and reasoning. Students were expected to engage in conversations about math with each other. Ms. Martin viewed her own math mistakes as teachable moments. Intentionality was seen during goal setting for the integrative curriculum, planning for math integration during lesson planning, and during implementation of those lesson plans.

Goal setting. Ms. Martin made the decision to integrate mathematics into her program (interview). She was not asked to do this by her administration or promoted to do so because of attractive funding. She initiated this goal because she saw a need. She observed her students struggling and chose to begin working toward including mathematics in areas that she found were naturally occurring in the agriculture content. The intention was set to integrate mathematics. Solicitation to be involved in this research project opened the door to Ms. Martin to be more focused on her efforts (personal communication, August 18, 2016); an opportunity she expressed interest and excitement about.

Planning. Ms. Martin stated during the interview, "I think when you start by making sure that you start with the objective and you very clearly state that math objective and keep referring to it, it makes kind of a critical impact on the kids." She follows through with this intent with the written plans for the Words into Math activity. The lesson plan includes the objective: "Students will be able to examine word problems using math literacy strategies" (Getting Fruity: Injection Techniques). The activities planned in this lesson are on par with the lessons that were implemented during the Words into Math activity (video). The correlation between the written lesson plans and the implementation suggest Ms. Martin was intentional in her planning to include the math laden activity.

During the collaborative work session, I noted Ms. Martin's intentionality for integrating math as well. During discussions that lead to adapting a current multiple-choice quiz about medication dosing, Ms. Martin initiated the conversation about converting some of the multiple-choice questions into short answer questions. Her intention was to require students to show their work and demonstrate their mathematical thinking rather than giving them an excuse for not doing the work involved in calculating dosages. She also wanted to include a question that required students to use multiple steps to complete the question and shared a desire to have students share their answer as a complete thought. Ms. Martin's intention was clearly to highlight the mathematics she believes is important and reinforce the multiple-step process that is common in math and agriculture.

Implementation. Ms. Martin's intentionality during implementation runs steadily through all lessons. An activity designed to have students practice medication label reading and understanding medication storage ends up providing an opportunity for Ms. Martin to remind students that they will still use mathematics in instances for which they do not plan. Throughout the Wilbur Record Keeping activity, Ms. Martin reminds students they will need to use ratios and will need to do a conversation on one of the questions included in the activity. While monitoring student progress, Ms. Martin made a class announcement inquiring about incomplete questions that require calculating dosages for Wilbur. She encourages her students to attempt these problems, to check their answers with others at their tables, and reinforces that they will go over those problems together later but they need to make the attempt on their own first.

Ms. Martin's intentions of integrating math are also seen as she repeatedly suggested students talk to one another when they find themselves at an impasse. During both the Calculating Dosages and Words into Math activities, Ms. Martin reminded students to talk to the other students at their table, and get as far as they could in the problem before asking her for help. She wanted to see they tried. She shared her strong belief about having students work in groups, especially when they were working on math related activities, during the interview. Ms. Martin said, "They've got to talk about it to process some of it. And if they're at least sitting there going, 'I don't get why this would mean this,' at least they are trying to think about it. Whereas the kid that is just sitting there going, 'I don't know this!'; they learn nothing."

Talking openly with her students about math is also a strategy that Ms. Martin used regularly to support the intentionality of including math in the agriculture curriculum. As the Wilbur's Record Keeping activity was coming to a close, Ms. Martin was at the board demonstrating for students how to transition from a medication concentration to a dosing unit. She began working the problem on the board herself for a brief moment before she called her students attention to the work. She shared her thinking process with the students as she continued to work,

> There are .o6 mg/ml. So how many ml's do you need? Take this and divide it by .06 . . .I think. (Doing calculations on calculator.) Multip . . .Trying to figure out which one you multiple it by. Or divide by. (long pause) Try multiplying that out and tell me what we get (to a student). Multiply this times that (points to 5.68 mg and .06 mg/ml written on the board). (pause) Let me try this. I'm going to try it one way and you are going to try it the other. [student calls out a value] (long pause) Uhm...alright, I'll look up to see how to do the rest of this one at the end.

This attempt to include the mathematical process did not end as Ms. Martin had hoped, with a solution to the dosage question, however, this was not interpreted as a failure. Ms. Martin used this mistake as an opportunity to demonstrate mathematical thinking which turned the mistake into a teachable moment even if there was no answer found in the end. Ms. Martin refers to these moments as developing a sense of "We are in it together" in her classroom (interview). She realizes she will make mistakes but she has the impression her students appreciate that she does not let the mistakes frustrate or embarrass her. Turning them into moments that demonstrate how to work through struggles with math is approached with intention and those challenges are faced head on by Ms. Martin in an effort to make her students feel like they are doing it together.

The final component of intentionality Ms. Martin exemplifies in her implementation is the intention to highlight the direct connections between math and agriculture not to create an add-on math lesson for students. This is best seen in the way Ms. Martin presents the Words into

Math activity. In the introduction of the activity Ms. Martin initiates students' prior knowledge through a rapid succession of questions that relate to what they have learned in their math courses that relate to the activity. As Ms. Martin begins the activity, it appeared to be an add-on math lesson. She brings agriculture back to the forefront of the learning by turning students' attention to herd management terminology they recently learned.

> "How many of you can tell me, right off the top of your head, the words that translate into parenthesis? [pause for student answers.] What about all the words that mean equal to, or add them up, or take away? [pause for student answers.] But, can you come up with them off the top of your head? Okay, how about this, there are even industries that have their own words for it. For instance, agriculture, let's talk about our words. What might be a word in agriculture that means we are going to have more of something? Okay, remember this word [writes on board], parturition? What about gestation? [students answer.] So, parturition means it's giving birth. So, hopefully if it's giving birth you are going to get what? [students answer.] So, addition or maybe some multiplication going on, right?"

Ms. Martin is intentional when she includes math as part of the lesson but does not integrate it at the sake of the agriculture content. The agriculture should still be at the forefront of the learning (interview). Math activities drew on the direct relationship with the agriculture content with the intention of helping students better understand the math concepts by using the agriculture to make sense of it. Ms. Martin recalled a struggling student enthusiastically telling her after working on a math related activity, "Well that made perfect sense! Why can't we do that all the time."

Content. Content was viewed as coming from two foci; the agriculture first, then the math. Agriculture content should not be sacrificed for the math but is needed to make mathematics clearer and understandable for students. The math should be foundational; skills and knowledge thought to be needed for everyday situations. It is perceived that in this combination students will improve their QR skills. Ms. Martin's beliefs about content give way to the strategies she included during implementation of the content material.

Agriculture content is priority. Ms. Martin perceives integration in agriculture as a way to provide students a well-rounded experience that is relevant, rigorous, and applicable to their lives. Her goal is to develop capable people outside of school. She believes education is about creating thinkers and decision makers. Agriculture is held as a flexible and interesting context for students to practice these skills. Including math in agriculture must be done in an authentic way with the agriculture always being the focus of instruction.

Words into Math provides an obvious example of Ms. Martin's focus on agriculture. As this lesson is introduced it seems to be an activity that will only review words commonly associated with mathematical operations just as they would have been used in a math class. Ms. Martin turned to reviewing industry related terminology with students to also associate the need for mathematical operations pulls the activity directly back into agriculture. Further supporting this focus on agriculture, the problem Ms. Martin has students dissect to identify the mathematical information they will need to solve the problem is a problem that would be found in agriculture and is directly related to the learning objective Ms. Martin included in the lesson plan associated with the Words into Math activity (Getting Fruity: Injection Techniques).

As Ms. Martin's introduces the Breeds activity to student, she asks them to recall information they learned earlier that related to why certain breeds were developed; associating developing and traits to needs for survival. She leads the discussion, asking for student input in the conversation to engage and make them active participants in the conversation. This activity includes no mathematics however, the method that is used to introduce this activity is similar in many ways to the method Ms. Martin uses when introducing the Words into Math activity. The interesting aspect to notice here is that despite the different objective for the activities, the agriculture remained the focus and the technique to activate students' prior knowledge and engagement with the activity are staples in Ms. Martin's teaching strategies.

Foundational Mathematics Content Integrated. The math that is integrated should be foundational and useful. Foundational in this case means calculations, problem solving using mathematical thinking in complex situations, and some basic equation solving skill. Ms. Martin noted a change in some students' attitude about how mathematics is applied and understood (interview). Ms. Martin further suggests during collaborative work sessions and during the final interview that opportunities offered in agricultural education can provide students practice in application and reasoning instead of only focusing on information for the purpose of testing in math class. The math presented in each of the activities represented in this project was foundational and highly procedural, that is computation based and based on routine procedures to complete calculations. Translating words into operations is a fundamental skill reviewed through Algebra 1 typically. Writing equations, such as the one introduced during the Dosage activity, is also a fundamental skill reviewed through Algebra 1.

Strategies to Support Students' Math and QR Development. Strategies for support of students' math and QR development were seen implemented alongside the agriculture content. Ms. Martin assumed without the agricultural content the support strategies were less helpful to student learning (interview). Ms. Martin used real-world examples to support students' use of math. She referred to using money as a good way to explain reading the graduations on a syringe (interview) and uses football penalties as an alternative way to explain “turn around words” in the Words into Math activity.

The context of the activity provides a backdrop for many of the support strategies Ms. Martin used. She expects her students to talk to one another when they are working on any of the activities she assigned. She is particularly habitual with the suggestion of talking to a neighbor during math related activities. This same strategy was seen used heavily when unforeseen problems arise during agriculture based activities. For example, when internet access is lost during the Wilbur Record Keeping activity, Ms. Martin repeatedly asked students to talk to their neighbor to share information and talk about the information they have and what they do not have to try to help each other finish the activity.

The context of the activity also helps students to explain their own thinking by aligning with the information provided to them in the activity. Ms. Martin clarified that when she helped students one-on-one, which is also a common support strategy seen in all the math laden activities, she would ask them to explain the way they solved the problem. If they had a strategy that worked consistently she would be satisfied with their answer. If they had a haphazard process, she would remind them that unless it fit into the rules of mathematics and worked all of the time, then they did not have good mathematical way of solving they just had a one-time strategy. Students used the activity however to provide context to their thinking and related their answers to the problem at hand which Ms. Martin interpreted as helping them make sense of the math as they worked with the constraints of the problem (interview).

While the resource was not used during the teaching episodes, one of the artifacts designed as a result of the collaborative work sessions was an adapted Skill-A-Thon Quiz. Ms.

Martin wanted to provide students with an opportunity to practice their mathematical thinking and problem solving skills through a multiple step, short answer question on the graded assignment. This same strategy was seen used during the Wilber Record Keeping activity as students had to continue build off of the weight and date calculations they began with during the early questions on the activity worksheet. In both activities, the support strategy required the use of the content to guide the math concepts being used.

An additional strategy that is used by Ms. Martin comes into play with the heavy procedural mathematics that is seen throughout the activities. During the Dosage activity, Ms. Martin approaches the board to provide a whole-class demonstration of how to calculate the dosages for several calves. After she writes the equation for the problem and talks about how she is working through the steps to solve the equation a student makes a suggestion. Ms. Martin agrees with the student and repeats the suggestion for the class, "Yep, you can just divide those two numbers." This strategy is simplifying the mathematics to keep it basic and procedural. "Just cross multiple" is heard rather often during activities that involve dosage calculations reinforcing the use of the strategy.

Discussion

Ms. Martin made efforts to integrate mathematics into the agriculture curriculum. These efforts resulted in meeting much of the criteria as it was expected for IAE. Defining exactly what integration of STEM area content in agricultural education looks like is a challenge because the practice has yet to be clearly defined in the field (Scherer et al., 2017). In this study, the conceptualized framework for integrative agricultural education provided guidance in determining the integration of the lessons and activities Ms. Martin offered her students. Using this framework, Ms. Martin's efforts to integrate mathematics with the intention of improving students' QR skills were admirable. It comes as no surprise that highly integrative lessons were not presented in this first attempt. It takes repeated attempts and a great deal of reflection to improve the praxis of teaching (Brown & Smith, 1997; Fennema & Franke, 1992). There is more work to do in this area however, Ms. Martin's experience suggests, in general, the teaching techniques used regularly in her agricultural education courses work to present math concepts embedded in the agriculture context as well. Ms. Martin shared a similar sentiment during a conversation in the second collaborative work session, suggesting that if you have strong teaching skills, she believed good teachers could teach anything if you had some knowledge about it.

This comment is further interesting when mathematical content knowledge is considered. Deep mathematical content knowledge was not expected of Ms. Martin as she is trained as an agricultural education teacher. Her content knowledge lies in agriculture and her passion is clearly in this field as well. Ms. Martin presents mathematical knowledge that meets the goals she set for the integration of mathematics. There are moments during the teaching episodes in this study that suggest Ms. Martin also presented mathematical information that she felt comfortable with but that did not push far outside her comfort levels of mathematical knowledge. Ms. Martin shows strong procedural knowledge in mathematics and a good deal of flexibility in her procedural knowledge which suggests she is building toward mathematical conceptual knowledge. Hiebert & Lefevre (1986) provide concise explanations of mathematical procedural and conceptual knowledge. Procedural knowledge is the ability to follow the steps and definitions in mathematics and preforming actions related to the processes of mathematics. Conceptual knowledge reveals meaning in the processes of mathematics by connecting ideas and experience that lead to understanding why procedures are used. In the continuum between procedural and conceptual knowledge, Star (2005) & Kieran (2007) describe a middle ground that is demonstrated through flexible procedural knowledge that does not come with the same flexible application in context. Ms. Martin exemplifies this middle ground on the mathematical knowledge continuum during moments like the stumble during the Wilbur Record Keeping activity when she is unable to make the conversion calculations work out correctly. This stumble was handled well. Ms. Martin provided her students with a great example of mathematical reasoning by soliciting help from students as she reasoned, out loud, through different approaches to making the conversion work. In the end, however, the conversation was unsuccessful and there was no evidence, within the scope of this project, that would suggest she revisited the problem for clarification with her students. This was interpreted as a challenge to Ms. Martin's mathematical content knowledge.

To counter this instance in mathematical knowledge, Ms. Martin was quick on her feet to discuss a point of discourse when internet access was lost. During the Wilbur Record Keeping activity, students were expected to search the internet for medication labels. Ms. Martin's agricultural content knowledge was strong enough to recognize the similarities between two medications that were required on the activity. She relayed this information to the students matter-of-factly but clearly demonstrated her extensive and fluid ability to recall and share content information even in a situation that was not planned and rather hectic within the classroom setting.

Intentionality is a component that is expected in IAE as it is designed. Ms. Martin brings a new light to the importance of being intentional during integrative teaching. In her experience, intentionally is found in the goal for integration, the planning of the curriculum, and in the strategies used for implementing the lessons. Ms. Martin clearly believes there is an importance to expose her students to mathematics within a context and that her students will benefit from that exposure. To help students "realize that [math is] a part of everything they do," Ms. Martin sets the goal for using integrative practices as need to include math in the context and being intentional and thoughtful about doing it. Ms. Martin's belief that math needs a context and with the context math begins to make sense pushes the intentionality of integrating mathematics into the planning stage. During the final interview, Ms. Martin points out that objectives, including math objectives, need to be the starting point of the planning process. This level of intentionality is supported further as she develops lesson plans with the focus on mathematics. Math into Words was the activity that was well-developed and included in formal lesson plans. The lesson that included the Math in Words activity performed well in the IAE rubric evaluation overall, especially in the inclusion of mathematics in the lesson. During most lessons, Ms. Martin repeatedly pointed out to students that they would be doing math and would often refer to the process they would need to implement (cross multiplication and ratios typically) as students worked through the activity. This strategy during implementation reiterates Ms. Martin's reflection during the final interview that referring back to the objective makes a "critical impact on the kids." Ms. Martin believes this helps the students "know why I'm doing it [math]." Clearly making math intentional and approaching the integrative instruction with the mindset that it is important to let students know they will be doing math, that the expectation is they do the mathematics, and that they will use it again in the future.

"I can help you" was a very common phrase heard throughout Ms. Martin's lessons, particularly while she was asking students to focus on math laden activities. Ms. Martin shares several times during the collaborative work sessions and again during the final interview that she feels capable of helping students with math and does believe in her abilities to provide instruction that would support students' understanding. She also believes that she is human and makes mistakes. She sees these as an opportunity to demonstrate to her students that everyone makes mistakes. Talking through those struggles, she believes, "shows them [students] I'm on their side." The quantitative reasoning Ms. Martin shows in how she openly supports her students with statements of confidence and reassurance of her own understanding and ability to do math may be infectious. This is the impression she gives as she is teaching and as she reflects on her teaching. She wants her students to believe "they are in it together." To do this, Ms. Martin exudes confidence, does not shy away from doing mathematics that she did not carefully plan for even when it is challenging, and enthusiastically engages with mathematics that is embedded in the agricultural content she aims to teach. Her positive disposition toward mathematics is clear and her ability to reason mathematically is alive and well as she helps students one-on-one. None of the one-on-one conversations with students was captured on video, however, Ms. Martin retells about helping students in the final interview. In this retelling, she shares that she realizes there is often more than one way to solve a problem. She is willing to allow students to share with her how they went through the solving process and as long as they can explain it and are within the rules of mathematics, she is fine with their approach. She stresses to students as well that unless they can repeatedly use their method, then it is not a good approach. This ability to follow a students' reasoning and evaluate it for soundness suggests Ms. Martin's own mathematical reasoning abilities are fairly strong. Acceptance of alternative approaches to solving problems suggests a flexibility in her understanding of math and how it applies to unique situations. The suggestion that she stresses the reuse of a method to students further supports her understanding of the nature of mathematics. Ms. Martin has worked to find mathematics concepts that are related and relevant in the BQA lessons she teaches; this real-world engagement between mathematics and agriculture brings in each of the six criteria that are expected of strong quantitative reasoning. Ms. Martin's own QR skills are evident as she plans and instructs her students. Possessing quantitative reasoning skills is the driving force for Ms. Martin's choice to pursue integrating mathematics. Ms. Martin's goals for her attempt at IAE highlight the aspects of QR that she finds most important and reflect her own QR strengths.

Implications

To integrate STEM content into agricultural education, Stubbs and Myers (2015) suggest that teachers need a significant amount of STEM content knowledge. This same research suggests the more preparation teachers have in a content area the more likely they will integrate that content. Specifically, more practice in math and reasoning skills will lead to more instruction to support QR skills (Türker, Sağlam, & Umay, 2010). Teachers' participation in curriculum development has been found to relate to student achievement in mathematics (Huffman, Thomas, & Lawrenz, 2003). When curriculum development is coupled with collaboration with other exemplar teachers, experts in the field of study, and quality facilitation of the collaborative efforts, teachers report improved content knowledge (Drits-Esser & Stark, 2015). From participation in the collaborative work during this project, I experienced the same frustrations that Ms. Martin discussed as a barrier to collaboration with the lack of facilitation of quality collaboration efforts. It is speculated, and seems to be supported by Drits-Esser and Stark (2015), that Ms. Martin and myself may have gained more content knowledge outside our areas of expertise had the collaborative experience addressed the barriers identified in this study. For effective collaboration, goals are needed with a focus on a topic, be that curriculum development, student engagement, or other such interest in the teaching and learning process (Drits-Esser & Stark, 2015; Huffman, et al., 2003). These goals should also be directed at the teachers' own students directly and highly applicable in their classrooms to make the efforts at collaboration have long-term consequences for students and teachers (Drits-Esser & Stark, 2015; Huffman, et al., 2003). As this is a case study, the collaborative curriculum development that did occur was directed specifically at Ms. Martin's students and was applicable in her classroom. This is an important aspect of the collaboration because Ms. Martin was comfortable with the activities and materials that were developed. Having a hand in the development was important to Ms. Martin albeit she would often defer development of some math laden materials to me, as the expert in the content area. This deferral to expertise was reciprocated as well as I nearly as often, possibility more so than Ms. Martin, requested her help with building better context around the math components we designed together. Better facilitated collaboration with clearly set goals for the collaboration would have likely resulted in Ms. Martin's mathematical content knowledge gains being more significant. Ms. Martin provided many situations that were off-script teaching. Off-script teaching is instruction that occurs outside of the strict plans for the lesson and requires that teachers have significant knowledge and high self-efficacy in their practice (Fennema & Franke, 1992). These off-script teaching occurrences, may be stronger and approached with more confidence with improvements in mathematical content knowledge.

Wiggins (2003) suggests that students need to be taught to question; to ask if one piece of information is more important than another, what is assumed in the context of a situation, and what limits exist implicitly and explicitly in a situation. It takes well-developed teacher-designed activities to provide students opportunities to learn to ask questions that will also develop their QR skills (Madison, 2014). The activities are messy but with the context providing constraints, decisions must be made to determine what information is worthwhile and what is meant to lead the work astray (Gal, 1997). Constraints are natural and show hidden relationship in the context. Intuition, creativity, and knowledge guide students toward a solution that may look different for each student (Cobb, 1997). Developing instruction, activities, and curriculum with the objective of developing not only students' content knowledge but also their critical thinking and questioning skills when faced with numbers and mathematical situations takes planning with those goals in mind. A teacher must plan with intention in order to meet those objectives. They need to "make it more likely by design than by luck . . . . Without lessons designed to bring ideas to life, concepts . . . remain empty phrases to be memorized, depriving learners of the realization that ideas have power" (Wiggins & McTighe, 2005, p. 43).

Conclusion

The intention of this case study was to begin the discussion about integrative agricultural education. From Ms. Martin, two teacher characteristics seem to play a significant role in integrative instruction in agriculture. The first teacher characteristic is a strong desire to integrate mathematics and see the importance of doing so for students' benefit. The second teacher characteristic important for integrative agricultural education is quantitative reasoning skills. These characteristics are the driving force behind Ms. Martin's attempt to integrate mathematics into her agriculture curriculum. Ms. Martin had goals for integrating math and because of these goals she was showed a significant amount of intentionality in her planning, lesson development, and teaching. This intentionality, Ms. Martin suggestions, was reflected in her perception of students' improvement in attitude toward math.

Ms. Martin's intentionality is the most significant strategy used in implementing integrative agricultural education. From a more practical perspective, in the classroom, Ms. Martin was comfortable with student-centered instruction techniques. These techniques were the mainstay in this case study classroom and permeated throughout agriculture related and math laden lessons and activities. Without specific information on student learning or reports of improvement in QR skill development, it is difficult to conclude this is the best practice for IAE, however, these techniques do align well with the IAE framework provided in this study and illustrated by the IAE rubric.

Clarity on what mathematical knowledge students should be expected to have at the high school level and a more flexible understanding of mathematical concepts as it relates to content may have provided Ms. Martin a stronger base when faced with off-script teaching moments. Strong content knowledge in agriculture made it easy for Ms. Martin to handle challenging situations and move instruction along even in difficult teaching moments. Stumbles seen while working in math driven situations were handled well, which is likely related to Ms. Martin's QR skill set, but deeper mathematical content knowledge may have given her the same fluid recovery that was seen while focusing on agriculture topics while teaching.

Well-structured and administration-supported collaboration may be the key to developing mathematical knowledge that is reaching conceptual understanding of concepts. Ms. Martin shared far more obstacles to collaboration than successes. However, the collaborative experience included in this project, albeit not as well-structured as it could have been, was perceived as beneficial and positive. Goals for and clearer expectations of the collaborative effort as well as time to focus on working together would have been the greatest assets to making the collaborative work more rewarding.

These points provide an excellent foundation to begin discussing what is needed to strengthen the integrative approach to teaching mathematics in agricultural education to develop students' quantitative reasoning skills. Teacher buy-in is needed as well as the teacher possessing mathematical literacy and reasoning skills. Using the integrative agricultural education framework provided goals for development of lessons and resources that supported student-centered learning and teaching techniques that were within the case study teacher's repertoire. Finally, well-facilitated collaboration between agricultural education and mathematics teachers has potential to strengthen content knowledge for both teachers if obstacles to successful and positive collaboration can be overcome.

The next steps in further developing integrative agricultural education may be in facilitation of collaboration between agriculture and math teachers. Promoting this effort may reveal a support system that will build content knowledge, teachers' quantitative reasoning, and build a curriculum that supports the goals of both teachers involved in the work. It is speculated that more teachers will buy-in as they begin to see positive results of integration in agriculture, having potential to make agricultural education a frontrunner the movement toward STEM education.

References

Agustin, M. Z., Agustin, M., Brunkow, P., & Thomas, S. (2012). Developing quantitative reasoning: Will taking traditional math courses suffice? An empirical study. *Journal of General Eduation, 61*, 305-313.

Boose, D. (2014). Teaching quantitative reasoning for nonscience majors through carbon footpring analysis. *Journal of College Science Teaching*, 44(2), 18-25.

Brown, C.A., & Smith, M. S. (1997). Supporting the development of mathematical pedagogy. *The Mathematics Teacher*, 90(2), 138-143.

Cobb, G.W. (1997). Mere literacy is not enough. Steen, L. A. (Ed.). *Why numbers count: quantitative literacy for tomorrow's America* (pp. 75 – 90). New York: College Entrance Examination Board.

Committee on Agricultural Education in Secondary Schools Board on Agriculture National Research Council. (1988). *Understanding agriculture: New directions for education.* Washington, D.C.: National Academy Press.

Corbin, J., & Strauss, A. (2005). Basics of qualitative research: Techniques and procedures for developing grounded theory (4th ed.). Thousand Oaks, CA.

Creamer, E.G., Simmons, D.R., & Yu, R. (2015). *Using mixed methods to conduct a meta-synthesis of the literature: Moving from words to numbers*. Paper presented at the Conference on Higher Education Pedagogy, Blacksburg, VA. Retrieved from http://www.cider.vt.edu/conference/proceedings/2015ConferenceProceedings.pdf.

Creswell, J.W. & Plano Clark, V.L. (2011). *Designing and conducting mixed methods research*. Thousand Oaks, CA: SAGE Publications, Inc.

Cromwell, L. (1992). Assessing critical thinking. *New Directions for Community Colleges, 77*(Spring), 37-50.

deLange, J. (1995). Assessment: No change without problems. T. A. Romberg (Ed.), Reform in school mathematics and authentic assessment (pp. 87 – 172). Albany, NY: State University of New York Press.

Fennema, E., & Franke, M. L. (1992). Teachers' knowledge and its impact. In D. A. Grouws (Ed.), Handbook of Research on Mathematics Teaching and Learning. Reston,VA: NCTM.

Foutz, T., Navarro, M., Bill, R., Thompson, S., Miller, K., & Riddleberger, D. (2011). Using the discipline of agricultural engineering to integrate math and science. *Journal of STEM Education, 12*(1&2), 24-32.

Gal, I. (1997). Numeracy: Imperatives of a forgotten goal. Steen, L. A. (Ed.). *Why numbers count: quantitative literacy for tomorrow's America* (pp. 36 -44). New York: College Entrance Examination Board.

Gardner, D. P., Larsen, Y. W., & Baker, W. (1983). A nation at risk: The imperative for educational reform. *Washington, DC: US Government Printing Office*.

Hiebert, J., & Lefevre, P. (1986). Conceptual and procedural knowledge in mathematics: An introductory analysis. In J. Hiebert (Ed.), *Conceptual and procedural knowledge: The case of mathematics* (pp. 1-27). Hillsdale, NJ: Lawrence Erlbaum Associates.

Hmelo-Silver, C. E. (2004). Problem-based learning: what and how do students learn? *Educational Psychology Review, 16*(3), 235-266.

Hoachlander, G. (1997). Organizing mathematics education around work. **Steen, L. A. (Ed.).** *Why numbers count: quantitative literacy for tomorrow's America*. New York: College Entrance Examination Board.

Kieran, C. (Ed.). (2007). *Learning and teaching algebra at the middle school through college levels: Building meaning for symbols and their manipulation*. United States of America: Information Age Publishing Inc.

Kennedy, T., & Odell, M. (2014). Engaging students in STEM education. *Science Education International, 25*(3), 246-258.

Koedinger, K. R., & Nathan, M. J. (2004). The Real Story Behind Story Problems: Effects of Representations on Quantitative Reasoning. *Journal of the Learning Sciences, 13*(2), 129-164.

Kruse, G. & Drews, D. (2013). Using performance tasks to improve quantitative reasoning in an introductory mathematics course. *International Journal for the Scholarship of Teaching and Learning*, 7(2), article 19.

Laboy-Rush, D. (2011). Integrating STEM education through project based learning. Retrieved from http://www.rondout.k12.ny.us/common/pages/DisplayFile.aspx?itemId=16466975

Lobato, J. & Siebert, D. (2002). Quantitative reasoning in a reconcieved view of transfer. *Journal of Mathematical Behavior*, 21(2002), 87-116.

Madison, B.L. (2014). How does one design or evaluate a course in quantitative reasoning? *Numeracy*, 7(2), article 3.

Marshall, C., & Rossman, G. B. (2011). *Designing qualitative research* (5th ed.). Thousand Oaks, CA: Sage.

McCormick, R. (2004). Issues of learning and knowledge in technology education. *International Journal of Technology and Design Education, 14*, 21-44.

Moore, K., & Carlson, M. (2012). Students' images of problem contexts when solving applied problems. *The Journal of Mathematical Behavior, 31*, 48-59.

Moye, J., Dugger, W., & Stark-Weather, K. (2014). “Learning by doing” research introduction. Retrieved from http://iteea.org/39126.aspx

Moylan, W.A. (2008). Learning by project: Developing essential 21st century skills using student team projects. *The International Journal of Learning*, 15(9), 287-292.

Nathan, M. J., Kintsch, W., & Young, E. (1992). A Theory of Algebra-Word-Problem Comprehension and Its Implications for the Design of Learning Environments. *Cognition and Instruction, 9*(4), 329-389.

National Research Council. (2011). *Adding it up: Helping children learn mathematics*. Washington, D.C.: National Academy Press.

National Research Council. (2011b). *Assessing 21st century skill: Summery of a workshop*. J.A. Koenig, rapporteur. Committee on the Assessment of 21st Century Skills. Board on Testing and Assessment, Division of Behavioral and Social Sciences and Education. Washington D.C.: The National Academies Press.

The National Council for Agricultural Education. (2015). Agriculture, food and natural resources (AFNR) career cluster content standards. Retrieved from: https://www.ffa.org/SiteCollectionDocuments/council_afnr_career_cluster_content_standards.pdf

National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation standards for school mathematics.* Reston, Va.: The Council.

National Council of Teachers of Mathematics (2000). *Principles and Standards for School Mathematics*. Reston, Va.: The National Council of Teachers of Mathematics, Inc.

The Partnership for 21st Century Learning. (2015). *Framework for 21st century learning*. Retrieved from: http://www.p21.org/our-work/p21-framework

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

Robinson, K. (2017). *Conceptualizing integrative agricultural education: A introductory framework for integrating mathematics in agricultural curriculum.* Unpublished manuscript, Department of Agricultural, Leadership, and Community Education, Virginia Tech, Blacksburg, VA.

Star, J. R. (2005). Reconceptualizing procedural knowledge. *Journal for Research in Mathematics Education, 36*(5), 404-411.

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

Stake, R.E. (1995). *The art of case study research*. Thousdand Oaks, CA: SAGE Publications, Inc.

Stubbs, E., & Myers, B. (2015). Multiple case study of STEM in school-based agricultural education. *Journal of Agricultural Education, 56*(2), 188-203.

Steen, L. A. (2002). Quantitative Literacy: Why numeracy matters for schools and colleges. *FOCUS*, 22(2), 8-9.

Steen, L. A. (2004). *Achieving quantitative literacy: An urgent challenge for higher education*. Washington, D.C.: The Mathematical Association of America

Steen, L. A. (Ed.). (1997). Preface: The new literacy. In L. A. Steen (Ed.), *Why numbers count: quantitative literacy for tomorrow's America* (pp. xv -xxviii). New York: College Entrance Examination Board.

Stone, J. I. (2011). Delivering STEM education through career and technical education schools and programs. Retrieved from http://sites.nationalacademies.org/cs/groups/dbassesite/documents/webpage/dbasse_072641.pdf

Stone, J. R., Alfeld, C., & Pearson, D. (2008). Rigor and relevance: Enhancing high school students' math skills through career and technical education. *American Educational Research Association, 45*(3), 767-795.

Türker, B., Sağlam, Y., & Umay, A. (2010). Preservice teachers' performances at mathematical modeling process and views on mathematical modeling. *Procedia-Social and Behavioral Sciences, 2*(2), 4622-4628.

Wiggins, G. (2003). Get real! Assessing for quantitative literacy. In B. L. Madison & L. A. Steen (Eds.), *Quantitative literacy: Why numeracy matters in schools and colleges* (pp. 121-143). Princeton, N.J.: National Council on Education and the Disciplines.

Wiggins, G., & McTighe, J. (2006). *Understanding by Design* (2nd ed.). Upper Saddle River, NJ: Pearson Education, Inc.

Wilkins, J. L. M. (2000). Preparing for the 21st century: The status of quantitative literacy in the United States. *School Science and Mathematics*, 100(8), 405-418.

Yin, R.K. (2009). Case Study Research Design and Methods: Applied Social Research Methods Series (Vol. 5). Thousand Oaks, CA: SAGE, Inc.

Young, R., Edwards, M., & Leising, J. (2009). Does a math-enhanced curriculum and instructional approach diminish students' attainment of technical skills? A year-long experimental study in agricultural power and technology. *Journal of Agricultural Education, 50*(1), 116-126.

Appendix
IAE Rubric & Rubric Scoring Explanations

The criteria below are elements that are expected to be present in an integrative agricultural education program. Determine how well each criterion 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
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
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

Integration			
Is the lesson problem or project based?			
Problem or project based learning has students working toward a big idea. The goal is finding a solution to the problem or completing a project. A problem would be a well-organized challenge that provides the big picture details but leaves students to work on discovering other needed information or skills as they work toward a solution. Likewise, a project would include clear directions on beginning the project, provide constraints on materials or resources, and communicate to students the criteria needed for completing the project. In the process of reaching the goal, students are engaged in the learning process through hands-on activities and cognitively active learning activities that are relevant to the purpose of the problem or project.			
0	1	2	3
Lesson is dependent on lecture, worksheets, brief hands-on activities, etc.	There is a problem or project but the big idea is not clear.	Students are engaged with work that seems related to the big idea of the project or problem.	The problem or project is clearly defined and obvious. Students are engaged in the learning process through activities that have them involved, taking ownership of their learning, and thinking about the big idea as they learn about details that support the idea.

Integration			
Were connections between agriculture topics and math topics obvious?			
Learning objectives explicitly include math and agriculture connections. Students will find opportunities when math is required during work related to learning about an agriculture topic. Math is clearly needed in order to better understand the agriculture topic.			
0	1	2	3
No math is done during the lesson. OR Math processes are performed but the need for the process is not clear or not required to move the activity along. It seems to be added on or unrelated.	There is math being done or mathematical topics/concepts are referred to during an activity that supported the agriculture topic. (e.g.: "To make sure the frame is square we measure the diagonals. This is like doing the Pythagorean Theorem in math class.")	The reason for doing the math was clearly stated or highlighted by the agriculture activity. If the math were not completed, the activity would have stalled or been more difficult.	The reason for doing the math is clearly stated or highlighted by the activity. Students would likely not be able to complete the activity without using the math.

Integration			
Were authentic resources used?			
Authentic resources are information sources that can be found in everyday life and come from legitimate, real-life sources. Examples of authentic resources include but are not limited to newspapers, reputable internet sites, drug labels, peer reviewed research articles, and technical manuals.			
0	1	2	3
Resources are fictitious, provide unrealistic information, or cannot be traced back to a real source. OR No resources are used.	Resources provide realistic information and appear to be from a real source. Resources have been edited to streamline the information being provided.	Resources provide realistic information and appear to contain all information needed to complete the activity but modifications have been made when compared to original sources. (e.g.: instead of using an original food label, a computer generated, slightly simplified label is provided to students)	Resource is provided to students with no modifications and all intact information is as provided by the source.

Integration			
Were students encouraged to ask critical questions about the topic or the mathematics?			
Critical questions guide students to a more thorough understanding of the topic. Students should have opportunities to ask their own questions that look at alternative points of view, future predictions, or relate one topic to another. Opportunities may also be scaffolded with guiding questions that focus students thinking in a similar fashion.			
0	1	2	3
Students are not given the opportunity to ask questions. Students may be given questions to answer but do not prompt critical thinking. For example, the questions are superficial, solutions or answers are found verbatim in resources provided, or do not require some speculation.	Students are given limited opportunities or limited time to ask questions. Guiding questions are provided, but the activity does not require students to thoroughly explain "why" or "how" when addressing the questions. (e.g. What type of triangle would help represent a squared-up terraced bed?)	Students are given opportunities to ask questions with ample time for questions to be posed and considered. Students are given opportunities to explain "why" or "how" type questions but there lacks a focus on details. (e.g. Explain, in one sentence only, how you used right triangles in designing your terraced garden bed and how triangles were helpful.)	Students are given several opportunities to ask questions either in class discussions, in groups, or in written assignments. Students should be encouraged to ask about background information, seek new connections, engage with prior experience/knowledge (apply intuition), consider future use or implications of the topic (ag or math), etc.

Integration			
Was scaffolding support provided for math concepts?			
Scaffolding is a technique that provides students with support through challenging material. Of particular interest is support for math concepts that are used in the lesson or activities. For example, scaffolding can be provided through guided questions that initially help students think through the process to be used, verbal cues to trigger appropriate techniques or mathematical thinking, or similar examples that students can reference as needed when working with challenging concepts. These are only a few examples of scaffolding.			
0	1	2	3
There is no evidence of scaffolding in the planning. Math related activities stand alone in the lesson with the expectation that students should already be proficient in the math or mathematical concepts being used.	Scaffolding is included in the planning of the math related activities.	Scaffolding is somewhat evident in the planning of math related activities. Scaffolding may be weak or unclear in some cases.	Scaffolding is evident in the planning of all math related activities. Scaffolding is appropriate and provides clear direction toward achieving the mathematical goal of the lesson.

Integration			
Were at least two subject areas covered in the lesson (agriculture + *n*)?			
Agriculture topics should be at the forefront of the lessons however to be integrative, there should be an embedded subject area apparent.			
0	1	2	3
Only agriculture topics are included in the lesson. Other subjects may be included but are add on activities that are not directly related to the agriculture.	Other subjects are in included in the lesson. The connection between the agriculture and the subject is minimal. The connections may be interesting and directly related to the agriculture topic but students would have likely been able to learn about the topic with only slight challenges if the additional subject was not included.	Other subjects are included in the lesson. The connection between the agriculture and the subject is minimal; students would have likely been able to learn about the agriculture but it may have been slightly more challenging.	Other subject areas were included in the lesson that was embedded in the agriculture topic. Without including the learning activities associated with the other subjects, the agriculture would have been more challenging to understand.

Integration			
Were students sharing ideas in groups?			
Students are asked to hold relevant conversations in small or whole group settings. Students will be given guidance to ensure they are talking about details of the activity, asking each other questions, providing explanations of their own thinking, or constructively working toward completing the activity at hand as a group.			
0	1	2	3
Working in groups or having whole group discussions are not part of the lesson. If whole group discussions are included but focus on students answering direct questions without explanation or elaboration this would not be considered sharing ideas.	At least one of all of the group interactions meets the requirements of an exceptional example. See explanation for a 3 rating.	At least half of the group interactions meets the requirements of an exceptional example. See explanation for a 3 rating.	Each time group interactions occur during the lesson, students are engaged with one another. The structure of the discussion promotes in-depth conversations, elaboration, and constructive critiques of other's ideas. The structure of the activity may provide guiding questions, a focused and complex associated problem, the expectation of a well-developed group presentation, etc.

<table>
<tr><td colspan="4">Integration</td></tr>
<tr><td colspan="4">Were students asked to reflect on their learning either in writing or orally?</td></tr>
<tr><td colspan="4">Students may be asked to reflect on their learning by responding to well-developed writing prompts that pose complex or in-depth questions related to the content. In a less formal method, students may also be asked to share their experience and explain how they will be able to use their new knowledge or skill now or in the future, especially focusing on unique or different situations. Students may also be asked to consider how they best learned or how they may be able to improve their learning process in the future. (metacognition)</td></tr>
<tr><td>0</td><td>1</td><td>2</td><td>3</td></tr>
<tr><td>No opportunities for reflection are provided.
OR
Prompts or questions may attempt to relate newly learned information to future situations however, if students are not asked to explain how, why, or when the new knowledge will be used they are not being reflective.</td><td>Students are asked to consider how they may use new information in new situations. Elaboration is minimal and focus is on when to use the new information.</td><td>Students are asked to think about what was learned, relate the information to other situations or prior experiences. Explanations are focused on how and when to use the information.</td><td>Students are asked several times during the lesson or when appropriate following a significant learning activity to consider what they have learned and how it relates to prior experiences, anticipated new experiences, or upcoming activity work. Students may also be asked to consider how to improve on their learning experience or habits.</td></tr>
</table>

Integration			
Were activities offered with multiple methods or variations for ability levels?			
Accommodations or variations should be made so each student can participate in all aspects of the learning activity. This may come in many forms from role assignments during group work to variations in project specifications to meet special needs.			
0	1	2	3
No variations are apparent but do seem to be needed depending on the activity. OR No variations are needed to support students during the activity.	Methods or variations are apparent but are minimal. There are many other suggestions that could be made.	Methods or variations are apparent however there are others that would likely help students. OR Methods or variations are inappropriate for the activity or activities included in the lesson.	Methods or variations are apparent and appropriate given the activity or activities included in the lesson.

Integration			
Were students asked to relate the learning to their own experiences?			
Students use prior experience to make meaning of learning and generate connections between new and old information. Students should have opportunities to relate new information to their prior knowledge. For example, students may be asked to apply intuitive guesses at the onset of an activity, think about their own experiences, or by having students share a relevant story. Activities that allow students to be engaged on a very personal level (e.g. achieve a personal benefit, meet a personal goal outside of school, etc.) highly relate to students' own experiences.			
0	1	2	3
Students are not asked to relate the learning to their own experiences. Including the student in a problem story is superficial (e.g. You have three lambs that have developed a cough…)	Prior knowledge contributes to the introduction or a small part of the lesson. Students provide input of a personal nature that requires storytelling to relate to the activity but does not require reflection on the connections to the new situation. (e.g. Think about a bad customer service experience you've had in the past, or you've witnessed with your parents, etc. What could have been done differently to make the situation better?)	Prior knowledge provides a personal connection to the activity and provides some use of the prior knowledge to work through the activity. (e.g. Heavy rains have caused serious flooding in our area. What are some of your personal concerns about the flooding? Could some of those concerns be related to the topography of the land around your home? Could there be a connection between the flooding concerns and the use of the land near your home?)	Prior knowledge provides a guide to the work for the activity. Students may use their experiences as an example, a non-example, or a starting point to try new methods. Questions about the situation may be generated as a result of the previous experience. (e.g. recording water use at home for a project, talking with a school board member about the agricultural education program budget, sharing local news articles that focus on the current in-class topic followed by discussion and analysis of the facts/situation.)

Integration			
Did the teacher model mathematical thinking?			
Modeling mathematical thinking allows students to see, hear, or experience how the teacher thinks through a problem, considers mathematical processes, or understands values and variables.			
0	1	2	3
There are no occasions for modeling to be demonstrated. OR If there are opportunities for math to be done, those opportunities are not used to model mathematical thinking and there are no plans that include the use of teacher demonstration of using or doing math.	Opportunities are taken occasionally to model thinking. Thoughts may be incomplete or the full process not shared with students. Lessons provide opportunity for model but modeling is not explicitly planned.	Modeling is demonstrated but inconsistently shared with students. Opportunities for modeling are evident in the lesson plan.	Each time the teacher has an opportunity to demonstrate mathematical thinking the opportunity is taken. The teacher is vocal when thinking, sharing with students the thought process from start to finish. In the planning stage, there are built in demonstrations for the teacher to model mathematical thinking.

Integration			
Were students asked to seek out more information that related to the topic?			
Students should be given problems or projects that may not provide all needed information explicitly. Instead, some information is left for the student to seek out to better understand the context or complete the needed procedure. As an alternative, students may also be given opportunities to research topics, numerical information or representations that relate to the activity.			
0	1	2	3
When students are given a problem or project, all information, processes, procedures, materials, etc. are explicitly included.	Some information has been left out of the problem, however, it is trivial information or only a small amount of important information has been left for students to interpret or find on their own.	More information is implied. The balance between trivial and important information has shifted to more important information being left for student interpretation or research.	Problems or projects are posed with valuable information left to be interpreted or researched by the student. Students are asked to research a topic, values, or representations to complete an activity or project.

Integration			
Were students encouraged to consider alternative processes/solutions/consequences related to the topic?			
When students are given authentic, complex activities often there are multiple ways to arrive at an appropriate outcome. Students should have opportunities to discuss, view, or experience these alternatives. This may be done with class discussion, peer evaluation, tool design, guided group discussion, or experimentation/trial and error to name a few examples.			
0	1	2	3
Problems or projects are very directive and seek a final, correct solution with no variation in the method, approach, or process used to arrive at the final outcome.	Students are asked to consider alternatives but opportunities remain superficial. (e.g.: Can you think of other ways to solve this problem?)	Students have several opportunities to discuss, explore, or experience alternatives related to the topic or activity. (e.g.: Can you think of other ways to solve the problem? How would an alternative method change the long term outcomes?)	Students have several opportunities to discuss, explore, or experience alternatives related to the topic or activity. Students are asked to reflect on these alternatives or consider them in comparison in the light of different situations. (e.g.: Are there alternative methods? How would alternative approaches improve on your method? In what other situations would the same method be useful?)

Quantitative Reasoning			
Were math concepts included in the lesson?			
Math or mathematical thinking was included in the lesson through calculations or references to math terminology or concepts (e.g. area of a figure, parallel lines, solving equations, etc.).			
0	1	2	3
No math concepts were present. OR If math concepts were present in the context, there was no effort made to draw attention to their use. Simply referring to a process or concept as math does not justify inclusion in the lesson.	Occasionally, when math was present in the context, the math concepts were referred to by name.	Frequently, but not every time, math was present in the context, the math concepts were referred to by name.	Each time math was present in the context the math concepts were referred to by name. Presentation of the math would make clear to students they are using math, mathematical concepts, or mathematical thinking and reasoning.

Quantitative Reasoning			
Were the math activities appropriate and accurate?			
When math was used, it is appropriate and accurate. Calculations are correct. Examples, if provided, are appropriate, represent the mathematics well, and are accurate. For example, calculating a percentage may be inappropriately represented if the ratio is calculated but the answer is left as a decimal rather than doing the proper conversion (multiplying by 100).			
0	1	2	3
Mistakes are present in the mathematics being used. OR Examples are inappropriate for the activity. OR No math was used in the activity.	Some activities including math concepts used the concepts appropriately and calculations were accurate.	Frequently, activities including math concepts used the math concepts appropriately and calculations were accurate.	All activities including math concepts used the concepts appropriately and calculations were accurate.

Quantitative Reasoning			
Was the math needed or beneficial?			
The mathematics used should be directly related to the context and needed to complete the activity. Connections between the context and the math are obvious (easily explained.)			
0	1	2	3
No math was included in the lesson. OR Math or math concepts were included in the activity or lesson but showed no connection or benefit to the topic in other words, the math activity seemed to simply be added-on.	Students were asked to show the mathematical work they used to solve a problem from the context. This work would have been necessary to find a solution or continue to learn about the context. (e.g. Calculate the amount of nitrogen removed from the soil by a bushel of harvested rice plants.)	Students were asked to communicate the connection between the math and the context. (e.g. Calculate the amount of nitrogen removed from the soil from a bushel of harvested rice. In a complete sentence, explain what your solution means in this problem.)	Students were asked to communicate the connection between the math and the context and should be given opportunities explain why they used the math processes or concepts they choose. (e.g. In a brief statement, explain how you determine the amount of nitrogen removed from the soil from a bushel of harvested rice. Include in your statement what the values represent, what variables are present, and determine how and if changes in the values will affect the soil depreciation.)

Quantitative Reasoning			
Were students encouraged to use mathematical language/thinking during discussions/presentations?			
Students are asked and expected to use mathematical language correctly and appropriately.			
0	1	2	3
There is no math involved in the lesson. OR If math is used, correct terminology is not explicitly included as part of the activity. No attention is being placed on the use of appropriate language in the activity.	Students may be asked to associate correct terminology from time to time or in a final project only.	Students are asked in some activities to use accurate and appropriate terminology.	Students are asked to use accurate and appropriate terminology consistently.

Quantitative Reasoning			
Were students encouraged to explain math related concepts/processes used?			
Students can clearly communicate about the math used and explain the mathematical thinking that was used throughout the process. Calculations will be accurate and can be related back to the context. Number values come from the context.			
0	1	2	3
Students are asked to make mathematical calculations or apply mathematical concepts but are not asked to share any of their work or thinking.	Students are asked to show their work on math related activities.	Students are asked to show their work as the explanation for the math. Students are asked to conclude their math related activity with a summary statement that provides connection to the activity (e.g. The class can plant 25 plants in the garden without overcrowding.)	Students are asked to show their work and provide an explanation of their work in a brief written statement or oral explanation when appropriate. Students are asked to share their mathematical thinking and reasoning in written form regularly. Students are asked to conclude their math related activity with a summary statement that provides connection to the activity. (e.g. The garden has enough space for 25 ¼ plants. The class should plant 23 plants within 6 inches of each other. This will give the plants enough space to grow and will provide extra room for working in the garden when needed without appearing to be spaced out. A planting grid, systems equations, and calculations are provided.)