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Arizona Agriculture Teachers' Mathematical Content Knowledge

Sarah McNall[1] and Amber H. Rice[2]

Abstract

Mathematics and science are both essential to the field of agriculture; however, while science curriculum is currently integrated in many secondary school-based agricultural education classrooms nationwide, mathematics integration remains limited. 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 for learning the content. The purpose of this study was to determine Arizona agriculture teachers' perceived and actual mathematical content knowledge. The objectives of this study were to describe teachers' perceived mathematical content knowledge, actual mathematical content knowledge, and the relationship between perceived and actual mathematical content knowledge. The content knowledge framework was utilized in determining teachers' content knowledge for the subject area of mathematics. A quantitative analysis revealed school-based agricultural education teachers perceived their average mathematical ability as being at a moderate level, while their average actual mathematical ability was 44% on a mathematics content exam. The analysis also revealed a negative correlation between teachers' perceived ability and years spent teaching and a positive correlation between teachers' actual ability and years spent teaching. It is recommended that mathematics requirements at the teacher preparation level be reexamined. Additionally, professional development for Arizona school-based agricultural education teachers in various mathematics content is encouraged.

Keywords: content knowledge; school-based agricultural education; agriculture teachers, mathematical content knowledge

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 nine 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 et al., 2015).

Despite the importance placed on STEM education for almost two decades, the United States is falling behind many other countries around the world. The United States currently ranks 41st in mathematics and 25th in science out of 72 developed countries (Organization for Economic Co-

[1] Amber Rice is an Assistant Professor of Agricultural Education in the Department of Agricultural Education, Technology and Innovation at The University of Arizona, 205C Saguaro Hall, 1110 E South Campus Drive, Tucson, AZ 85271, amrice@email.arizona.edu
[2] Sarah McNall is a former graduate student at The University of Arizona and current Agriscience Teacher at Cienega High School, 12775 E Mary Ann Cleveland Way, Vail, AZ 85641, sarahmcnall@email.arizona.edu

operation and Development, 2016). 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, United Kingdom, Australia, and South Korea have all implemented changes to include STEM as a cornerstone of their education programs (Hallinen, 2015). The United States 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.

There are a growing number of careers opportunities in STEM fields in the United States; however, there is also 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 mathematics and science related skills and as a result they avoid careers or educational opportunities that would apply to those content areas (Wang, 2013). Students who participated in mathematics 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 secondary education. School-based agricultural education (SBAE) courses are one solution to this issue. Students in SBAE courses have higher achievement gains through inquiry-based instruction than students learning through traditional subject matter approaches (Thoron & Myers, 2011). Utilizing the three-component model, SBAE courses combine classroom and laboratory instruction with leadership opportunities in FFA and experiential learning through supervised agricultural experiences (SAE) (National FFA Organization, 2020). 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 in SBAE classrooms (National Council for Agricultural Education, 2015). The AFNR standards follow specialized career pathways from agribusiness and food production to animal and plant systems, while integrating STEM concepts within a majority of the standards (National Council for Agricultural Education, 2015). While the AFNR standards are the basis for many states' agriculture courses, SBAE teachers in Arizona are also guided by state specific Career and Technical Education (CTE) standards (Arizona Department of Education, 2011), which include science and mathematics components. While a variety of STEM aspects are currently being implemented into SBAE courses, science is still the primary focus as the depth of mathematics content taught in these courses is limited (Haynes & Stripling, 2014).

The integration of mathematics into SBAE courses is necessary for implementing all facets of STEM education. Many SBAE teachers in Arizona, and nationwide, take the biology National Evaluation Series (NES) certification test or an equivalent to be certified to teach biology at the secondary level (Pearson Education, 2017). However, there is no such test required for mathematics for SBAE teachers, leaving the mathematic knowledge of these teachers largely unknown. At The University of Arizona, where the majority of Arizona SBAE teachers are prepared and certified, the mathematical preparation is minimal, with the requirement being a single College Algebra course (The University of Arizona, 2020). The vast majority of graduation requirements are science courses, ranging from chemistry and biology to entomology and soil science due to the CTE standards focus on science curriculum (The University of Arizona, 2020). Defining SBAE teachers' knowledge of mathematics is the first step in describing and enhancing the teaching of mathematics in secondary agricultural education courses.

Need for Study

Despite the importance of teachers' content knowledge (CK) in mathematics, researchers have found Florida pre-service SBAE teachers cannot meet the National Council of Teachers of Mathematics content areas and their sub-standards which relate to the National AFNR Career Cluster Content Standards (Stripling et al., 2014). SBAE courses can expose students to mathematics in hands on, real life situations. 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 the incorporation of all aspects of STEM, but there is less consistency in the integration of mathematics and engineering, whereas high levels of science and technology are currently being taught (Stubbs & Myers, 2015). Students have the opportunity to engage in real world application of mathematical content through SBAE programs, but if the teachers themselves do not possess the CK necessary to teach mathematics, students are then left at a disadvantage for learning the content.

As the global economy becomes more focused on STEM centered employment opportunities, the United States must prepare students to meet the growing work force requirements. SBAE courses are an engaging way to garner high school students' interest and involvement in the concepts of STEM. While all areas of STEM are covered within SBAE programs, the thoroughness and depth varies from teacher to teacher (Stubbs & Myers, 2015). Mathematics is an essential and necessary part of the agriculture field (Miller & Gliem, 1994), but it is not being taught at a deep and rigorous level in the majority of SBAE courses (Stubbs & Myers, 2015).

Determining Arizona SBAE teachers' perceived mathematical CK in conjunction with their actual mathematical CK is essential for identifying the current CK levels of teachers and will inform future action to alleviate any existing knowledge gaps. Identification of this knowledge gap will allow for various universities across the country who offer SBAE teacher preparation programs to re-evaluate and refine their required coursework to ensure students are graduating with not just high CK in science, but also in mathematics. If SBAE teachers are deficient in mathematical CK, their students' achievement could be negatively impacted (Newcomb et al., 2004). Focused improvement of SBAE teachers' mathematical CK will allow for students to have greater access to rigorous STEM education opportunities, while increasing their likelihood of pursuing degrees and careers within STEM focused fields.

Purpose and Research Objectives

The purpose of this study was to determine Arizona SBAE teachers' perceived and actual CK in mathematics. Research Priority 5 for The American Association for Agricultural Education National Research Agenda 2016-2020 discussed the growing need for mathematics and science curriculum in agricultural education programs due to the deep connection these content areas have within the agriculture field (Roberts et al., 2016). However, while science curriculum is being applied and taught through various practices within SBAE, mathematics is typically covered at the surface level (Stubbs & Myers, 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. The following research objectives guided the study:

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

Relevant Literature and Frameworks

Teacher Knowledge

Teacher 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 et al., 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 and 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 or concept, but draws on teachers' understanding of connections and relationships within the subject (Even, 1990).

Teachers' CK also greatly impacts student outcomes. If a teacher has CK for teaching mathematics, there is a positive relationship to the likelihood of student achievement measured by points gained on assessments (Hill et al., 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 of concepts 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 all basic rules and concepts by the teacher (Ball et al., 2008). For example, a strong foundation in the concept of addition is necessary before being able to subtract, multiply, divide, or solve equations. According to the Educational Testing Service (2017), mathematics teachers should be able 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 to be prepared to teach one specific aspect or concept.

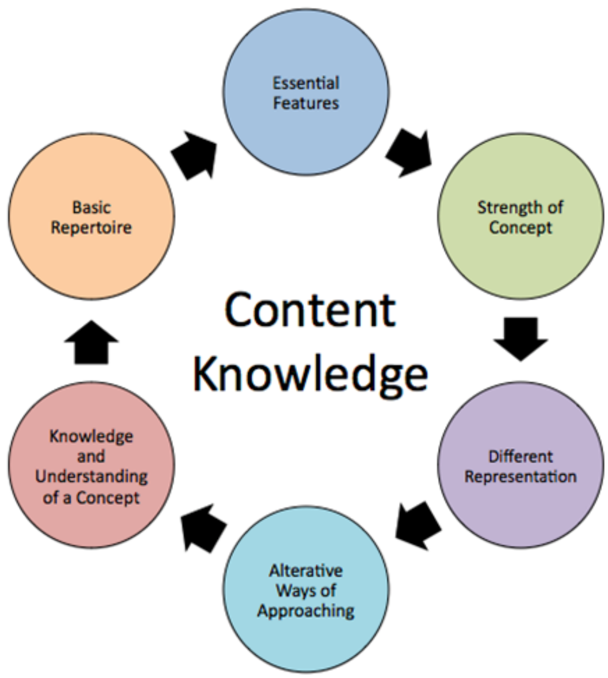
Algebra, geometry, statistics, and number theory are just a few of the CK areas mathematic teachers must be prepared to teach in a high school setting (Usiskin, 2001). Many high school mathematics teachers have degrees or minors in mathematics; however, research has shown that pre-service mathematics teachers have shortcomings in their depth of mathematical CK (Bryan, 1999). While pre-service 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 (Usiskin, 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 (2001), echoes the importance of future mathematics teachers acquiring the knowledge about concepts they will be teaching at a deep level. This prompts the question, how are SBAE teachers fairing while having received less mathematical training during their undergraduate curriculum if pre-service mathematics teachers are struggling with their own ability to relate mathematical CK to their students' level?

Content Knowledge Framework

The CK Framework developed by Ruhama Even (1990) guided this study. The CK Framework creates a categorical breakdown of teachers' mathematical subject matter knowledge (see figure 1). Even (1990) used the framework for investigating a specific mathematical topic and how different areas of knowledge affect a teacher's CK.

Figure 1

Content Knowledge Framework (Even, 1990)



For this study, six of the seven topics were utilized in describing Arizona SBAE 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).

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. Being knowledgeable in the different representations of concepts allows 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 for 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, they are able to explain the concept at 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 situation is better suited for each to promote student understanding. 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 also 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 the specific characteristics associated with each. Familiarity with difference equations, like the Pythagorean Theorem ($a^2 + b^2 = c^2$) and the area of a triangle ($a = ½b$ x 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 sub-groups 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 & Lefevre, 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 et al., 1989). Researchers have 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, the formation of one's effort, and the evaluation of the completed task are all directly related to one's self-perceived ability (Halisch & Kuhl, 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 pre-service teachers possessed a strong 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 pre-service 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 their 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 student 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 SBAE teachers.

Agriculture Teachers' Mathematical Content Knowledge

While mathematics is an essential component of SBAE, little is known about SBAE teachers' mathematical abilities, with the majority of the research being completed at the pre-service level (Stripling & Roberts, 2012; 2013). Researchers found a lack of mathematical knowledge in pre-service SBAE teachers when entering the classroom (Stripling & Roberts, 2012; 2013). If SBAE teachers are beginning their careers with a lack of mathematical CK, are they able to gain additional mathematical knowledge post-graduation? There are little to no studies currently completed on practicing SBAE teachers' mathematical CK.

Stripling and Roberts (2012) found through two mathematical assessment exams that Florida pre-service SBAE teachers lacked proficiency in solving agriculture-based mathematical problems. They also found that Florida pre-service SBAE teachers scored higher on mathematical assessments when they had taken an advanced mathematics course in high school or college compared to pre-service teachers who had only taken basic or intermediate courses (Stripling & Roberts, 2012). Of the 25 Florida pre-service SBAE teachers who participated in the mathematical assessments, the average test scores were 9.26 out of 26 problems, or 35.6% (Stripling & Roberts, 2012). SBAE pre-service teachers' efficacy for mathematics was also examined and researchers found that pre-service teachers believed they were proficient in mathematical ability and teaching (Stripling & Roberts, 2012). This research demonstrates that while Florida SBAE pre-service teachers had a high efficacy score in mathematical ability, they lacked the knowledge to complete mathematical problems. This disconnect could lead to teachers confidently teaching students mathematical concepts when they lack the mathematical CK themselves.

A subsequent study was conducted to determine if pre-service SBAE teachers' mathematical abilities would improve if a math-enhanced agricultural education teaching methods course was offered (Stripling & Roberts, 2013). Through this math-enhanced course, SBAE pre-service teachers were educated on the seven components of math-enhanced lessons to teach with an agriculture focus by National Research Center for CTE (Stone et al., 2006). The researchers assigned two of the National Council of Teachers of Mathematics sub-standards with cross references for the AFNR Career Cluster Content Standards and required pre-service teachers to teach two of the sub-standards using the seven components of the math-enhanced lesson to their fellow pre-service teachers (Stripling & Roberts, 2013). The researchers found that Florida SBAE pre-service teachers' mathematic abilities improved through participation in the math-enhanced methods course (Stripling & Roberts, 2013).

Even though there is minimal research focused on practicing SBAE teachers, it has been found that pre-service SBAE teachers lack mathematical CK (Stripling & Roberts, 2012; 2013). While pre-service 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 SBAE teachers to determine their current mathematical CK to better target additions and improvements at pre-service and in-service levels.

Methods

The design of this study was descriptive correlation research. The two variables of the study were Arizona SBAE teachers' ability to solve mathematical problems and the perceived mathematical ability of Arizona SBAE teachers. SBAE teachers' abilities to solve mathematical problems (mathematics CK) were operationalized using Stripling and Roberts (2012) *Mathematics Ability Test*. The CK Framework, in combination with Arizona's CTE Standards and perceived ability literature, guided the questions on perceived mathematical ability (Arizona Agriculture Teachers Association, 2017; Even, 1990).

Participants

As the target population, all current Arizona SBAE 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 SBAE teachers were registered in the Arizona Agricultural Education Directory for the 2016-2017 school year (Arizona FFA Association, 2016). Due to the manageable number of SBAE teachers in Arizona, 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 Arizona Association FFA webpage (Arizona Association FFA, 2016). Since every SBAE teacher in Arizona was provided with the survey, there is little chance for sampling error; however, the potential for error could result from misinformation in the frame. To address any potential error, the Arizona FFA State Executive Secretary was consulted to ensure accuracy of the frame.

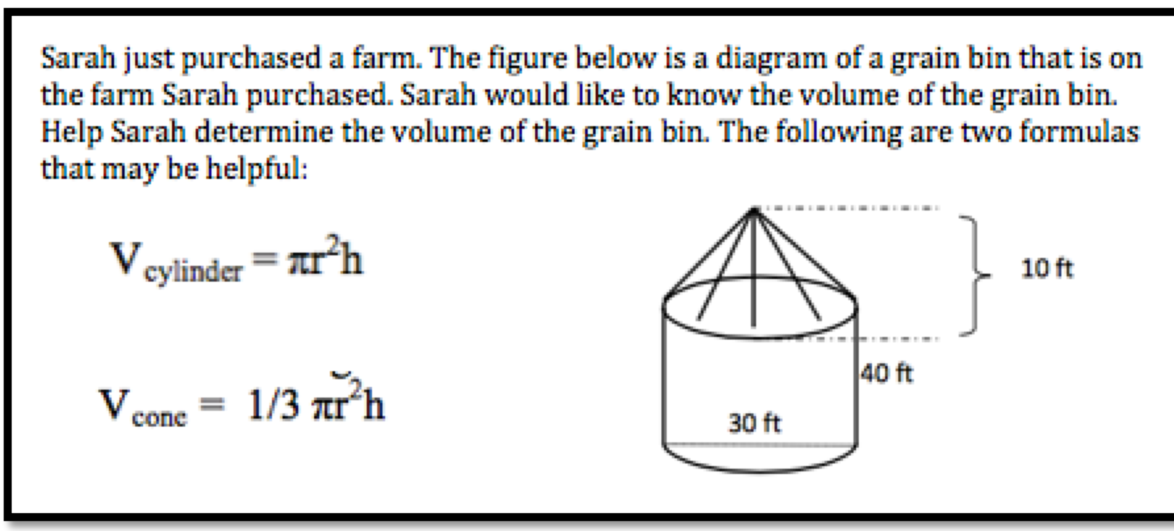
Instrumentation

The instrument created was used to determine the relationship between perceived mathematic ability and actual mathematical ability of Arizona SBAE teachers. The questionnaire was a combination of the Stripling and Roberts (2012) *Mathematics Ability Test* and self-perceived mathematical ability questions. The first section of the questionnaire asked SBAE 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 Mechanics Application, which has a direct connection to mathematics (Arizona Agriculture Teachers Association, 2017). Participants answered the eight questions to assess their level of confidence in CK using a Likert scale to select their perceived ability level related to the specified sub-standards of Demonstrate Agriscience Mechanics Application. These sub-standards included: 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 (Even, 1990). 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."

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 & Roberts, 2012) and slightly altered by the addition of multiple-choice answers. The ten questions were chosen due to their connection with the Arizona CTE standards. These mathematical problems also related back to the CTE standards from the perceived self-assessment section of the questionnaire. See figure 2. for an example question.

Figure 2

Mathematics Ability Test (Stripling & Roberts, 2012)



The final section of the questionnaire asked participants to self-select their demographic characteristics. 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 identity.

Validity and Reliability

The questionnaire was reviewed by a panel of experts (n = 4) 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 *Mathematics Ability Test* was reliability tested with Cronbach's alpha coefficient and a 0.80 alpha coefficient was established (Stripling & Roberts, 2012). A pilot questionnaire was given to the University of Arizona's pre-service SBAE teachers (n = 12) to test the reliability of the perceived mathematical ability section of the questionnaire. The Cronbach's alpha for the pilot questionnaire for the perceived CK in mathematics was 0.95 or higher for each construct.

Data Collection and Analysis

A recruitment email was sent out to Arizona SBAE teachers with a link to the online questionnaire. The questionnaire was dispersed in May 2018 with four additional reminder emails to participants over the two-week response period (Dillman et al., 2014). Respondents who did not submit their questionnaire by June 5, 2018 were considered non-respondents.

Objectives 1-3 were analyzed using means and standard deviations. To analyze objective 4, a correlation was used to determine the relationship between Arizona SBAE teachers' years spent teaching and actual mathematical ability and years spent teaching and perceived mathematical ability. The first section of the questionnaire, Arizona SBAE 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.

Findings

Objective 1 sought to describe the characteristics of the sample: gender identity, highest degree earned, major and minor, subjects taught, and years spent teaching. Of the 51 respondents, 24 of those yielded usable data. Of those 24 participants, 11 identified as men, 12 identified as women, and 1 participant chose not to disclose their gender identity. Master's degrees had been earned by 17 participants, 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. Agriscience courses had been taught by 20 participants, 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 Arizona SBAE teachers. Seven sub-constructs were explored: Measurement, Construction, Bill of Materials, Structure, Masonry, Mechanics (Operation), and Mechanics (Maintenance), and asked teachers to rank their perceived ability in each of these areas. On a scale of 1 to 5, with 1 being No Ability to 5 being Extremely Able, Table 1 displays the overall score for all sub-constructs for the 34 participants (M = 3.69; SD = 0.73). In Table 2, the seven sub-constructs were broken out individually. Bill of Materials (M = 4.45, SD = 0.82) had the highest average perceived ability and Measurement (M = 3.35, SD = 0.91) had the lowest average perceived ability.

Table 1

Average Perceived Ability of Sub-constructs (n =34)

	M	*SD*
Averaged Perceived Ability of Sub-constructs	3.69	0.73

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

Table 2

Individual Perceived Ability of Sub-constructs (n = 34)

Sub-constructs	*M*	*SD*
Measurement	3.35	0.91
Construction	3.71	0.99
Bill of Materials	4.45	0.82
Structure	3.72	0.85
Masonry	3.50	0.97
Mechanics Operation	3.57	0.99
Mechanics Maintenance	3.51	0.93

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 Arizona SBAE teachers. Ten mathematical problems from the Stripling and Roberts (2012) *Mathematics Ability Test* that had been connected with the Arizona CTE standards were given to determine Arizona SBAE teachers' actual mathematical ability. In Table 3, of the 25 usable responses, the average score was 44%. Table 4 shows the various scores earned along with each score's frequency. There were no scores above 70% for any participant in the study.

Table 3

Average Mathematical Ability Scores (n = 25)

	M	*SD*
Ability - Percent Correct	44.00	19.58

Table 4

Mathematical Ability Scores by Percent Correct (n = 25)

Mathematical Score Received	*F*	Cumulative Percent
0%	1	4.0
10%	1	8.0
20%	2	16.0
30%	3	28.0
40%	7	56.0
50%	3	68.0
60%	3	80.0
70%	5	100.0
Total	25	

Objective 4 sought to describe the relationship between perceived and actual mathematical CK for Arizona SBAE teachers. When comparing perceived ability there is a moderate perceived ability, which is not consistent with the test performance of an average of 44%. Table 5 shows there was a negative and negligible (r = -0.114) correlation to teachers' perceived ability and years spent teaching. This showed that teachers with less experience had a higher perceived ability. There was a positive and moderate (r = 0.340) correlation between teachers' actual ability and years teaching. This shows that teachers with more experience teaching demonstrated greater actual ability in mathematics.

Table 5

Correlation Between Years Teaching and Perceived and Actual Ability (n = 24)

Variable	*Perceived Ability*	*Actual Ability*
Years Teaching	(-0.11)	0.34
Effect Size	0.012	0.116

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

Conclusions, Implications, and Recommendations

The finding of this study suggests that additional steps and practices should be taken to improve Arizona SBAE teachers' mathematical CK. This study is limited to SBAE teachers in Arizona who participated in the study, with additional limitations being potential question misinterpretation, additional resources being used to aide in the mathematical ability questions, some participants not completing the entire questionnaire, and SBAE teachers not being able to connect the mathematical concepts from their courses to Arizona CTE Standards. The researchers also acknowledge the low response rate of participants and caution readers against making generalizable conclusions or broad recommendations based on the data presented. All findings and subsequent conclusions, implications, and recommendations presented here are limited to the participants of this study.

Objective 1

Objective 1 sought to describe the characteristics of the sample; gender identity, highest degree earned, major and minor, courses taught, and years spent teaching. It was found that teachers' gender identity was 50% women and 45.83% men, with one participant (4.17%) choosing to not disclose their gender identity. Of the Arizona SBAE teachers, 70.83% reported having earned a master's degree or higher. The demographic data showed that Arizona SBAE 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 Arizona SBAE 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 Arizona SBAE teachers having a high education level, there were still issues with actual mathematical CK. Deeper exploration into 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 SBAE teachers' mathematical CK.

Objective 2

Objective 2 sought to describe the perceived mathematical CK for Arizona SBAE teachers. The average total score was a 3.63, 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 affect student success (Bandura, 1993). With Arizona SBAE teachers' beliefs 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.

Arizona SBAE teachers ranked Bill of Materials the highest, being categorized as very able. SBAE 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, Arizona SBAE teachers could be avoiding the use of measurement focused topics due to their low perceived ability within this area.

Within the field of SBAE, the development of programs to improve teachers' efficacy in mathematics is essential for 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 integration is limited (Haynes & Stripling, 2014). Further research should be conducted to determine the most efficient practices to help integrate mathematics into SBAE programs. Additionally, we recommend that SBAE teacher preparation programs investigate additional avenues for enhancing pre-service teacher efficacy in mathematics. Degree requirements beyond College Algebra should be explored for potential inclusion to support mathematics knowledge.

Additional studies should also be conducted to look specifically into the area of Bill of Materials. This area had the highest ranked perceived ability out of all seven sub-constructs, warranting additional research to ensure this level of perceived ability remains at its current level. Similar to Rice and Kitchel's (2015) study of SBAE 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 conducted to determine why this mathematical concept was the lowest out of the seven sub-constructs. Measurement is an essential aspect of the agricultural industry, and ensuring SBAE 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 SBAE 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 Arizona SBAE 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 Arizona SBAE teachers that participated in the questionnaire, only eight got over half of the questions correct. When Stripling and Roberts (2012) administered their *Mathematics Ability Test* to Florida SBAE pre-service 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 SBAE teachers mathematical CK across pre-service and in-service teachers. If SBAE courses are presented as a learning environment that implements all aspect of STEM within the curriculum, additional steps must be taken to improve SBAE teachers mathematical CK to meet this precedent (Thoron & Myers, 2011). Finding different ways to improve SBAE teachers' mathematical CK is essential in creating courses that truly apply all aspects of STEM education.

The perceived ability section of the questionnaire was guided by Even's (1990) CK Framework. The six constructs from the CK Framework that were utilized to determine Arizona SBAE teachers perceived ability are all essential in developing SBAE 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 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 within their teacher preparation programs.

Along with the *Mathematics Ability Test*, the perceived ability questions Stripling and Roberts (2012) administered were to assess pre-service agriculture teachers' efficacy towards CK related to mathematics. Their results indicated that personal mathematics efficacy in subject matter knowledge had a mean score of 3.45 on a Likert scale of (1 = not at all confident to 4 = very confident) and mathematics teaching efficacy in pedagogical content knowledge had a mean score of 3.32 with (1 = strongly disagree to 5 = strongly agree) (Stripling & Roberts, 2012). Arizona SBAE teachers' average score was 3.69 on a Likert scale of (1 = no ability to 5 = extremely able). As stated earlier, both these two scores cannot be directly compared due to sample and questionnaire differences; however, both groups indicated a high level of efficacy in various mathematical content areas.

It is recommended that professional development be implemented to help develop practicing SBAE teachers' actual mathematical CK, while additional supplementary mathematical courses are recommended for pre-service SBAE teachers. The implementation of a math-enhanced course was found to improve Florida pre-service SBAE teachers' mathematical CK (Stripling & Roberts, 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 SBAE teachers in additional states other than Arizona. Currently very little research is done in the area of SBAE teachers' mathematical CK.

Objective 4

Objective 4 sought to describe the relationship between perceived and actual mathematical CK for Arizona SBAE teachers. It was found that more experienced Arizona SBAE teachers had a higher mathematical ability compared to less experienced teachers. 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 et al., 2001; Wenglinsky, 2000).

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

With a small correlation between years of teaching and mathematical ability, the results of the study indicated that SBAE teachers who have more experience teaching scored higher on the ability portion of the questionnaire as compared to teachers who have not been teaching as long. While this correlation does exist, a slight correlation of 0.3 between the two values would suggest that SBAE teachers of all experience levels are lacking in their mathematical CK.

Within the field of SBAE, it is suggested that the implementation of mentor opportunities for beginning SBAE teachers be developed and utilized. Objective 4 results indicate that experience does have a slight positive effect on ability, implying experience does matter. Creating connections between more experience and less experienced teachers will help develop an opportunity for the transfer of mathematical CK to occur. It is recommended that these efforts begin at the SBAE teacher preparation level and continue throughout a teacher's career. Additional research should also be conducted to determine when the transition occurs, specifically when high perceived ability decreases and actual ability increases. Exploring when SBAE teachers go from having a high-perceived ability but lacking actual mathematical ability to having a lower perceived ability but having higher actual mathematical ability would be beneficial in developing different ways to address this important issue in the profession.

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