DOES A MATH-ENHANCED CURRICULUM AND INSTRUCTIONAL APPROACH DIMINISH STUDENTS' ATTAINMENT OF TECHNICAL COMPETENCE? A YEAR-LONG EXPERIMENTAL STUDY IN AGRICULTURAL POWER AND TECHNOLOGY

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Abstract

The purpose of this study was to empirically test the posit that students who participated in a contextualized, mathematics-enhanced high school agricultural power and technology curriculum and aligned instructional approach would not differ significantly ($p < .05$) in their technical competence as compared to students who participated in the traditional agricultural power and technology curriculum and instruction. This study included teachers and students from 32 high schools in Oklahoma (16 experimental classrooms; 16 control classrooms). Students were enrolled in an agricultural power and technology course during the 2004-2005 school year. The experimental design employed was a posttest only control group; unit of analysis was the classroom. One-way analysis of variance (ANOVA) was used to test the study's null hypothesis. The measure of students' technical competence did not reveal results that held statistical significance and supported use of the experimental treatment.

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Introduction

> 'I swear by Esculupius, Hygeia, and Panacea, and I take to witness all the gods, all the goddesses, to keep according to my ability and my judgment, the following Oath. . . . I will prescribe regimens for the good of my patients according to my ability and my judgment and never do harm to anyone.' (as cited in Farnell, 1921, p. 269)

Although the phrase "do no harm" as written by Hippocrates some 2400 years ago was directed towards physicians, many practitioners of Career and Technical Education (CTE) have pondered what harm may be inflicted in our attempts to build academic skills in the context of career and technical education (Miller, 1997). Are we somehow decreasing the technical skills that students acquire in CTE courses through our efforts to integrate occupational curriculum with core academic areas?

Curriculum Integration is not a new concept. The 20th Century educational reformer, John Dewey, believed very strongly in the importance of curriculum integration and the consequences of separating knowledge from application. Dewey's position is shown clearly in the following passage:

> 'The divorce between learning and its use is the most serious defect of our existing education. Without the consciousness of application, learning has no motive. . . . [It] is separated from the actual conditions of the child's life, and a fatal split is introduced between school learning and vital experience.' (as cited in Fishman & McCarthy, 1997, p. 180)

The Association for Career and Technical Education (ACTE) (2006), in its recent publication *Reinventing the American High School for the 21st Century*, captured the current state of curriculum integration between academic and CTE courses when it stated, "Academic integration has been required in federal CTE legislation for 15 years but has not been implemented as widely as possible" (p. 14). Moreover, the ACTE (2006) called for a dramatic improvement in where and how academic content is taught:

> In the new American high school, the entire school must own the mission of academic proficiency, and teachers should be required to collaborate across disciplines to help students reach these proficiencies. CTE teachers will need to explicitly integrate academic standards into their CTE classes, and academic teachers will also need to learn ways of demonstrating real-world context and application from coursework that is more contextual than traditional teaching methods. (p. 15)

What is more, Susan Sclafani, former U.S. Department of Education's acting chief of Career and Technical Education, in a presentation to career and technical education practitioners, asserted that CTE could help students become more engaged in learning because of the contextual learning opportunities which can make learning academics more exciting (ACTE, 2004).

Although persistent calls for curriculum integration have been sounded, examples from the field are somewhat sparse. Accordingly, some observers believe that certain barriers must exist that prevent teachers from implementing curriculum integration in their classrooms. To that end, Hernandez and Brendefur (2003) analyzed the efforts of mathematics and CTE teachers in eight sites across the United States as they developed integrated mathematics curricula. Their findings were summarized as follows:

> In sum, although the quality of the units varies, our findings suggest that it is possible for interdisciplinary teams of mathematics and VTE [i.e., vocational and technical education] teachers to create high quality integrated curriculum units if certain conditions are met. Team dynamics, teachers' beliefs and school supports, in particular, appeared to be critical to sustain productive collaborative curriculum development work. It appeared that having support from the school's community, meeting regularly with all the team members, focusing conversations toward student understanding and writing tasks that promote conceptual and integrated understandings of the concepts, and writing the unit together with reflective thought, all seemed to be critical complementary conditions in successful integrated unit writing. (p. 17)

So, if curriculum integration is desirable, and it appears that it is possible at the classroom level, does it improve student achievement? In a quasi-experimental research study, Childress (1996) attempted to determine if an integrated technology, science, and mathematics curriculum would improve the problem solving abilities of middle school students. Although the results of the study proved to be statistically non-significant, the researcher did find that the experimental group students were better able to apply the mathematical and scientific principles learned as a result of the integrated curriculum.

Further evidence of the value of integrated curriculum efforts between mathematics and CTE courses can be found in the results of a study conducted by Wu and Greenan (2003). In another quasi-experimental trial, Wu and Greenan administered a treatment that consisted of the Generalizable Mathematics Skill Instructional (GMSI) intervention to an experimental group drawn from a population of secondary CTE students in Indiana. The GMSI intervention was a 22 lesson curriculum that integrated mathematics concepts into CTE curricula. As a result of the treatment, the experimental group students had significantly higher mathematics skills achievement than did students in the control group.

Curriculum integration is a pedagogical approach with roots in the educational philosophy of John Dewey that has also earned the endorsement of modern scholars and policy-makers (ACTE, 2006; Childress, 1996; Hernandez, & Brendefur, 2003; Wu, & Greenan, 2003). Although barriers to implementing curriculum integration that involves academic and CTE courses may exist, they are not insurmountable. The potential to increase student achievement through curriculum integration that would involve the intersection of core academic and CTE courses appears to outweigh any imposed barriers, perceived and otherwise (Southern Regional Education Board, 2000).

Conceptual Framework

> Mathematics isn't a palm tree, with a single long straight trunk covered with scratchy formulas. It's a banyan tree, with many interconnected trunks and branches—a banyan tree that has grown to the size of a forest, inviting us to climb and explore. (Thurston, 1990, p. 7)

Thurston used this metaphor to describe mathematics in terms of a human activity rather than an unrelated set of formulas. Unfortunately, most students are taught mathematics through a traditional approach that isolates it from other disciplines and results in the development of symbol manipulation and a set routine devoid of creation or discovery (Romberg & Kaput, 1999). Romberg and Kaput stated further:

> Previously, students studied number for number's sake, or algebra for algebra's sake, and later applied what they had learned to solve problems and perhaps even engage in serious mathematical modeling. We suggest the reverse: that number, algebra, and most other core school mathematics should arise in the service of making sense of individual experience. (p. 13)

Parnell (1998) echoed this sentiment when he asserted that, "In many of today's classrooms . . . teaching is a matter of putting students in classrooms marked English, history, or mathematics and then attempting to fill their heads through lectures, textbooks, and the like" (p. 14). And, he lamented that contextual learning is, for the most part, absent and little is done to connect students' learning with the real world in which they live.

This notion of teaching mathematics in context has not gone unheeded entirely. Many mathematics education researchers and reformers have called for greater emphasis on the use of context to teach mathematics. For example, Carpenter and Lehrer (1999) noted that to teach mathematics for understanding, applications in which contexts are provided were essential to the development of skills linked to their applications. Other researchers have made claims of increased retention due to teaching subject matter through context (Romberg, 1994). For example, a study conducted in Kentucky, where mathematics was integrated into an environment-based learning program in the context of a local community, provided students with a deeper understanding of math and enabled them to more readily master crucial math skills (Liberman & Hoody, 1998).

In an effort to provide guidance for school administrators and teachers of mathematics, who were working to improve student achievement in mathematics, the National Council of Teachers of Mathematics (NCTM) (2004) released the publication, *Principles and Standards for School Mathematics.* Six principles as well as five content and five process standards were identified. Two of the process standards dealt directly with the concept of teaching and learning math in context. The process standard identified as "connections" has direct implications for contextual teaching and learning:

> Mathematics is not a collection of separate strands or standards, even though it is often partitioned in this manner. Rather, mathematics is an integrated field of study. When

> students connect mathematical ideas, their understanding is deeper and more lasting, and they come to view mathematics as a coherent whole. They see mathematical connections in rich interplay among mathematical topics, in contexts that relate mathematics to other subjects, and in their own interest and experience. Through instruction that emphasizes the interrelatedness of mathematical ideas, students learn not only mathematics but also about the utility of mathematics. (p. 4)

A second process standard, "problem solving," also has implications for contextual teaching and learning as well as the future transfer of learning:

> Solving problems is not only a goal of learning mathematics but also a means of doing so. It is an integral part of mathematics, not an isolated piece of the mathematics program. Students require frequent opportunities to formulate, grapple with, and solve complex problems that involve a significant amount of effort. They are to be encouraged to reflect on their thinking during the problem-solving process so that they can apply and adapt the strategies they develop to other problems and in other contexts [i.e., transfer of learning]. By solving mathematical problems, students acquire ways of thinking, habits of persistence and curiosity, and confidence in unfamiliar situations that serve them well outside the mathematics classroom. (NCTM, 2004, p. 4)

Berns and Erickson (2001) made the connection between career and technical education and contextualized teaching and learning when they posited that,

> . . . contextual teaching and learning draws upon the latest research on effective teaching and student learning. As a pedagogical aspect of school reform, it places responsibility on the student with the teacher serving as a significant contributor in the process. Engaging, active learning replaces passive, traditional methods through a variety of hands-on, collaborative, high-level approaches. These approaches result in a motivational, invigorating educational experience for all students as they learn at a higher level. As a result of CTL [contextual teaching and learning], students are better prepared for the new economy. They better retain knowledge and skills, thus raising student academic and career-technical achievement. Indeed, they are better prepared for post-secondary education, careers, and bright futures in the 21st century. (p. 8)

Scholars (Parnell, 1998; Romberg & Kaput, 1999; Thurston, 1990) identified the absence of connections to the "real world" as a major problem facing the current methods used to teach mathematics. Some researchers (Carpenter & Lehrer, 1999; Fennema, Sowder, & Carpenter, 1999; Parnell, 1998; Romberg & Kaput, 1999) have recognized the need for a more contextualized approach to the teaching and learning of mathematics that would allow students to construct meaning in a situated or contextual way: An approach that holds potential for deepening understanding and thus improving future performance as it relates to mathematics. To that end, the NCTM (2004) has developed principles and standards for teaching mathematics, including process standards relating to contextual learning and problem solving.

Many agricultural education scholars (Miller & Vogelzang, 1983; Moss, 1988; National Research Council, 1988; Shepardson, 1929; Shinn et al., 2003) have supported the use of agriculture as a context for teaching and learning mathematics. However, little has been reported about any concomitant detrimental effects on students' acquisition of technical competence.

Purpose

The purpose of this study was to empirically test the hypothesis that students who participated in a contextualized, mathematics-enhanced high school agricultural power and technology curriculum (i.e., an experimental curriculum and instructional approach) would not differ significantly ($p < .05$) in their technical competence as compared to students who participated in the traditional agricultural power and technology curriculum.

Research Questions and Null Hypothesis

The following research questions guided the study: 1) What were selected characteristics of students enrolled in and instructors teaching Agricultural Power and Technology in Oklahoma during the 2004-2005 school year? 2) Does a math-enhanced agricultural power and technology curriculum and aligned instructional approach diminish students' attainment of technical competence? The following null hypothesis guided the study's statistical analyses: H_0 There is no difference between the two study groups on technical competence in agricultural power and technology as measured by an examination used to determine students' agricultural power and technology competence.

Methods and Procedures

This year-long study was conducted as a result of a pilot study carried out during the spring 2004 semester (Parr, 2004). Accordingly, the investigation's research questions and null hypothesis echo those of the pilot study (Parr). Both studies were conducted as replications of a larger study (Stone III, Alfeld, Pearson, Lewis, & Jensen 2005); the pilot being one of six replications and this study one of five nationwide. All involved a different career and technical education curriculum area. The National Research Center for Career and Technical Education (NRCCTE) funded and facilitated coordination of the larger study.

This study utilized a posttest only control group experimental design (Campbell & Stanley, 1963). The volunteer teacher participants and their classrooms were randomly assigned to either the experimental or control groups. Accordingly, the resulting units of analysis were intact classrooms. The randomly assigned classrooms were pre-tested to determine level of equivalence regarding students' basic mathematical skills (Campbell & Stanley, 1963; Tuckman, 1999). The Terra Nova CAT Survey examination (25 items) was used as the pre-treatment measure to establish equivalence of groups prior to the experiment; the test had a reliability coefficient of 0.84 (Cronbach' s alpha) (McGraw-Hill, 2000). A significant difference ($p = .047$) was found between groups on the math pre-treatment measure.

Student technical competence was measured by the Oklahoma Department of Career and Technology Education's (ODCTE's), on-line agricultural mechanics competency examination (42 items). The content validity of this examination is assured based on methods employed by the Testing Division of the ODCTE to develop individual test items. This method is outlined in the department's *Testing Handbook* (2004) and is as follows:

> Using values and information in the skills standards, the Testing Division determines the test specifications and contracts with subject matter experts to develop the test. When writing test items, subject matter experts typically reference materials identified in the curriculum crosswalk that is included in the skills standard, which reinforces the connection between standards, instruction, and assessment. A committee of subject matter experts reviews the test and carefully scrutinizes individual test items. Specifically, the committee validates the structure and content of each question and verifies the question has been keyed correctly. (p. 6)

The treatment in this study consisted of the *Math-in-GTE* model developed by the NRCCTE (Stone III et al., 2005). The model involved both a particular pedagogy and a prescribed process that can be expressed in the following mathematical equation: (Pedagogy)(Process) = Student Math Performance. This model is based on the basic assumption that occupations aligned to career and technical programs are rich in math content and thus Career and Technical Education (CTE) programs, including secondary agricultural education, should strive to enhance the math embedded in their existing curricula. This model was developed to assist CTE teachers in identifying math in their curricula and to improve their instruction as it related to those math concepts. The goal of such instruction was for students to view math as they would any other tool (e.g., a saw, tractor, or plow) necessary to complete a task in their occupational area (Stone III et al.).

The pedagogical part of the NRCCTE model for this study consisted of 17, math-enhanced, agricultural power and technology lessons developed by the experimental agricultural education teachers and their math teacher partners during the pilot study (Parr, 2004). These lessons were refined further at additional professional development sessions provided for teachers during the summer of 2004, prior to the 2004-2005 school year (Young, 2006). All lessons were revised and improved to conform to the NRCCTE model for a math-enhanced lesson (Figure 1).

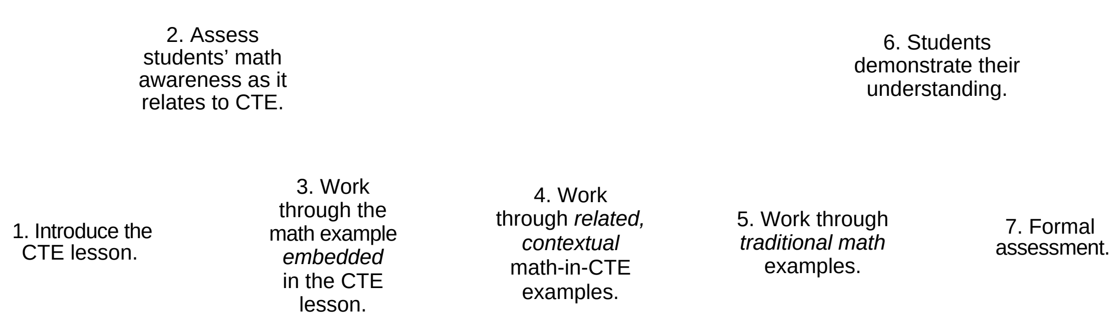

Figure 1. The NRCCTE Model: The Seven-elements of a Math-Enhanced Lesson (Stone III et al., 2005)

The development of math-enhanced agricultural power and technology lessons and the treatment's pedagogy (i.e., an aligned instructional approach) was just one aspect of the NRCCTE model. The study's treatment also included the creation of a process by which agricultural education teachers in the experimental group "learned" to develop and teach the math-enhanced agricultural power and technology lessons. This process consisted of sustaining the agriculture-math teacher partnerships (i.e., communities of practice), curriculum mapping, developing a scope and sequence for teaching the lessons, providing professional development, and implementing the lessons.

During the study, the control group teachers were asked to teach their agricultural power and technology classes using the same curriculum and teaching method(s) (i.e., "traditional") they had used previously. Due to the nature of the study, the researcher had very limited contact with members of the control group. Control group teachers' students were made available for testing per the study's testing regimen, which was carried out by testing liaisons at each school.

Teacher and student questionnaires were administered so that selected characteristics of both groups could be described. That administration took place before the study's treatment occurred. Teachers returned their completed questionnaires to the researchers via postal mail. Campus-based testing liaisons administered all student questionnaires and examinations. The ODCTE' s, on-line agricultural mechanics competency examination was administered upon completion of the treatment. The final day of post-treatment testing was reserved for the testing of student technical competence in agricultural power and technology. That test was administered on-line via the Internet in the participating schools' computer laboratories. The examination was a measure of students' agricultural power and technology competence. Subsequently, students' test data were delivered to the researchers electronically for the purpose of analysis.

Findings

Selected characteristics of participating students and teachers were summarized using frequencies and percentages derived from the study's questionnaires. The post-treatment measure to determine students' agricultural power and technology competence was analyzed using one-way analysis of variance (ANOVA).

Selected Characteristics of Students and Teachers

The student questionnaire revealed that the students were mostly male (77.5%) and of European/Anglo descent (62.9%). However, one-in four-students reported their race as Native American. Most of the students were either 16 (29.5%) or 17 (31.4%) years of age at the time of the study and were enrolled almost equally in the 12th (28.8%), 11th (3 1.9%), and 10th grades (32.1%). Approximately 7-in- 10 (70.5%) students reported that their average grades for all courses were mostly B's and C's or higher. Except for one teacher participant, all were male (96.9%). Nearly 4 of 5 teachers (78.1%) reported they were of European/Anglo descent.

Post-treatment Analysis

In the spring of 2005, the two groups of student participants were tested using the ODCTE' s, on-line agricultural mechanics competency examination to determine students' agricultural power and technology competence. The control group mean score for this examination was 45.5522 with a standard deviation of 5.61946; the experimental group mean score was 44.3050 with a standard deviation of 4.82438 (Table 1). A comparison of this data using a one-way ANOVA indicated that no significant difference in mean scores existed between the groups on technical competence in agricultural power and technology at an *a priori* determined alpha level of .05 (p = .495; Table 2); the control group students' scores were not significantly higher. Therefore, the study's null hypothesis was not rejected.

Table 1

Descriptive Statistics of Students' Technical Competence by Group as Measured by the ODCTE's, On-line Agricultural Mechanics Competency Examination

	n	*M*	*SD*	Minimum	Maximum
Control	18	45.5522	5.61946	33.20	57.18
Experimental	16	44.3050	4.82438	34.85	52.40
Total	34	44.9653	5.21980	33.20	57.18

Note. The total number of classes that took the On-line Agricultural Mechanics Competency Examination differ when compared to the total number of agricultural education teachers who participated in the study (N = 32) due to the fact that two control group teachers taught two sections of agricultural power and technology. Thus, two sections (classes) were tested for each of those teachers.

Table 2

Comparative Analysis of Students' Technical Competence by Group as Measured by the ODCTE 's, On-line Agricultural Mechanics Competency Examination

	SS	*df*	*MS*	*F*	*p*
Between Groups	13.177	1	13.177	.476	.495
Within Groups	885.951	32	27.686		
Total	899.128	33			

Conclusions

Concerning research question number one, this study found that the students were mostly male and of European/Anglo descent. However, one-in-four reported their race as Native American. Most students were either 16 or 17 years of age at the time of the study and were enrolled almost equally in the 10th, 11th, and 12th grades. Approximately 70% of students reported that their average grades for all courses were mostly B's and C's or higher. Except for one participant all teachers were male, and nearly 80% reported they were of European/Anglo descent. Regarding research question two and the study's null hypothesis, it was found that within this particular population, a math-enhanced agricultural power and technology curriculum and aligned instructional approach did not significantly diminish ($p < .05$) students' attainment of technical competence; so, the study's null hypothesis was not rejected.

Recommendations, Discussion, and Implications

The findings of this investigation are congruent with the results of a pilot study carried out during the spring 2004 semester (Parr, 2004). In the pilot study, the National Occupational Competency Testing Institute (NOCTI) – Agriculture Mechanics examination (42 items) was the posttest used to assess students' agricultural power and technology competence. Similarly, no significant difference ($p < .05$) in student technical competence between groups was detected following the pilot study's experimental treatment (Parr). So, findings from both the one-semester pilot and this full-year study indicated that the contextualized, mathematics-enhanced high school agricultural power and technology curriculum and aligned instructional approach could be a practical method of increasing students' academic skills in mathematics (Parr, Edwards, & Leising, 2006; Young, Edwards, & Leising, 2006) without diminishing their acquisition of technical competence. Accordingly, teachers who teach agricultural power and technology should be encouraged to use the curriculum integration model implemented in this study (Stone III et al., 2005), especially if they are charged with helping students to improve their mathematics achievement. What is more, teachers should not fear a diminishment in students' technical competence. i.e., assuming that a similar curriculum and instructional approach was followed.

Future investigations should be conducted to determine the efficacy of the *Math-in-GTE* model, as developed by the NRCCTE, for its usefulness in improving student achievement in other academic areas without experiencing a loss of technical competence by students for the agricultural education context in question. For example, could this model, i.e., one that involves both the pedagogical approach and process, be used to improve students' achievement in science with the resulting equation: (Pedagogy)(Process) = Student *Science* Performance?

No significant difference was detected per the study's null hypothesis, i.e., the presentation of 17 mathematics-enhanced lessons taught in an agricultural power and technology curriculum did not diminish students' attainment of technical competence. However, one might ask at what point is competence jeopardized? In other words, is there a "tipping point"? Future research should be conducted to determine the point at which the teaching of additional mathematics-enhanced lessons may have an adverse effect on students' competence.

Finally, this study should be replicated with other student populations and with teachers from comprehensive educational organizations (e.g., entire school districts, regions within states, and/or intact states), so that generalizations across teaching abilities and teacher motivation could be drawn. Teachers who participated in this study were volunteers and as such were self-selected; in addition, they received monetary compensation for their participation. Is it possible that the results would be different for a study conducted with teacher participants who represent a wider array of teaching abilities, levels of motivation, and school contexts?

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