Journal of Agricultural Education, 55(1), 24-37.
doi: 10.5032/jae.2014.01024

Mathematical Strengths and Weaknesses of Preservice Agricultural Education Teachers

Christopher T. Stripling[1], T. Grady Roberts[2], and Carrie A. Stephens[3]

Abstract

The purpose of this study was to describe the mathematics ability of preservice agricultural education teachers related to each of the National Council of Teachers of Mathematics (NCTM) content/process areas and their corresponding sub-standards that are cross-referenced with the National Agriculture, Food and Natural Resources Career Cluster Content Standards. To that end, the preservice teachers were not completely proficient in any of the content/process areas and were below proficiency in all of the corresponding NCTM sub-standards for 4 of the 6 content/process areas. They were proficient in 3 of the 13 NCTM sub-standards, moderately proficient in 4 of the 13 NCTM sub-standards, and not proficient in 6 of the 13 NCTM sub-standards. The results of this study suggest current practices are not sufficient for developing the mathematics content knowledge required for teaching the NCTM sub-standards found within the agricultural education curricula. To prepare preservice teachers for teaching mathematical concepts within the agricultural education curricula, agricultural educators should integrate mathematics subject matter related to the cross-referenced NCTM sub-standards into teacher education coursework, with an emphasis on the 10 NCTM sub-standards in which the preservice teachers were below the proficient level.

Keywords: math; mathematics; preservice; teacher education; STEM

> For people to participate fully in society, they must know basic mathematics. Citizens who cannot reason mathematically are cut off from whole realms of human endeavor. Innumeracy deprives them not only of opportunity but also of competence in everyday tasks…. Moreover, mathematics is a realm no longer restricted to a select few. *All young Americans must learn to think mathematically, and they must think mathematically to learn.* (National Research Council, 2001, p. 1)

Therefore, there is a need to ensure the mathematics proficiency of U.S. students; however, national assessments reveal a majority of U.S. students are not adequately proficient in mathematics (National Center for Educational Statistics, 2009, 2010, 2011). This is troubling given the implications above and the fact "there is growing concern that the United States is not preparing a sufficient number of students, teachers, and professionals in the areas of science, technology, engineering, and mathematics [STEM]" (Kuenzi, 2008, p. 1).

According to the National Academy of Sciences (2007), a key element to improving the mathematics performance of U.S. students and developing a scientifically literate workforce is developing exceptional K-12 teachers. The National Research Council (2001) stated "the

---

[1] Christopher T. Stripling is an Assistant Professor in the Department of Agricultural Leadership, Education and Communications at the University of Tennessee, 320B Morgan Hall, 2621 Morgan Circle, Knoxville, TN 37996-4511, Email:cstripling@utk.edu
[2] T. Grady Roberts is a Professor of Agricultural Education in the Department of Agricultural Education and Communication at the University of Florida, PO Box 112060, Gainesville, FL 32611-2060, Email:groberts@ufl.edu
[3] Carrie A. Stephens is an Associate Professor in the Department of Agricultural Leadership, Education and Communications at the University of Tennessee, 320B Morgan Hall, 2621 Morgan Circle, Knoxville, TN 37996-4511, Email:cfritz@utk.edu

effectiveness of mathematics teaching and learning is a function of teachers' knowledge and use of mathematical content, of teachers' attention to and work with students, and of students' engagement in and use of mathematical tasks" (p. 9). The role of mathematics teaching and learning is not solely the responsibility of K-12 science and mathematics teachers. Shinn et al. (2003) proclaimed improving student performance in mathematics is an important role for secondary agricultural education in the 21st century. Similarly, Conroy, Trumbell, and Johnson (1999) purported agricultural education was a rich context for learning mathematics and stated there is a need for agricultural educators to include more mathematics in their instruction. Before Shinn et al. and Conroy et al.'s calls for agricultural education to support the mathematics education of secondary students, the National Research Council (1988) called for secondary agricultural education to become more than vocational agriculture, to prepare students for careers that require competencies in science and mathematics, and to help students to effectively use new technologies. The National Research Council (1988) also posited that "teacher preparation and in-service education programs must be revised and expanded to develop more competent teachers" (pp. 6-7) of agriculture to make the changes described above.

With that in mind, are preservice agricultural education teachers prepared for this role? Research suggests preservice agricultural education teachers are not prepared to effectively teach mathematical concepts (Stripling & Roberts, 2012a, 2012b, 2013; Miller & Gliem, 1996). However, the aforementioned research does not identify specific mathematical strengths and weaknesses of preservice teachers related to the agricultural education curricula. This study will seek to identify mathematical strengths and weaknesses of preservice agricultural education teachers in relation to the NCTM sub-standards (Carpenter & Gorg, 2000) that are cross-referenced with the *National Agriculture, Food and Natural Resources Career Cluster Content Standards* (National Council for Agricultural Education, 2009).

Theoretical Framework

The theoretical framework for this study was Dunkin and Biddle's (1974) model for the study of classroom teaching, which is based on the original work of Mitzel (1960). Dunkin and Biddle's model for the study of classroom teaching is classified into the following four categories of variables: (a) presage, (b) context, (c) process, and (d) product. According to Dunkin and Biddle, presage and context variables have a causative relationship with process variables, and process variables have a causative relationship with product variables (Figure 1).

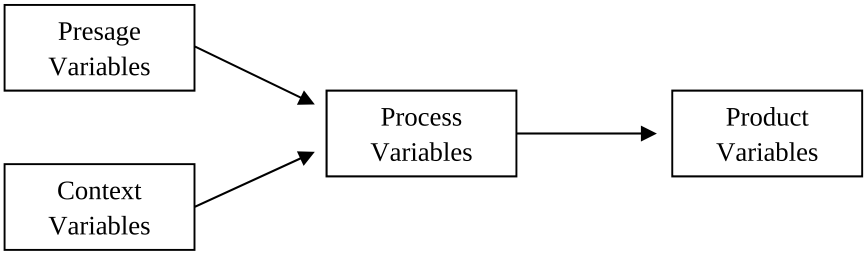

Figure 1. Adapted model for the study of classroom teaching.

First in Dunkin and Biddle's (1974) model for the study of classroom teaching are presage and context variables. Presage variables are described as "characteristics of teachers that may be examined for their effects on the teaching process–thus, teacher formative experiences, teacher-training experiences, and teacher properties" (Dunkin & Biddle, 1974, p. 39). Context variables are described as "characteristics of the environment about which teachers, school administrators, and teacher-educators can do very little" (Dunkin & Biddle, 1974, p. 41).

Community, school, and classroom contexts, student populations, student formative experiences, and school and classroom budgets are examples of context variables. Presage and context variables influence process variables. Process variables are described as "the actual activities of classroom teaching–what teachers and pupils do in the classroom" (Dunkin & Biddle, 1974, p. 44). Furthermore, in the classroom, teacher and student behaviors interact and result in observable positive or negative changes in a student's behavior or academic learning. These changes that result from the interaction of student and teacher behaviors are described by Dunkin and Biddle (1974) as product variables or as "the outcomes of teaching" (p. 46).

Dunkin and Biddle (1974) stated the "entire business of teacher education is founded on the assumption that we can 'improve' teaching practices by providing appropriate educational experiences for young teachers" (p. 49), and thus, decisions made by teacher education programs concerning the "relationship between presage conditions and teaching processes" (p. 49) should be based on evidence. To that end, this study focused on one presage variable, the mathematics ability of preservice agricultural education teachers during their final year of an agricultural teacher education program.

More recent works have also proclaimed the importance of teacher characteristics or presage variables in the learning process. Bransford, Brown, and Cocking (2000) suggested that teachers must possess subject matter knowledge, pedagogical knowledge, and pedagogical content knowledge. Darling-Hammond and Bransford (2005) stated all teachers should

> acquire knowledge of learners and how they learn and develop within social contexts, conceptions of curriculum content and goals: an understanding of the subject matter and skills to be taught in light of the social purposes of education, and an understanding of teaching in light of the content and learners to be taught, as informed by assessments and supported by classroom environments. (p. 10)

Roberts and Kitchel (2010) synthesized theories related to the types of knowledge teachers must possess into four dimensions: (a) general knowledge, (b) subject matter knowledge, (c) pedagogical knowledge, and (d) pedagogical content knowledge. In light of these works, a preservice teacher's mathematics ability is related to general knowledge (mathematics needed as a citizen of a society), subject matter knowledge (contextualized mathematics in the agricultural education curricula), and pedagogical content knowledge (the teaching of contextualized mathematics in the agricultural education curricula).

Literature Review

Preservice Teachers' Mathematics Ability

Four studies were found that specifically examined the mathematics ability of preservice agricultural education teachers – Miller and Gliem (1996) and Stripling and Roberts (2012a, 2012b, 2013). Miller and Gliem investigated the mathematical problem-solving ability of 49 preservice agricultural education teachers from The Ohio State University. The preservice teachers' average mathematics score on a mathematical problem-solving test was 37%, and 87% solved fewer than 60% of the mathematics problems correctly. Miller and Gliem reported a low negative association between mathematics ability of the preservice teachers and completion of intermediate mathematics courses and a low positive association between mathematics ability and advanced mathematics courses. Also, a substantial negative association was found between mathematics ability and students that completed basic mathematics courses. Miller and Gliem (1996) found "preservice educators with higher scores on the problem-solving test had taken advanced mathematics courses in addition to or instead of basic and intermediate math" (p. 18). In conclusion, the researchers stated "preservice agricultural educators were not capable of applying basic mathematics skills to agricultural problems" (Miller & Gliem, 1996, p. 19) and considerable attention should be given to improving the mathematics ability of preservice agricultural education teachers.

Stripling and Roberts (2012a) investigated the mathematics ability of preservice agricultural education teachers in their final year of a teacher education program at the University of Florida. Stripling and Roberts reported University of Florida preservice teachers averaged 35.6% on a 26 item agricultural mathematics instrument and concluded the preservice teachers were not proficient in agricultural mathematics concepts. Additionally, Stripling and Roberts investigated the associations between the types of mathematics courses completed in high school and college and the preservice teachers' score on the mathematics ability instrument, and concluded the associations suggested that "preservice teachers that completed an advanced mathematics course in high school and/or college scored higher on the mathematics assessment than preservice teachers that completed a basic or intermediate mathematics course in high school and/or college" (p. 118). This finding is consistent with Miller and Gliem (1996).

Stripling and Roberts (2012b) studied the mathematics ability of U.S. preservice agricultural education teachers and the types of mathematics courses completed by the preservice teachers in high school and college. Consistent with preservice agricultural education teachers from The Ohio State University (Miller & Gliem, 1996) and the University of Florida (Stripling & Roberts, 2012a), Stripling and Roberts reported the nation's preservice teachers were not proficient in mathematics. Furthermore, Stripling and Roberts reported the highest level of mathematics completed by a majority of the preservice teachers in high school and college was basic or intermediate mathematics. Additionally, the researchers reported preservice teachers who completed an advanced mathematics course scored 19.48 percentage points higher than those who did not, and preservice teachers that received an A in their highest college mathematics course scored 6.40 percentage points higher than those who received a grade lower than an A.

Based on the results of the aforementioned studies, Stripling and Roberts (2013) sought to improve the mathematics ability and mathematics teaching efficacy of preservice teachers by incorporating mathematics into an agricultural education teaching methods course. The pretest mathematics ability mean was 34.4% on a 26 item mathematics instrument, which is consistent with Miller and Gliem (1996) and Stripling and Roberts (2012a, 2012b). After the math-enhanced agricultural teaching methods course, Stripling and Roberts stated the preservice teachers mathematics ability scores had improved 12.15 percentage points. This difference was found to be statistically significant and a medium effect size was reported. However, a statistically significant difference was not found related to the preservice teachers' mathematics teaching efficacy, mathematics efficacy, or personal teaching efficacy.

Teaching Contextualized Mathematics

"The basis for good teaching is combining an information rich subject matter content with an experience rich context of application" (Parnell, 1996, p.1). Today's reform efforts in mathematics education "challenge prospective teachers in their thinking about mathematics teaching and learning. Teachers are asked to teach in ways that promote an integrated, connected view of mathematics, rather than a procedural, rule-based view" (Benken & Brown, 2008, p. 1). As a result, emphasis has been placed on teaching academic subjects in context. Contextualized learning advocates that neither general education nor career education can be taught in isolation, but must be integrated to maximize the benefit for the learner (Prescott, Rinard, Cockerill, & Baker, 1996).

Based on the philosophical stance above, Stone, Alfeld, Pearson, Lewis, and Jensen (2006) experimentally tested a "model for enhancing mathematics instruction in five high school career and technical education (CTE) programs (agriculture, auto technology, business/marketing, health, and information technology)" (p. ix). The study was conducted for one academic school year, and the combined number of participants from each program area/sample consisted of 236 career and technical teachers, 104 math teachers, and 3,950 students from 12 states. The career and technical educators had a mathematics teacher partner that provided support in developing math-enhanced lessons and suggested instructional methodologies. Survey data collected from the participants of the study indicated the “pedagogic framework to be ‘very effective’” (Stone et al., 2006, p. 40). In addition, Stone et al. found the math-enhanced curriculum did not reduce the secondary students’ technical skill or occupational content knowledge and had a positive effect on the mathematics ability of the secondary students.

Specific to secondary agricultural education, several studies have examined the effectiveness of Stone et al.’s (2006) Math-in-CTE model. Using the Math-in-CTE model, Parr, Edwards, and Leising (2006) found students were less likely to need postsecondary mathematics remediation. Parr, Edwards, and Leising (2008) and Young, Edwards, and Leising (2009) reported a math-enhanced agricultural power and technology course did not lesson secondary students’ technical skills. In two additional studies, Parr, Edward, and Leising (2009) and Young, Edwards, and Leising (2008) did not find a significant difference in the mathematics ability of secondary students that participated in a power and technology course that utilized the Math-in-CTE model. However, Young et al. (2008) stated students’ mathematics achievement “did show a positive effect in favor of the experimental group [Math-in-CTE]” (p. 14). In Parr et al.’s (2009) study, the authors suggested a significant difference may not have been found due to incomplete implementation of the treatment and an intervention time frame of only one semester.

Furthermore, in a survey of 26 outstanding secondary agricultural educators, Anderson, Williams, and Hillison (2008) reported agricultural educators taught mathematics in 23% of their lessons with a range of 0 to 75%. Similarly, Hunnicutt (as cited in Anderson, Williams, & Hillison, 2008) found secondary agricultural educators in Alabama self-reported to have integrated mathematics into 26-50% of their instructional units.

Purpose and Objective

This study is part of a larger study (Stripling & Roberts, 2012b), which investigated the mathematics requirements of agricultural teacher education programs and the mathematics ability of U.S. preservice agricultural education teachers. The purpose and the guiding objective of this study was to describe the mathematics ability of preservice agricultural education teachers related to each of the NCTM content/process areas and the corresponding sub-standards (Carpenter & Gorg, 2000) that are cross-referenced with the *National Agriculture, Food and Natural Resources Career Cluster Content Standards* (National Council for Agricultural Education, 2009).

Methods and Procedures

Research Design and Sample

The research design of this study was a one shot case study (Campbell & Stanley, 1963). The target population for this descriptive study was preservice agriculture teachers in their final year of a teacher education program, and based on Kantrovich’s (2007) agricultural education supply and demand study, the population of preservice teachers in the United States was determined to be approximately 800. Since a list of all members of the target population was not available, cluster random sampling was utilized to select a random sample (Fraenkel & Wallen, 2006). Hence, the preservice teachers in their final year at each institution were considered a cluster. For this reason, preservice teacher education programs were randomly selected until an adequate number of teacher education programs agreed to participate to meet the predetermined needed sample size of 89 (Table 1). According to Israel (1992), a sample size of 89 is needed for a population of 800, a ±10% precision level, and a 95% confidence level. Precision level is a limiting factor of this study. A precision level of ±10% was chosen based on the resources available to conduct this study.

Table 1

Agricultural Teacher Education Programs

University	*n*	AAAE region	Approximate university enrollment	Carnegie classification
1	8	Western	19,000	Research Universities (high research activity)
2	10	Southern	35,000	Research Universities (very high research activity)
3	16	North Central	29,000	Research Universities (high research activity)
4	12	North Central	12,000	Research Universities (high research activity)
5	2	Southern	29,000	Research Universities (very high research activity)
6	8	Western	29,000	Research Universities (very high research activity)
7	15	North Central	31,000	Research Universities (very high research activity)
8	2	Southern	10,000	Master's Colleges and Universities (larger programs)
9	25	Southern	51,000	Research Universities (very high research activity)

For this study, the random sample consisted of 98 preservice agricultural education teachers, 61 females and 34 males (three participants did not provide this data). The average age of the sample was 22 years old (*SD* = 3.36) with a range of 20 to 51. Ninety-one participants described their ethnicity as white, one as African American, one as Hispanic, one as American Indian, and one as other. Of the participants that reported their program level, the majority of the participants were in an undergraduate program (*n* = 85, 89.47%), and the remaining were completing a graduate program (*n* = 10, 10.53%). Ninety-one participants provided their college grade point average, and the mean GPA was 3.44 (*SD* = 0.39) on a 4-point scale. The number of college level mathematics courses completed by the participants ranged from 0 to 6 with a mode of 1. The timing when the participants took their last math course ranged from the previous semester to 15 years prior with a mean of 3.33 years (*SD* = 1.85). Additionally, in their highest level of mathematics in college, 34.8% received an A, 37.1% a B, 23.6% a C, 3.4% a D, and 1.1% a F.

Instrumentation, Data Collection, and Data Analysis

Participants consented to take the *Mathematics Ability Test* (Stripling & Roberts, 2012a) by signing an informed consent approved by the University of Florida’s Institutional Review Board. The *Mathematics Ability Test* consist of 26 open-ended mathematical word problems and was administered during the 2010-11 academic year at each of the randomly selected universities. At each university, the teaching methods course instructor or a graduate assistant administered the instrument and followed a script prepared by one of the researchers. Also, since the preservice teachers were asked to complete the instrument during instructional time, and to avoid coercion, participants were informed that participation in the study would not have an impact on their course grades. The *Mathematics Ability Test* took approximately 60 minutes to complete, and according to Stripling and Roberts (2012a), the instrument’s 26 items were developed based on 13 NCTM sub-standards (Carpenter & Gorg, 2000) that are cross-referenced with the *National Agriculture, Food and Natural Resources Career Cluster Content Standards* (National Council for Agricultural Education, 2009). Furthermore, during item development, one of the researchers met with a secondary mathematics expert to determine which items from Miller and Gliem's (1996) agricultural problem-solving test would meet the requirements of the 13 NCTM sub-standards. The secondary mathematics expert determined seven of Miller and Gliem's 15 items aligned with the 13 NCTM sub-standards, and therefore, all seven items were included on the *Mathematics Ability Test*. The remaining 19 items were developed based on NCTM examples problems (Carpenter & Gorg, 2000). A list of the 13 sub-standards and the content/process areas are presented in Table 2. In addition, Stripling and Roberts stated face and content validity of the *Mathematics Ability Test* was "established by a panel of experts consisting of agricultural education faculty and mathematics faculty from three universities and two secondary mathematics experts" (p. 115). Stripling and Roberts reported the reliability or the Cronbach's alpha coefficient to be .80. The *Mathematics Ability Test* was scored using a rubric that, according to Stripling and Roberts, was developed by two secondary mathematics experts, and all items were scored as incorrect or correct. For this study, the categorization of correct included preservice teacher responses in which the preservice teachers set the problem up correctly but made a calculation error. Descriptive statistics were used to summarize demographics, and the *Mathematics Ability Test* results related to each of the NCTM sub-standards and the content/process areas. Lastly, the percentages of correct response for the NCTM sub-standards were categorized into the following levels of proficiency by the authors for discussion purposes: (a) 0 to 39% – not proficient, (b) 40 to 69% – moderately proficient, and (c) 70 to 100% – proficient.

Table 2

Cross-referenced NCTM Sub-standards for Grades 9-12

Content/Process Area	NCTM Sub-standards
Number & Operations	1A. Understand numbers, ways of representing numbers, relationships among numbers, and number systems.
	1B. Understand meanings of operations and how they relate to one another.
	1C. Compute fluently and make reasonable estimates.
Algebra	2C. Use mathematical models to represent and understand quantitative relationships.
	2D. Analyze change in various contexts.
Geometry	3A. Analyze characteristics and properties of two– and three–dimensional geometric shapes and develop mathematical arguments about geometric relationships.
Measurement	4A. Understand measurable attributes of objects and the units, systems, and processes of measurement.
	4B. Apply appropriate techniques, tools, and formulas to determine measurements.
Data Analysis & Probability	5A. Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them.
	5B. Select and use appropriate statistical methods to analyze data.
	5C. Develop and evaluate inferences and predictions that are based on data.
Problem Solving	6B. Solve problems that arise in mathematics in other contexts.
	6C. Apply and adapt a variety of appropriate strategies to solve problems.

Findings

The items related to NCTM sub-standard 1C had the highest frequency of correct responses (*f* = 159). NCTM sub-standard 1C was followed closely by NCTM sub-standards 5A (*f* = 155) and 1A (*f* = 145). The NCTM sub-standards with the lowest frequency of correct responses were 1B (*f* = 20), 4A (*f* = 19), and 5B (*f* = 16). A complete summary of the frequency and percentage of correct/incorrect responses is presented in Table 3.

Table 3

Descriptive Statistics of Preservice Teachers Responses

		Correct		Incorrect	
Content/Process Area	NCTM sub-standard	*f*	%	*f*	%
Number & Operations	1A	145	74.0	51	26.0
	1B	20	10.2	176	89.8
	1C	159	81.9	37	18.9
Algebra	2C	89	45.4	107	54.6
	2D	79	40.3	117	59.7
Geometry	3A	33	16.8	163	83.2
Measurement	4A	19	9.7	177	90.3
	4B	117	59.7	79	40.3
Data Analysis & Probability	5A	155	79.1	41	20.9
	5B	16	8.2	180	91.8
	5C	69	35.2	127	64.8
Problem Solving	6B	87	44.4	109	55.6
	6C	38	19.4	158	80.6

As depicted in Table 4, the preservice teachers were not completely proficient in any of the content/process areas and were below proficiency in all of the corresponding NCTM sub-standards for the following content/process areas: (a) algebra, (b) geometry, (c) measurement, and (d) problem solving. In regard to the individual NCTM sub-standards, the preservice teachers were proficient in three NCTM sub-standards: (a) understand numbers, ways of representing numbers, relationships among numbers, and number systems; (b) compute fluently and make reasonable estimates; and (c) formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them. Examples of mathematical concepts within the abovementioned standards are fractions, exponents, scientific notation, whole numbers, rational and irrational numbers, approximation, sampling, types of data, and the term variable.

The preservice teachers were moderately proficient in four NCTM sub-standards: (a) use mathematical models to represent and understand quantitative relationships; (b) analyze change in various contexts; (c) apply appropriate techniques, tools, and formulas to determine measurements, and (d) solve problems that arise in mathematics in other contexts. Examples of mathematical concepts within these standards are growth rates, compound interest, log functions, slope, solving word problems, and interpretation of statements related to rates of change, volume, area, and unit conversion.

Furthermore, the preservice teachers were not proficient in six NCTM sub-standards: (a) understand meanings of operations and how they relate to one another; (b) analyze characteristics and properties of two– and three–dimensional geometric shapes and develop mathematical arguments about geometric relationships; (c) understand measurable attributes of objects and the units, systems, and processes of measurement; (d) select and use appropriate statistical methods to analyze data; (e) develop and evaluate inferences and predictions that are based on data; and (f) apply and adapt a variety of appropriate strategies to solve problems. Examples of mathematical concepts within the six previously mentioned sub-standards are matrices, understanding of permutations and combinations as counting techniques, effect of operations (e.g., multiplication and division), computing powers and roots on the magnitude of quantities, proving theorems, determining lengths and angle measures using trigonometric relationships, making decisions about units and scales, using the quadratic formula, line of best fit, regression coefficients, displaying and discussing bivariate data when at least one variable is categorical, using models of a data set to make predictions and recognizing limitations of those predictions, and applying multiple strategies for solving word problems.

Table 4

NCTM Sub-standard Proficiency

Content/Process Area	NCTM sub-standard	Not proficient	Moderately proficient	Proficient
Number & Operations	1A			X
	1B	X		
	1C			X
Algebra	2C		X	
	2D		X	
Geometry	3A	X		
Measurement	4A	X		
	4B		X	
Data Analysis & Probability	5A			X
	5B	X		
	5C	X		
Problem Solving	6B		X	
	6C	X		

Note. Not proficient (0 to 39%), moderately proficient (40 to 69%), proficient (70 to 100%).

Conclusions, Implications, and Recommendations

The preservice teachers were not completely proficient in any of the content/process areas and were below proficiency in all of the corresponding NCTM sub-standards for 4 of the 6 content/process areas. They were proficient in 3 of the 13 NCTM sub-standards, moderately proficient in 4 of the 13 NCTM sub-standards, and not proficient in 6 of the 13 NCTM sub-standards. Based upon Dunkin and Biddle (1974), mathematics proficiency, a presage variable, has a causative relationship with process variables or classroom activities and process variables have a causative relationship with product variables (student learning outcomes). Thus, not being proficient in mathematics may negatively influence the teaching and learning of contextualized mathematics in school-based agricultural education.

Given the fact that the preservice teachers were not completely proficient in any content/process area and were only proficient in 3 of the 13 NCTM sub-standards, are the current cross-referenced NCTM sub-standards appropriate for secondary agricultural education? Jansen and Thompson (2008) purported that “as agricultural education becomes a viable avenue for increasing the rigor and relevance of core-academic connections, pre-service teaching requirements in mathematics may need to be increased to meet the demands of interdisciplinary instruction” (p. 26). The authors believe the NCTM sub-standards are appropriate for secondary agricultural education. The NCTM sub-standards require the teaching of basic and intermediate mathematics such as algebra, geometry, and basic statistics, which are embedded within essential agricultural skills needed for agricultural careers and college preparation. The authors also believe lowering the mathematics standards for secondary agricultural education would prevent the profession from answering the numerous calls for agricultural education to support core academics and the STEM disciplines in an era of higher accountability and more rigorous educational standards. Additionally, the authors hold the view that mathematics is fundamental to science, and research has shown that mathematics teaching is associated with increases in science achievement (Phipps, Osborne, Dyer, & Ball, 2008). Thus, lowering the secondary mathematics standards found within the agricultural education curricula may have a negative effect on science achievement of secondary students and minimize agricultural education's role in preparing a scientifically literate workforce.

With that in mind, future research should determine why preservice teachers are not proficient in 10 of the 13 NCTM sub-standards and investigate the most appropriate strategies and methods agricultural teacher education can utilize to improve the mathematics subject matter knowledge of preservice teachers. Stripling and Roberts (2013) found that a math-enhanced agricultural methods course significantly improved the mathematics ability of Florida preservice teachers, and as a result, hypothesized the summative effects of minor changes in agricultural teacher education may produce mathematics proficient preservice teachers and improve the teaching of mathematical concepts in the secondary agricultural education curricula. Future research should also explore pairing preservice agricultural education teachers and preservice mathematics teachers during their programs of studies as a means for improving mathematics subject matter, pedagogical, and pedagogical content knowledge. This recommendation is based on the fact that the preservice teachers were not proficient in the NCTM sub-standard and the finding of Stone et al. (2006).

A major component of Stone et al.'s Math-in-CTE model was the pairing of a mathematics educator and a career and technical educator. In Stone et al.'s study, many of the CTE educators were not proficient in mathematical concepts and relied on their mathematics educator partner for support before and after teaching mathematics concepts. Pairing mathematics preservice teachers and agricultural education preservice teachers may also benefit the mathematics preservice teachers by exposing them to the context of agriculture as an avenue for teaching mathematical concepts. Furthermore, a major component of agricultural teacher education is the student teaching experience. If secondary agricultural education teachers are incorporating few mathematical concepts into daily instruction (Anderson et al., 2008), the lack of exposure to teaching contextualized mathematics during the student teaching experience may have a negative effect on preservice teachers' mathematics subject matter, pedagogical, and pedagogical content knowledge. For that reason, research should also evaluate the mathematics ability and teaching of current secondary agricultural education teachers, and if deficiencies are found, determine the most appropriate means to improve their mathematics subject matter and pedagogical knowledge. To that end, providing professional development on utilizing the seven elements of a math-enhanced lesson found within the Math-in-CTE model (Stone et al., 2006) and the cross-referenced NCTM sub-standards may be appropriate strategies from increasing the subject matter, pedagogical, and pedagogical content knowledge of secondary agricultural educators.

Furthermore, based on the results of this study, the following recommendations are given for agricultural teacher education:

- A review of current baccalaureate agricultural education coursework requirements should be conducted to determine if the current requirements are appropriate for developing a fluid conceptual understanding of mathematical concepts found within state and national agricultural education standards. The results of this study suggest current practices are not sufficient for developing the mathematics content knowledge required for teaching the NCTM sub-standards found within the agricultural education curricula.
- To prepare preservice teachers for teaching mathematical concepts within the agricultural education curricula, agricultural educators should integrate mathematics subject matter

related to the cross-referenced NCTM sub-standards into teacher education coursework, with an emphasis on the 10 NCTM sub-standards in which the preservice teachers were below the proficient level. This will aid preservice agricultural education teachers in connecting mathematics subject matter knowledge and pedagogical knowledge. This recommendation aligns with Stripling and Roberts (2013), who found that a math-enhanced teaching methods course that incorporated the NCTM sub-standards significantly increased the mathematics ability scores of preservice agricultural education teachers.

The authors believe the recommendations for future research and those given to agricultural teacher education above are vital to producing preservice agricultural education teacher that are proficient in mathematics and for answering the calls for secondary agricultural education to contribute to student achievement in mathematics. Additionally, the authors feel the recommendations are important because subject matter knowledge, pedagogical knowledge, and pedagogical content knowledge are essential for effective teaching (Bransford et al., 2000; Darling-Hammond & Bransford, 2005; Roberts & Kitchel, 2010), and the effectiveness of mathematics teaching and learning is a function of teachers’ knowledge and use of mathematical content (National Research Council, 2001, p. 9). Moreover, Dunkin and Biddle (1974), professed presage variables have a causative relationship with process variables and process variables have a causative relationship with product variables. Therefore, without sufficient preparation in mathematics teaching and learning, preservice agricultural education teachers will not be able to fully utilize the context of agriculture to maximize the academic benefits for their students.

References

Anderson, R., Williams, R., & Hillison, J. (2008). Self-reported level of mathematics integration of outstanding Virginia agricultural educators. *Journal of Southern Agricultural Education Research, 58*(1), 81-93.

Benken, B. M., & Brown, N. (2008). Integrating teacher candidates’ conceptions of mathematics, teaching, and learning: A cross-university collaboration. *IUMPST: The Journal*, *1*, 1-15. Retrieved from http://www.k-12prep.math.ttu.edu/journal/contentknowledge/benken01/article.pdf

Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (2000). *How people learn: Brain, mind, experience, and school*. Washington, DC: National Academy Press.

Campbell, D. T., & Stanley, J. C. (1963). *Experimental and quasi-experimental designs for research.* Boston, MA: Houghton Mifflin.

Carpenter, J., & Gorg, S. (Eds.). (2000). *Principles and standards for school mathematics*. Reston, VA: National Council of Teachers of Mathematics.

Conroy, C. A., Trumbull, D. J., & Johnson, D. (1999, September). *Agriculture as a rich context for teaching and learning, and for learning mathematics and science to prepare for the workforce of the 21st century*. White paper prepared for the National Science Foundation and presented at the Transitions from Childhood to the Workforce Teaching and Learning Conference, Ithaca, NY

Darling-Hammond, L., & Bransford, J. (2005). *Preparing teachers for a changing world*. San Francisco, CA: Jossey-Bass.

Dunkin, M. J., & Biddle, B. J. (1974). *The study of teaching*. Washington, DC: University Press of America.

Fraenkel, J. R., & Wallen, N. E. (2006). *How to design and evaluate research in education*. Boston, MA: McGraw Hill.

Israel, G. D. (1992). *Determining sample size* (IFAS Report PEOD6). Retrieved from University of Florida, Institute of Food and Agricultural Sciences Extension website: http://edis.ifas.ufl.edu/pd006

Jansen, D. J., & Thompson, G. W. (2008). Pacific northwest agricultural educators' perceived teacher efficacy toward enhancing mathematics. *Proceedings of the 2008 Western Region American Association of Agricultural Educators Research Conference, 27*, 16-28. Retrieved from http://aaaeonline.org/uploads/allconferences/35902008Proceedings.pdf

Kantrovich, A. J. (2007). *A national study of the supply and demand for teachers of agricultural education from 2004-2006*. Retrieved from http://aaaeonline.org/supplyanddemand.php

Kuenzi, J. J. (2008). *Science, technology, engineering and mathematics (STEM) education: Background, federal policy, and legislative action* (Paper 35). Lincoln, NE: Congressional Research Service Reports. Retrieved from http://digitalcommons.unl.edu/crsdocs/35

Miller, G., & Gliem, J. A. (1996). Preservice agricultural educators' ability to solve agriculturally related mathematics problems. *Journal of Agricultural Education, 37*(1), 15-21. doi: 10.5032/jae.1996.01015

Mitzel, H. E. (1960). Teacher effectiveness. In C. E. Harris (Ed.), *Encyclopedia of Educational Research* (3rd ed.). New York, NY: Macmillan.

National Academy of Sciences. (2007). *Rising above the gathering storm: Energizing and employing America for a brighter economic future*. Washington, DC: The National Academies Press. Retrieved from http://www.nap.edu/catalog/11463.html

National Center for Education Statistics. (2009). *The nation's report card: Mathematics 2009* (NCES 2010–451). Retrieved from http://nces.ed.gov/programs/coe/

National Center for Education Statistics. (2010). *The condition of education 2010* (NCES 2010-028). Retrieved from http://nces.ed.gov/programs/coe/

National Center for Education Statistics. (2011). *The nation's report card: Grade 12 reading and mathematics 2009 national and pilot state results* (NCES 2011–455). Retrieved from http://nces.ed.gov/nationsreportcard/pdf/main2009/2011455.pdf

National Council for Agricultural Education. (2009). *National agriculture, food and natural resource career cluster content standards.* Retrieved from http://www.teamaged.org/council/

National Research Council. (1988) *Understanding agriculture: New directions for education*. Washington, DC: National Academy Press.

National Research Council. (2001). *Adding it up: Helping children learn mathematics.* Washington, DC: National Academy Press.

Parnell, D. (1996). Cerebral context. *Vocational Education Journal, 71*(3), 18-21.

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

Parr, B. A., Edwards, M. C., & Leising, J. G. (2008). Does a curriculum integration intervention to improve the mathematics achievement of students diminish their acquisition of technical competence? An experimental study in agricultural mechanics. *Journal of Agricultural Education, 49*(1), 61-71. doi: 10.5032/jae.2008.01061

Parr, B. A., Edwards, M. C., & Leising, J. G. (2009). Selected effects of a curriculum integration intervention on the mathematics performance of secondary students enrolled in an agricultural power and technology course: An experimental study. *Journal of Agricultural Education, 50*(1), 57-69. doi: 10.5032/jae.2009.01057

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

Prescott, C., Rinard, B., Cockerill, J., & Baker, N. W. (1996). Science through workplace lenses. *Educational Leadership, 53*(8), 10-13.

Roberts, T. G., & Kitchel, T. (2010). Designing professional knowledge curriculum and instruction. In R. M. Torres, R. Kitchel, & A. L. Ball (Eds.), *Preparing and advancing teachers in agricultural education* (pp. 100-111). Columbus, OH: Curriculum Materials Service The Ohio State University.

Shinn, G. C., Briers, G. E., Christiansen, J. E., Edwards, M. C., Harlin, J. F., Lawver, D. E., Lindner, J. R., Murphy, T. H., & Parr, B.A. (2003). *Improving student achievement in mathematics: An important role for secondary agricultural education in the 21st Century*. Unpublished manuscript, Texas A&M University. College Station, TX.

Stone, J. R., III, Alfeld, C., Pearson, D., Lewis, M. V., & Jensen, S. (2006). *Building academic skills in context: Testing the value of enhanced math learning in CTE.* Retrieved from http://136.165.122.102/UserFiles/File/Math-in-CTE/MathLearningFinalStudy.pdf

Stripling, C. T., & Roberts, T. G. (2012a). Florida preservice agricultural education teachers' mathematics ability and efficacy. *Journal of Agricultural Education, 53*(1), 109-122. doi: 10.5032/jae.2012.01109

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

Stripling, C. T., & Roberts, T. G. (2013). Investigating the effects of a math-enhanced agricultural teaching methods course. *Journal of Agricultural Education. 54*(1), 124-138. doi: 10.5032/jae.2013.01124

Young, R. B., Edwards, M. C., & Leising, J. G. (2008). Effects of a math enhanced curriculum and instructional approach on students' achievement in mathematics: A year-long experimental study in agricultural power and technology. *Journal of Southern Agricultural Education Research, 58*(1), 4-17.

Young, R. B., Edwards, M. C., & Leising, J. G. (2009). Does a math-enhanced curriculum and instructional approach diminish students' attainment of teaching skills? A year-long experimental study in agricultural power and technology. *Journal of Agricultural Education, 50*(1), 116-126. doi: 10.5032/jae.2009.01116