

SOUTH WESTERN AGRICULTURE TEACHERS' MATHEMATICAL CONTENT KNOWLEDGE

by

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Final approval and acceptance of this thesis is contingent upon the candidate's submission of the final copies of the thesis to the Graduate College.

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Abstract

The purpose of this study was to determine South Western agriculture teacher's mathematical content knowledge. Mathematics and science are both essential to the field of agriculture; however, while science curriculum is currently integrated in many high school agricultural education classrooms, mathematics coverage is limited (Stubbs & Myers, 2015). The opportunity for students to engage in real world applications of mathematical content through school-based agricultural education programs exists, but if teachers do not possess the content knowledge necessary to teach mathematics, students are then left at a disadvantage. Therefore, the objectives of this study were to describe agriculture teachers perceived mathematical content knowledge, actual mathematical content knowledge, and the relationship between perceived and actual mathematical content knowledge for South Western agriculture teachers. The Content Knowledge Framework was utilized in determining agriculture teacher's content knowledge for the subject area of mathematics (Even, 1990). A quantitative analysis revealed South Western agriculture teachers perceived their average mathematical ability as being at a moderate level, while their average actual mathematical ability was 44%. The analysis also revealed a negative correlation to teachers' perceived ability and years spent teaching and a positive correlation between teachers' actual ability and years teaching. It is recommended that mathematics requirements at the agricultural teacher preparation level be reexamined. Additionally, professional development for South Western agriculture teachers in various mathematics content is encouraged.

Key Words: Content Knowledge, Agriculture Teachers, Mathematical Content Knowledge

Chapter 1 - Introduction

Formally introduced in 2001, Science, Technology, Engineering, and Mathematics (STEM) education initiatives have since gained support from administrators, teachers, and industry stakeholders at all levels of education (Hallinen, 2015). The incorporation of STEM focused curriculum has spanned from elementary to post-secondary settings because many careers, including those in agriculture, are rooted in the fields of technology and science. As of 2015, approximately 9.0 million people were employed in STEM focused jobs with an expected 8.9% increase by 2024 (Noonan, 2017). Specifically, in the areas of food, agriculture, renewable resources, and the environment, 57,900 jobs are expected to open annually over this same time span (Goecker, Smith, Fernandez, Ali, & Theller, 2015).

While in office, former President Barack Obama made it a priority to enhance the quality and dissemination of STEM curriculum. He explained, “[Science] is more than a school subject, or the periodic table, or the properties of waves. It is an approach to the world...” (U.S. Department of Education, 2015). Allowing for all students to have access to quality STEM education was a major focus of President Obama’s Educate to Innovate plan (The White House, 2009). Programs like 100Kin10 plan on adding 100,000 new STEM teachers into schools across the country over the next 10 years, increasing the opportunity for students of all backgrounds to have access to high quality STEM education (President’s Council of Advisors on Science and Technology, 2010). President Obama’s hope was to have American students become worldwide leaders in the fields of STEM.

Despite the importance placed on STEM education for almost two decades, the United States (U.S.) is falling behind many countries around the world. Competition for jobs worldwide is becoming more challenging for American students as other countries increase their emphasis

on teaching STEM related topics. China, France, Taiwan, the United Kingdom, Australia, and South Korea have all implemented changes to include STEM as a cornerstone of their education programs (Hallinen, 2015). The U.S. must begin to find new and innovative ways to incorporate STEM into all levels of education to prepare students for employment, both locally and globally.

Despite the growing number of careers opportunities in STEM fields in the U.S., there is a shortage of knowledgeable employees ready to fill these positions. According to the Chairman's Staff of the Joint Economic Committee, there are two major reasons why there is a decline in qualified STEM employees; a smaller percentage of students are pursuing post-secondary STEM degrees and inadequate STEM achievement at the K-12 level (Casey, 2012). Students are graduating high school feeling unconfident in their mathematical and science skills and as a result they avoid careers or educational opportunities that would apply to those content areas (Wang, 2013). Students who participated in math and science courses, received high scores on their 12th grade mathematics standardized tests, and could see the benefits of mathematics were most likely to pursue STEM focused majors in college (Wang, 2013). Students must form a strong base knowledge of key concepts in STEM while applying this new understanding in a hands-on, real world context to strengthen their desire to engage with STEM focused curriculum and careers.

To assist students in developing an interest in STEM related content and future careers, there must be available courses that integrate STEM concepts and qualified teachers to teach STEM content at all education levels, including high school. Agriculture courses are one solution to this issue. Students in agriscience courses have higher achievement gains through inquiry-based instruction than those learning through traditional subject matter approaches (Thoron & Myers, 2011). Utilizing the three-component model, agriculture courses combined classroom

(inquiry-based learning) with leadership opportunities in FFA and experiential learning through SAE (National FFA Organization, 2015). School-based agricultural education (SBAE) programs routinely emphasize the importance of STEM curriculum, as evidenced in the Agriculture, Food and Natural Resources (AFNR) Career Cluster Content Standards that serve as a national guide for the specific agriculture content to be taught (National Council for Agricultural Education, 2015). The AFNR standards follow specific career pathways from agribusiness to food production to animal and plant systems and integrate STEM concepts within a majority of the standards (National Council for Agricultural Education, 2015). While the AFNR standards are the basis for many state's agriculture courses, South Western (SW) agriculture teachers are also guided by state specific Career and Technical Education (CTE) standards ([State] Department of Education, 2011), which also include science and mathematics components. While all aspects of STEM are being implemented into SBAE courses, science is still the primary focus as the depth of mathematics content taught in agriculture courses is limited (Haynes & Stripling, 2014).

The integration of mathematics into SBAE courses is necessary for implementing all facets of STEM education. Many agriculture teachers in the SW, and nationwide, take the biology National Evaluation Series (NES) certification test or an equivalent to be certified to teach biology (Pearson Education, 2017). However, there is no such test required for mathematics knowledge assessment for agriculture teachers, leaving the mathematic knowledge of agriculture teachers unknown. At the South Western Land Grant University (SWLGU) where the majority of the SW agriculture teachers are prepared and certified, the mathematical preparation for agriculture teachers is minimal, with the requirement being a single College Algebra course ([University], 2017). The vast majority of graduation requirements are science courses, ranging from chemistry and biology to entomology and soil science due to the CTE

Technical Standards focus on science curriculum ([University], 2017). Defining agriculture teachers' knowledge of mathematics is the first step in describing and enhancing the teaching of mathematics in SBAE courses.

Need for Study

Despite the importance of teachers' content knowledge (CK) in mathematics, researchers have found Florida preservice agriculture teachers cannot meet the National Council of Teachers of Mathematics (NCTM) content/process areas and their sub-standards which relate to the National Agriculture, Food and Natural Resources (AFNR) Career Cluster Content Standards (Stripling, Roberts & Stephens, 2014). SBAE courses have the opportunity to expose students to mathematics in hands on, real life situations (National FFA Organization, 2015). Students can learn geometry and fractions through construction projects, measurement when feeding and weighing livestock, and apply algebraic equations when calculating growth rates for animals and crops. SBAE programs focus on incorporation of all aspects of STEM within SBAE, but there is less consistency of integration of mathematics and engineering, whereas high levels of science and technology are currently being taught (Stubbs et al., 2015). Students have the opportunity to engage in real world application of mathematical content through SBAE programs, but if agriculture teachers do not possess the CK necessary to teach mathematics, students are then left at a disadvantage.

As the global economy becomes more focused on STEM centered employment opportunities, the U.S. must prepare students to meet the growing work force requirements. SBAE courses are an engaging way to get high school students interested and involved in the concepts of STEM. While all areas of STEM are covered within SBAE, the thoroughness and

depth varies from teacher to teacher (Stubbs et al., 2015). Mathematics is an essential and necessary part of the field of agriculture (Miller & Gliem, 1994) but it is not being taught at a deep and rigorous level in agriculture courses (Stubbs et al., 2015). Determining SW agriculture teachers' perceived mathematical CK versus their actual mathematical CK is essential in identifying the current CK levels of teachers and will inform future action to alleviate any existing knowledge gaps. If agriculture teachers are deficient in mathematical CK their students' achievement could be impacted (Newcomb, McCracken, Warmbrod, & Whittingtin, 2004). Helping improve teachers' mathematical CK will allow for students to have access to better STEM education opportunities, while increasing their likelihood to pursue degrees and careers within STEM focused fields.

Purpose of the Study

The purpose of this study was to determine SW agriculture teachers' perceived and actual CK in mathematics. Research Priority 5 for The American Association for Agricultural Education National Research Agenda for 2016-2022 discussed the growing need for mathematics and science curriculum in SBAE programs due to the deep connection the concepts have in the field of agriculture (Roberts, Harder, & Brashears, 2016). Mathematics and science are both essential to the field of agriculture; however, while science curriculum is being applied and taught through various practices, mathematics is covered at only a surface level (Stubbs et al., 2015). As STEM education opportunities become more prominent in SBAE courses, the need for highly qualified teachers with CK in all aspects of STEM is vital, including mathematics.

Research Objectives

1. Describe the characteristics of the sample: years spent teaching, highest degree earned, major and minor, subjects taught, and gender.
2. Describe the perceived mathematical CK for SW agriculture teachers.
3. Describe the actual mathematical CK for SW agriculture teachers.
4. Describe the relationship between perceived and actual mathematical CK for SW agriculture teachers.

Chapter 2 - Review of Literature

Teacher Knowledge

Teacher's professional knowledge bases (TPKB) are knowledge bases that has been cultivated over time by the teacher through different methods and practices to successfully educate students (Ball, Thames, & Phelps, 2008; Shulman, 1987; Wenglinsky, 2000). TPKB are supported by five aspects: assessment knowledge, pedagogical knowledge, content knowledge, knowledge of students, and curricular knowledge (Gess-Newsome, 2015). While all of these aspects are essential components of teacher knowledge, CK is the foundation (Ball et al., 2008). CK (i.e. subject matter knowledge) is the technical knowledge of a specific subject a teacher possesses (Ball et al., 2008). Teachers with knowledge of a content area are able to explain why certain theories/methods are necessary, the truths within the concept, the usefulness of the information, and the connections that can be made within and beyond the subject (Shulman, 1986). CK in a specific content area is not limited to one individual part of a topic, but draws on teachers understanding of connections and relationships within the subject (Even, 1990).

A subject can be divided into two aspects, the substantive and syntactic structure (Schwab, 1978). The different ways a subject can be used and manipulated to include all the important information is called the substantive structure (Schwab, 1978). Being knowledgeable of the theory behind the Pythagorean theorem is an example of substantive structure. A teacher must evaluate different skills, ideas, and practices to determine essential aspects and manipulate the information in ways that are beneficial to the subject and the students (Shulman, 1987). The syntactic structure is a method to establish soundness within a subject, essentially the rules to follow when working with concepts in the subject area (Schwab, 1978). Knowing that $a^2 + b^2 = c^2$ is the formula of the Pythagorean theorem is the syntactic structure. To be a good steward of

inquiry or learning, teachers must have knowledge of the processes and rules that must be followed to ensure a certain level of accuracy for the audience (Shulman, 1987). A teacher's knowledge of substantive and syntactic structure allows for a deeper understanding of CK.

Teacher's CK also greatly impacts student outcomes. If a teacher has CK for teaching mathematics, there is a positive relationship to the likelihood of elementary student achievement measured by points gained on assessments (Hill, Rowan & Ball, 2005). Additionally, students performed 40% higher in mathematics and science when their teacher had majored or minored in the area of study, compared with students whose teachers had not received a degree in mathematics or science (Wenglinsky, 2000). A teacher can also grow and develop their CK through professional developments events and application of learned knowledge. Teachers who have more experience and a deeper knowledge within their specific area of study will have a higher level of CK, allowing for better explanation and teaching practices to occur (Ball et al., 2008).

Many mathematical topics connect together and build upon one another creating a strong need for understanding in basic rules and concepts on part of the teacher (Ball et al., 2008). For example, a strong foundation in addition is necessary before being able to subtract, multiply, divide or solve equations. According to Educational Testing Service (2017), mathematics teachers should be able to “understand how to write algebraic expressions in equivalent forms; use the structure of an expression to identify ways to rewrite it, understand how to rewrite quadratic expressions for specific purposes and use the properties of exponents to rewrite expressions for exponential functions” (p. 8). This just begins to outline the degree of depth and understanding a teacher must acquire in a topic in order to be prepared to teach one specific aspect or concept.

Algebra, geometry, statistics, and number theory are just a few of the CK areas mathematic teachers must be prepared to teach in a high school setting (Usiskun, 2001). Many high school mathematics teachers have degrees or minors in mathematics; however, it has been found that preservice mathematics teachers have shortcomings in their depth of mathematical CK (Bryan, 1999). While preservice mathematics teachers are taking courses in various areas of mathematics, there are few connections being made back to the mathematical curriculum they will need to teach in middle school or high school courses (Wilburne & Long, 2010). As future mathematics teachers take additional and advanced mathematics courses, a gap between their overall mathematical CK and the mathematical content needed for teaching is created (Usiskun, 2001). This gap leaves teachers unprepared for the mathematical content taught in a high school setting. *The Mathematical Education of Teachers II*, a paper released from the Conference Board of the Mathematical Sciences, echoes the importance of future mathematic teachers acquiring the knowledge they will be teaching at a deep level (Conference Board of the Mathematical Sciences, 2010). This prompts the question, how are agriculture teachers fairing while having received less mathematical training during their undergraduate careers if preservice mathematics teachers are struggling with their ability to relate mathematical CK to their student's level?

Content Knowledge Framework

The CK Framework by Ruhama Even (1990) guided this study. The CK Framework creates a categorical breakdown of teacher's mathematical subject matter knowledge (see Figure 1). Even (1990) used his framework for investigating a specific mathematical topic and how different areas of knowledge affect a teacher's CK. For this study, six of the seven topics were utilized in describing SW agriculture teachers mathematical CK. Essential features, different representations, alternative ways of approaching, the strengths of the concepts, basic repertoire,

and knowledge and understanding of a concept were all suitable constructs for this study. The seventh aspect of the CK Framework, knowledge about mathematics, was excluded from the assessment because it analyzes a teacher’s knowledge of the nature of mathematics (Even, 1990).

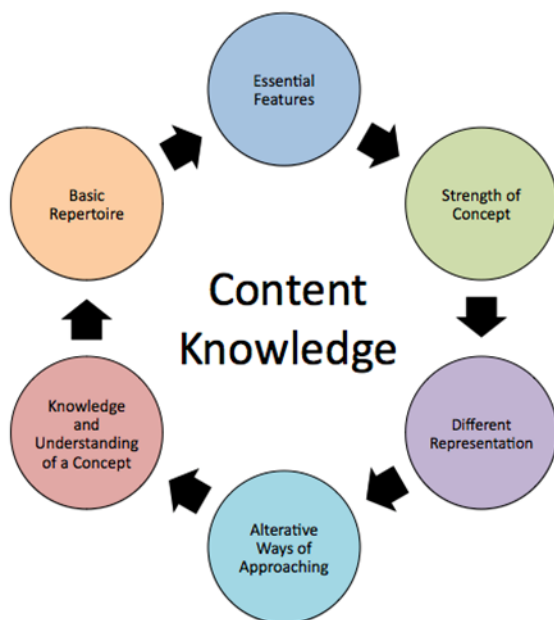


Figure 1. Content Knowledge Framework (Even, 1990)

The CK Framework first contains the essential features of a concept (i.e. an idea). A concept image is a mental depiction formed by a set of properties (Vinner, 1983). Concept images, concept examples versus non-examples, and essentially “what is it?” all fall into this section of the framework (Even, 1990). Concept images help form a mental picture of an idea that has been acquired over time and can be utilized in certain cases more easily than a definition (Vinner, 1983). Concept images, found in one’s mind, are also specific to the person who possesses them (Vinner, 1983). An example of a concept image would be a triangle. When someone hears the word triangle, they picture the image before thinking of the definition. Teachers must also be able to distinguish between concept examples and non-examples (Even,

1990). Teachers must use their CK in combination with their pedagogical knowledge and knowledge of students to be prepared for student questions, while determining which examples are specific to the concept and which are not beneficial to student learning (Even, 1990). Teachers with mathematical knowledge must not be limited by their concept image. As the mathematics discipline evolves, a teacher must be aware of and adjust to these changes to ensure they are not teaching outdated information (Even, 1990).

The different representations of a concept are the second part of the CK Framework. Teachers must be familiar with the various representations of a concept (Even, 1990). A representation is an expression in some term, character or symbol (Representation, n.d.). Being knowledgeable in the different representations of concepts allows for teachers to form connections between and among the representations (Even, 1990). A deeper, more powerful, and better understanding of a concept comes from a knowledge of different representations (Even, 1990). Knowledge of the various names, functions, and notations of a concept are necessary in understanding and utilizing different representations (Even, 1990). For example, in the concept of mathematical functions, a teacher with a knowledge of different representations knows linear functions ($y = m x + b$), quadratic functions ($y = a x^2 + b x + c$), and exponential functions ($y = a b^x$). Due to the teacher's knowledge of different representations, he or she is able to explain the concept in a deeper, more meaningful level. Even (1990) notes that "understanding a concept in one representation does not necessarily mean that one understands it in another representation" (p. 524). Each representation demands an understanding in that specific form and without this knowledge a teacher will have a limited understanding of the concept.

A deeper understanding of a concept is gained through the use of alternative ways of approaching a concept, component three of the CK Framework. The use of various notations,

labels, representations, and forms assists students in comprehending difficult concepts (Even, 1990). A teacher must know a variety of approaches and know which approach is most useful for a particular group of learners (Even, 1990). Students can learn about functions through solving equations or graphing equations, but the teacher must have knowledge of both approaches and determine which learning situations are better suited for each. Due to this variability in instruction, an awareness of which alternative approach is best suited for a particular concept is a necessity of teachers (Even, 1990). Not every alternative approach works for all situations and some alternative approaches work better than others (Even, 1990). A teacher must not only know and understand alternative approaches, but also be able to discern which alternative approaches work best for a concept.

The fourth aspect of the CK Framework is the strength of the concept. When a concept allows for new opportunities to be formulated, the concept becomes powerful and important (Even, 1990). Just like concepts, the understanding of sub-topics and sub-concepts cannot be analyzed in a simplistic way (Even, 1990). Sub-topics and sub-concepts are no less important than a concept; they also require a deep understanding of mathematics, definitions and concepts (Even, 1990). Teachers must understand what makes a concept powerful based on the various characteristics it possesses (Even, 1990). For example, knowledge in length, weight, liquid capacity, the use of fractions, units of measurement, and how to use a ruler all help strengthen a teacher's knowledge of the concept of measurement. The different definitions, numerous aspects of a concept, and the sub-groups are all essential in the strengthening a teacher's knowledge of a concept.

Basic repertoire is the fifth component of the CK Framework. Basic repertoire encompasses all the tools at a teacher's disposal in relation to a concept (Even, 1990). Important

properties, principles, theorems, and additional useful knowledge should all be included as examples in this repertoire to help students develop an understanding of a concept at a deeper, more meaningful level (Even, 1990). Specific, easily accessible examples are a necessity for every concept to aide in student learning (Even, 1990). However, if knowledge within one's repertoire is gained in a non-meaningful way, through memorization without a foundational knowledge of associated rules or with a lack of appropriate usage, this information will not be beneficial (Even, 1990). This information must be easily accessible, allowing teachers to retrieve the important information in a quick manner. For example, a teacher will be knowledgeable on the differences between an equilateral, isosceles, and scalene triangles and what the specific characteristics are associated with each one. Familiarity with difference equations like Pythagorean Theorem ($a^2 + b^2 = c^2$) and the area of a triangle ($a = \frac{1}{2}b \times h$) all would exist in a teacher's basic repertoire. A teacher demonstrates their basic repertoire through explaining why a rule holds true for a concept (Even, 1990).

The final category of the CK Framework that was utilized for this study was knowledge and understanding of a concept. This category is broken into two groupings of knowledge: conceptual and procedural (Even, 1990). Conceptual knowledge is knowledge that is learned in a meaningful way, with rich relationships (Hiebert & Lefevre, 1986). These relationships allow for new information to be connected to existing concepts, creating a more solid understanding (Even, 1990). Procedural knowledge is made up of two parts; the first is 'form' which is the understanding of symbols and the second is the rules and procedures used to solve mathematical problems (Hiebert et al., 1986). Procedural knowledge is learned with or without meaning and is simply knowing how to complete a task (Even, 1990). Both conceptual and procedural knowledge are meaningful in the execution of mathematical procedures. They can be applied

separately, but the most success will come from a combined usage of conceptual and procedural knowledge.

Teacher Perceived Ability

Beyond actual ability, perceived ability is one of the main aspects that is pertinent to motivation in achievement (Nicholls, Cheung, Laurer & Patashnick, 1989). It has been found that academic attainment, affect, and behavior are all predictors of one's perceived ability (Nicholls et al., 1989). Self-perceived ability has effects on behavior and feelings, being the most influential thoughts in tasks (Halisch & Kuhl, 1987). How much effort and the formation of one's effort, and the evaluation of the completed task are all directly related to one's self-perceived ability (Halisch et al., 1987). If someone believes they will have success at the assignment at hand, there is a higher likelihood this belief will hold true. While teachers' perceived ability can be difficult to measure, Kilic (2015) found that preservice teachers have a high belief in their knowledge of teaching. Shulman (1987) determined that teachers should possess seven key knowledge domains; subject-matter knowledge, general pedagogical knowledge, pedagogical content knowledge, knowledge of learners and learning, curriculum knowledge, knowledge of educational contexts, and knowledge of educational philosophies, goals and objectives. Kilic (2015) classified each knowledge point using Shulman's (1987) seven domains. They found courses taken during preparation and opinions on academic programs varied in preservice teachers' perceptions, while their own perceived teaching ability was high (Kilic, 2015).

Perceived ability and self-efficacy relate to one another when determining teachers' believed mathematical ability. Self-efficacy is the belief one has to accomplish his or her goals

(Bandura, 1977; 1997). For example, a teacher must believe in their mathematical skills and possess the ability to feel confident in teaching the content to students. This confidence can have a positive effect on the teaching and reception of the content (Hill et al., 2005). Determining teachers' perceived ability is essential in establishing if there is a relationship between perceived and actual ability. This will guide future efforts in professional development and training for agriculture teachers.

Agriculture Teachers' Mathematical Content Knowledge

While mathematics is an essential part of SBAE, little is known about agriculture teacher's mathematical abilities, with the majority of the research being done in the preservice teacher area (Stripling and Roberts, 2012; 2013). Research found a lack of mathematical knowledge in preservice agriculture teachers when entering the classroom (Stripling et al., 2012; 2013). If agriculture teachers are beginning their careers with a lack of mathematical CK, are they able to grow/gain additional mathematical knowledge post-graduation? There are little to no studies currently completed on practicing agriculture teacher's mathematical CK.

Stripling and Roberts (2012) found through two mathematical assessment tests that when solving agriculture based mathematical problems, Florida preservice agriculture teachers lacked proficiency in solving these questions. They also found that Florida preservice agriculture teachers scored higher on mathematical assessments when they had taken an advanced mathematics course in high school or college compared to preservice teachers who had only take basic or intermediate courses (Stripling et al., 2012). Of the 25 Florida preservice teachers who participated in the mathematical assessments, the average test scores were 9.26 out of 26 problems, or 35.6% (Stripling et al., 2012). Preservice teachers' efficacy for mathematics was also tested and found that preservice teachers believed they were proficient in mathematical

ability and teaching (Stripling et al., 2012). This study shows that while Florida preservice agriculture teacher had a high efficacy score in mathematical ability, they lack the knowledge to complete mathematical problems. This disconnection could lead to teachers confidently teaching students mathematical concepts when they lack the concept knowledge themselves.

A later study was conducted to determine if preservice agriculture teachers' mathematical abilities would improve if there was a math-enhanced agriculture education teaching methods course provided (Stripling & Roberts, 2013). Through this math-enhanced course, preservice teachers were educated on the seven components of math-enhanced lessons to teach with an agriculture focus by National Research Center for Career and Technical Education (Stone, Alfred, Pearson, Lewis, & Jensen, 2006). The researchers assigned two of the NCTM Substandards with cross references for the AFNR Career Cluster Content Standards and required preservice teachers to teach two of the NCTM substandards using the seven components of the math-enhanced lesson to their fellow preservice teachers (Stripling et al., 2013). The study found that Florida's preservice agriculture teachers' mathematic abilities improved by participating in the math-enhancement course. Once lessons and learning opportunities were implemented, Florida preservice agriculture teachers were able to enhance their mathematical CK.

Even though there is minimal research done on practicing agriculture teachers, it has been found that preservice agriculture teachers lack mathematical CK (Stripling et al., 2012; 2013). While preservice teachers are limited in their mathematical CK, improvement opportunities are possible while still in the university setting. More research needs to be conducted on practicing agriculture teachers to determine their current mathematical CK.

Chapter 3 - Methodology

Research Design

The design of this study was descriptive correlation research, which is a technique used in an attempt to define a directional relationship between two variables (Ary, Jacobs, & Sorensen, 2010). The two variables of the study were SW agriculture teachers' ability to solve mathematical problems (dependent variable) and the perceived mathematical ability of SW agriculture teachers (independent variable). Agriculture teacher's ability to solve mathematical problems (mathematics CK) were operationalized using Stripling et al. (2012) *Mathematics Ability Test*. The CK Framework in combination with SW's CTE Technical Standards and perceived ability literature guided the questions on perceived mathematical ability (Even, 1990; [State] Agriculture Teachers Association, 2017).

Participants

As the target population, all current SW agriculture teachers were given the opportunity to participate in the questionnaire, regardless of the specific courses they taught or the number of years they had been in the profession. A total of 106 agriculture teachers were registered in the SW Agricultural Education Directory for the 2016-2017 school year ([State] Association FFA, 2016). The SW Agricultural Education Directory for the 2016-2017 school year was the most update directory available. Due to the manageable number of agriculture teachers in the SW, a census was used to gather data. A census questionnaire gathers information from the entire population (Ary et al., 2010). The frame was accessed through the SW Association FFA webpage ([State] Association FFA, 2016). Due to the fact that every agriculture teacher in the SW was provided with the survey, there was no chance for sampling error.

Instrumentation

The questionnaire was created using Qualtrics in order to determine the relationship between perceived mathematic ability and actual mathematical ability of agriculture teachers. The questionnaire was a combination of the *Mathematics Ability Test* and self-perceived mathematical ability questions (Stripling et al., 2012). The first section of the questionnaire asked agriculture teachers to assess their level of confidence in their CK to complete a specific task. The specific tasks were derived from the CTE standard, Demonstrate Agriscience Mechanic Application, which has a connection to mathematics ([State] Agriculture Teachers Association, 2017). Participants answered eight questions using a Likert scale to select their ability level relating to the specified sub-standards of Demonstrate Agriscience Mechanic Application including: measurement, construction, bill of materials, structure, masonry, mechanics operation, and mechanics maintenance. This specific standard and sub-standards were selected because of their numerous connections to mathematics. The questions were guided by the CK Framework. Essential features, different representations, alternative ways of approaching, the strengths of the concepts, basic repertoire, and knowledge and understanding of a concept were all represented within one of the eight questions asked (Even, 1990). An example question for understanding alternative ways of approaching a concept was “I can choose the best approach to solve a problem related to this concept.” See Figure 2 for all the perceived ability questions.

Essential Features	I can explain the basic definition for this concept
Strength of Concept	I can identify subtopics related to this concept
Different Representations	I can describe multiple representations of this concept
Different Representations	I can connect multiple representations of the concept to one another
Alternative Ways of Approaching	I can choose the best approach to solve a problem related to this concept
Knowledge and Understanding of a Concept	I can use procedural knowledge to solve a problem related to this concept
Knowledge and Understanding of a Concept	I can link this concept to other concepts within and beyond the unit
Basic Repertoire	I can identify effective examples for teaching this concept

Figure 2. Perceived Ability Questionnaire Statements Aligned with Components of the CK Framework (Even, 1990)

In the second section of the questionnaire, participants were asked to solve mathematical problems to assess their actual mathematical ability. These ten mathematical problems were taken from the *Mathematics Ability Test* (Stripling et al., 2012) and slightly altered by the researcher to add the addition of multiple-choice answers. The ten questions were chosen due to the fact of connection with the SW Mathematics and CTE Technical Standards. These mathematical problems relate back to the CTE Technical Standards from the perceived self-assessment section. The mathematical questions were from the *Mathematics Ability Test* (Stripling et al., 2012). See Figure 3 for an example question.

Sarah just purchased a farm. The figure below is a diagram of a grain bin that is on the farm Sarah purchased. Sarah would like to know the volume of the grain bin. Help Sarah determine the volume of the grain bin. The following are two formulas that may be helpful:

$$V_{\text{cylinder}} = \pi r^2 h$$

$$V_{\text{cone}} = \frac{1}{3} \pi r^2 h$$

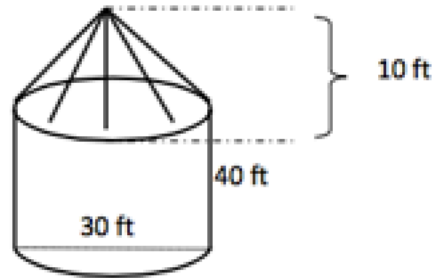


Figure 3. Mathematics Ability Test (Stripling et al., 2012)

The final section of the questionnaire asked participants to self-select their demographic characteristics. Using both force-choice and fill-in response questions. Participants were asked to identify the number of years they have been teaching agriculture, their highest degree earned, if they have a major or minor in a content area other than Agricultural Education, what agriculture subjects they have taught, and their gender. Participants were not asked about mathematical courses completed due to graduation requirements for a majority of participants (College Algebra), if trained elsewhere at a comparable level nationwide, and a course taken in mathematics does not equal knowledge gained. Due to the research aimed in determining CK using the *Mathematical Ability Test*, the research believed mathematical courses taken would yield much insight (Stripling et al., 2012).

Validity and Reliability

The questionnaire was reviewed by a panel of experts to determine face and content validity. The panel consisted of an agriculture teacher educator, a math teacher educator, an extension agent with questionnaire experience, and a graduate student with teaching experience and a degree in Agricultural Education. The *Mathematical Ability Test* was assessed for reliability with yielding Cronbach's alpha coefficient and a .8 alpha coefficient was established (Stripling et

al., 2012). A pilot questionnaire was given to the SWLGU’s preservice agriculture teachers to test the reliability of the perceived ability mathematical ability section of the questionnaire. The Cronbach’s alpha for the pilot questionnaire for the overall perceived CK in mathematics was 0.95.

Data Collection & Analysis

Dillman, Smyth, and Christian’s (2014) data collection method was used to maximized participants responses. A recruitment email was first sent out to SW agriculture teachers with a link to the online Qualtrics questionnaire. The questionnaire was sent out to participants in May 2018 with four additional reminder emails sent over the two-week response period (Dillman et al., 2014). After June 2018, respondents who had not submit the questionnaire were considered non-respondents. No additional steps were taken to capture non-respondents.

A correlation was used to determine the relationship between SW agriculture teachers’ mathematical ability and agriculture teachers’ perceived mathematical ability. To analyze objective 4, Davis’ conventions were utilized to interpret the correlations between years teaching to perceived ability and years teaching to actual ability, see table 1 (Davis, 1971).

Table 1

Davis’ Conventions for Correlation Coefficient

Convention	<i>Correlation Coefficient</i>
Perfect	1.00
Very High	.70 - .99
Substantial	.50 - .69
Moderate	.30 - .49
Low	.10 - .29
Negligible	.01 - .09

The first section of the questionnaire, SW agriculture teacher's perceived mathematical ability, was completed by 34 participants. The second section of the questionnaire, mathematical ability, was completed by 25 participants. The final section, demographics, was completed by 24 participants.

Chapter 4 - Findings

Objective 1 sought to describe the characteristics of the sample: gender, highest degree earned, major and minor, subject taught, and years spent teaching. Of the 51 respondents, 24 of those yielded usable data. Of those 24 participants, 11 were male, 12 were female, and 1 chose not to disclose their gender. Seventeen participants had earned a master's degree, with 12 of the 24 having a major in an area other than Agricultural Education and 7 possessing minors in areas other than Agricultural Education. There was also a wide range of classes taught by the participants. 20 participants had taught an Agriscience course, 18 had taught an Animal Science course, and 16 had taught Plant Systems and Introduction to Applied Biological Systems (Biology 1) courses. There was a wide range of total years spent in the classroom with participants ranging from 2-37 years of experience.

Objective 2 sought to describe the perceived mathematical CK for SW agriculture teachers. Seven subconstructs were explored: Measurement, Construction, Bill of Materials, Structure, Masonry, Mechanics (Operation), and Mechanics (Maintenance), and asked teachers to rank their perceived ability in these areas. On a scale of 1 to 5, with 1 being No Ability to 5 being Extremely Able, Table 2 shows the overall mean score was 3.69 for the 34 participants. In Table 3 the seven subconstructs were broken out by construct. Bill of Materials ($M = 4.45$, $SD = .82$) had the highest average perceived ability and Measurement ($M = 3.35$, $SD = .91$) had the lowest average perceived ability.

Table 2

Average Perceived Ability of Subconstructs (n = 34)

	<i>M</i>	<i>SD</i>
Averaged Perceived Ability of Subconstructs	3.69	.73

Scale: 1 = No Ability, 2 = Slight Ability, 3 = Moderate Ability, 4 = Very Able, 5 = Extremely Able

Table 3

Individual Perceived Ability of Subconstructs (n = 34)

Subconstructs	<i>M</i>	<i>SD</i>
Bill of Materials	4.45	.82
Structure	3.72	.85
Construction	3.71	.99
Mechanics Operation	3.57	.99
Mechanics Maintenance	3.51	.93
Masonry	3.50	.97
Measurement	3.35	.91

Scale: 1 = No Ability, 2 = Slight Ability, 3 = Moderate Ability, 4 = Very Able, 5 = Extremely Able

Objective 3 sought to describe the actual mathematical CK for SW agriculture teachers. Ten mathematical problems from the Stripling et al. (2012) *Mathematics Ability Test* that had been connected with the SW Mathematics and CTE Technical Standards were given to determine SW agriculture teachers' actual mathematical ability. In Table 4, of the 25 usable responses, the average score was 44%. Table 5 shows the various scores earned along with each scores frequency. There were no scores above 70% for any participant.

Table 4

Average Mathematical Ability Scores (n = 25)

	<i>M</i>	<i>SD</i>
Ability - Percent Correct	44	19.58

Table 5

Mathematical Ability Scores by Percent Correct (n = 25)

Mathematical Score Received	<i>F</i>	Percent
0%	1	4
10%	1	4
20%	2	8
30%	3	12
40%	7	28
50%	3	12
60%	3	12
70%	5	20
Total	25	

Objective 4 sought to describe the relationship between perceived and actual mathematical CK for SW agriculture teachers. Teachers assessed their perceived ability to be at a moderate perceived ability, which is not consistent with the test performance of an average of 40%. The correlation between perceived and actual ability was negative and negligible ($r = -.06$). There was practically no effect, due to an effect size of 0.01%.

Table 6

Correlation Between Perceived and Actual Ability

Variable	Perceived Ability
Actual Ability	-.06
Effect Size (r^2)	.01%

Scale: Perfect = 1.00, Very High = 0.70 - 0.99, Substantial = 0.50 - 0.69, Moderate = 0.30 - 0.49, Low = 0.10 - 0.29, Negligible = 0.10 - 0.09

Years spent teaching versus perceived and actual ability was explored in order to better understand actual and perceived ability. Table 7 shows there was a negative and negligible ($r = -.11$) correlation to teachers' perceived ability versus years spent teaching. This showed that teachers with less experience had a higher perceived ability. There was a positive and moderate

($r = .34$) correlation between teachers' actual ability versus years teaching. This shows that teachers with more experience teaching demonstrate more ability in mathematics.

Table 7

Correlation Between Years Teaching and Perceived and Actual Ability

Variable	Perceived Ability	Actual Ability
Years Teaching	-.11	.34
Effect Size (r^2)	.01%	.12%

Scale: Perfect = 1.00, Very High = 0.70 - 0.99, Substantial = 0.50 - 0.69, Moderate = 0.30 - 0.49, Low = 0.10 - 0.29, Negligible = 0.10 - 0.09

Chapter 5 – Conclusion, Implications, and Recommendations

The finding of this study suggests that additional steps and practices should be taken to improve SW agriculture teachers' mathematical CK. This study is limited to just SW agriculture teachers, with additional limitations being question misinterpretation, additional resources being used to aide in the mathematical ability questions, participants not completing the entire questionnaire, and agriculture teachers not being able to connect the mathematical concepts from their courses to SW CTE Technical Standards.

Objective 1

Objective 1 sought to describe the characteristics of the sample; gender, highest degree earned, major and minor, courses taught, and years spent teaching. It was found that teachers' gender was 50% female and 50% male. Gender does not appear to have any impact on SW agriculture teachers mathematical CK in this study. 70.83% of SW agriculture teachers reported having earned a master's degree or higher. The demographic data showed that SW agriculture teachers who had participated in the study had a broad range of teaching experience, with the lowest being 2 years and the highest being 37 years. This teaching experience affected teachers' actual mathematical ability and their perceived mathematical ability. Objective 4 found that beginning teachers' had a higher perceived ability, while more experienced teachers had a higher actual ability. These correlations will be further explored in Objective 4.

From the demographics gathered, 12 of the 24 SW agriculture teachers received a degree in an area of study other than Agricultural Education. Teachers who have received a degree in the area of study they are teaching have 40% higher student performance in the areas of mathematics and science compared to teachers who not received a degree in mathematics or

science (Wenglinsky, 2000). Despite SW agriculture teachers having a high education level, there are still issues with mathematical CK. Deeper exploration in specific classes taken compared to overall education level are recommended for further research. Additionally, further research should be conducted to determine the different educational degrees received to discover what experiences led to higher mathematical ability and what specific content areas have an impact on agriculture teachers' mathematical CK.

Objective 2

Objective 2 sought to describe the perceived mathematical CK for SW agriculture teachers. The average total score was a 3.64, which was considered a moderate ability (Davis, 1971). Teachers' beliefs in their classroom abilities, in areas like motivation and learning outcomes, have been found to directly effect student success (Bandura, 1993). With SW agriculture teachers' belief in their mathematical ability being only at a moderate level, this could be having a negative effect on their high school students' own perceived mathematical ability.

SW agriculture teachers ranked Bill of Materials the highest, being categorized as very able. Agriculture teachers ranked their ability in the area of Measurement to be the lowest out of the seven categories related to perceived ability in mathematics. A lower perceived ability will likely lead to lower levels of motivations (Nicholls et al., 1989). With Measurement being ranked lower than the other sub constructs, SW agriculture teachers could be avoiding the usage of measurement focused topics due to their low perceived ability within this topic.

Within the field of agricultural education, the development of programs to improve teachers' efficacy in mathematics is essential in increasing teachers' confidence in mathematics.

SBAE programs have a unique opportunity to allow students hands on, real world applications for the concepts being taught. These programs claim to integrate all aspects of STEM curriculum into the classroom; however, while science is the most prevalent and focused aspect, mathematics is limited (Haynes et al., 2014). Further research should be conducted to determine the most efficient practices to help integrate mathematics into SBAE programs.

Additional studies should also be conducted to look specifically into the area of Bill of Materials. Due to the fact this area was the highest ranked perceived ability out of all seven subconstructs, additional research should be done to ensure this level of perceived ability remains at its current level. Similar to Rice and Kitchel's (2015) study of agriculture teachers' knowledge bases, research should be conducted to determine what sources of knowledge contribute to this high level of perceived ability within the area of Bill of Materials.

Within the area of Measurement, additional research should be done to determine why this mathematical concept was the lowest out of the seven subconstructs. Measurement is an essential aspect of the agricultural industry, ensuring agriculture teachers feel comfortable with this topic is necessary for students' success. Further research should be done to identify agricultural teachers perceived ability in different mathematical areas. Determining mathematical perceived ability within subjects like agricultural economics or agricultural business, all which contain mathematical components, would be beneficial in establishing if agriculture teachers are lacking perceived ability in only certain agricultural mathematical content areas or within the whole area of agricultural mathematics.

Objective 3

Objective 3 sought to describe the actual mathematical CK for SW agriculture teachers. The average score of the actual mathematical ability section of the questionnaire was 44%. This was considered a failing score, with only five participants scoring a 70% and three scoring a 60%. Of the 25 SW agriculture teachers that participated in the questionnaire, only eight got over half of the questions correct. When Stripling et al. (2012) administered their *Mathematics Ability Test* to Florida preservice agriculture teachers, their average score was 35.6%. While these two scores cannot be directly compared due to sample and questionnaire differences, it gives the only opportunity for a depiction of agriculture teachers mathematical CK over time. With these two scores both being failing, there is little evidence of mathematical CK being gained prior and post agriculture teachers' entrance into the field. If SBAE courses are presented as a learning environment that implements all aspect of STEM into their curriculum, additional steps must be taken to improve agriculture teachers mathematical CK to meet this precedent (Thoron et al., 2011). Finding different ways to improve agriculture teachers mathematical CK is essential in creating a course that applies all aspects of STEM education.

The perceived ability section of the questionnaire was guided by the Even (1990) CK Framework. The six constructs from the CK Framework that were utilized to determine SW agriculture teachers perceived ability are all essential in developing agriculture teachers' mathematical CK. Basic repertoire, essential features, strength of a concept, different representations, alternative ways of approaching, and knowledge and understanding of a concept are all necessary for a teacher to possess in order to be knowledgeable about a concept. Even (1990) recommended that teachers should take specific courses to learn mathematics designed for teachers, in addition to their regular mathematics courses.

It is recommended that professional development be implemented to help develop practicing agriculture teachers actual mathematical CK, while additional supplementary mathematical courses are recommended for preservice agriculture teachers. The implementation of a math-enhanced course was found to improve Florida preservice agriculture teachers' mathematical CK (Stripling et al., 2013). Additional time spent learning mathematical content areas resulted in increased mathematical CK. Finally, additional research should be conducted to determine the actual mathematical ability of agriculture teachers in additional states other than the SW. Currently very little research is done in the area of agriculture teachers' mathematical CK.

Objective 4

Objective 4 sought to describe the relationship between perceived and actual mathematical CK for SW agriculture teachers. It was found that there is no relationship between SW agriculture teachers' perceived and actual ability. Nicholls, Cheung, Laurer, and Patashnick (1989) found that motivation in achievement is driven by one's perceived ability. In relation to this research, are SW agriculture teachers not knowledgeable of all the mathematical components within agricultural education curriculum or are agricultural education teachers not making the connection to the mathematical elements they are teaching. More research should be done to determine how SW agriculture teachers are classifying Bill of Materials. Determining if SW agriculture teachers are knowledgeable of Bill of Materials connection to mathematics or if teachers not associate Bill of Materials with mathematics will help in determining why Bill of Materials had the highest perceived ability out of the 7 subconstructs.

Kilic (2015) found that preservice teachers have a higher perceived ability compared to more experienced teacher. This overinflation of perceived ability is directly connected to actual ability. Even though motivation to achieve is driven by one's perceived ability, actual ability was much lower than perceived ability in SW agriculture teachers. When tested on actual ability, researchers found that preservice agriculture teachers were lacking in mathematical knowledge when entering the classroom (Stripling et al., 2012; 2013).

While little research is done on current agriculture teachers mathematical CK, Additional research should be done on SW agriculture teachers perceived and actual mathematical CK. Along with additional research in this region, research should be done to establish if the findings are unique to this area or expand throughout different states' agricultural teachers.

Years spent teaching versus perceived and actual ability was explored in order to better understand actual and perceived ability. It was found that more experienced SW agriculture teachers had little to no increase in their mathematical ability compared to less experienced teachers. Research has found that CK gained through professional development, years of professional education, or experience within a subject increases teachers' CK while having a positive effect on student outcomes and achievement (Garet, Porter, Desimone, Birman, & Yoon, 2001; Wenglinsky, 2000).

It was also found that less experienced agriculture teachers had a higher perceived ability compared to more experienced teachers. In research done by Kilic (2015), it was found that preservice teachers had a higher level of perceived ability than teachers with more experience. The data from SW agriculture teachers mirrors these results, with less experienced teachers having a higher perceived ability than more experienced agriculture teachers.

Years spent teaching versus years of experience was explored in order to better understand and see if actual and perceived ability played a role in SW agriculture teachers mathematical CK, however the effect sizes were so minimal that there is little evidence that years spent teaching had an effect on perceived and actual ability.

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