DOES A MATH-ENHANCED CURRICULUM AND INSTRUCTIONAL APPROACH DIMINISH STUDENTS' ATTAINMENT OF TECHNICAL SKILLS? 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 (APT) curriculum and aligned instructional approach would not differ significantly ($p < .05$) in their technical competence from students who participated in the traditional APT 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 APT course during the 2004-2005 school year. The experimental design used 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.

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 2,400 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 CTE (Miller, 1997). Are we somehow decreasing the technical skills that students should acquire in CTE courses through our efforts to integrate occupational curriculum with the 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: "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 acting chief of CTE, in a presentation to CTE practitioners, asserted that CTE could help students become more engaged in learning because of the opportunities for contextual teaching 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. (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 whether 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 nonsignificant, 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 consisting 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. The experimental group students had significantly higher mathematics achievement than pupils in the control group.

Regarding statewide initiatives, the state of Kentucky now offers 10 "interdisciplinary courses" that allow students to receive academic credit by taking courses with a more occupational-oriented focus. Moreover, two courses were developed to address all 23 state standards for geometry (ACTE, 2006). From 2003-2005, Arizona updated all of its 36 CTE programs to reinforce state academic standards. Arizona high school students who graduated in 2004 and who took two or more Carnegie units of CTE courses scored higher than the general high school student population on all three of Arizona's high stakes academic tests (Arizona Department of Education, 2005).

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 involving the intersection of core academic and CTE courses, including secondary agricultural education, 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 mathematics 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 further stated:

> 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 opined 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 further that contextual learning is, for the most part, absent, and little is done to connect students' learning with the real world in which they must live.

This notion of teaching mathematics in context has not gone entirely unheeded. 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 were provided are essential to the development of skills linked to the applications. Other researchers have made claims of increased retention due to teaching subject matter through context (Romberg, 1994). What is more, a study conducted in Kentucky, where mathematics was integrated into an environment-based learning program in the context of the local community, provided students with a deeper understanding of math, thus enabling 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, five content standards, 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 CTE 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. . . . 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; Romberg & Kaput) have recognized the need for a more contextualized approach to the teaching and learning of mathematics that allows students to construct meaning in a situated way, an approach that holds potential for deepening their understanding and thus improving their future performance as it relates to mathematics. To that end, the NCTM (2004) has developed principles and standards for teaching mathematics, including process standards related to contextual learning and problem solving.

Many agricultural education scholars (Miller & Vogelzang, 1983; Moss, 1988; National Research Council, 1988; 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 (APT) curriculum (i.e., an experimental curriculum and instructional approach) would not differ significantly ($p < .05$) in their technical competence from students who participated in the traditional APT 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 APT in Oklahoma during the 2004-2005 school year? (2) Does a math-enhanced APT curriculum and aligned instructional approach diminish students' attainment of technical skills? The following null hypothesis guided the study's statistical analyses: H_o There is no difference between the two study groups on technical competence in APT as measured by an examination used to determine students' APT 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, this investigation's research questions and null hypothesis echo those of the pilot study (Parr). Both studies were conducted as components of a larger experiment (Stone III, Alfeld, Pearson, Lewis, & Jensen, 2005); the pilot was one of six experiments conducted simultaneously, and this study was one of five done nationwide concurrenly. All involved a different CTE curriculum area. The National Research Center for Career and Technical Education (NRCCTE) funded and facilitated coordination of the larger study.

This study used 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, resulting units of analysis were intact classrooms. The randomly assigned classrooms were pretested to determine level of equivalence regarding students' basic mathematical skills (Campbell & Stanley; Tuckman, 1999). The Terra Nova CAT Survey examination (25 items) was used as the pretreatment 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 pretreatment measure (Young, 2006).

The design of this study was chosen based on its robust nature, that is, its adherence to the U.S. Department of Education's standards for considering funding of educational practices that are supported by research using experimental designs whereby participants are randomly assigned to treatment and control groups (U.S. Department of Education, 2003a). In addition, this study followed the guidelines set forth by the U.S. Department of Education (2003b) for evaluating whether an intervention is supported by rigorous evidence by using outcome measures that are considered "valid."

Student technical competence was measured by the Oklahoma Department of Career and Technology Education's (ODCTE's) online 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 items. This method is outlined in the department's *Testing Handbook* (ODCTE, 2004):

> 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-CTE 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 equation: (Pedagogy)(Process) = Improved 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 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 APT lessons developed by the experimental group 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).

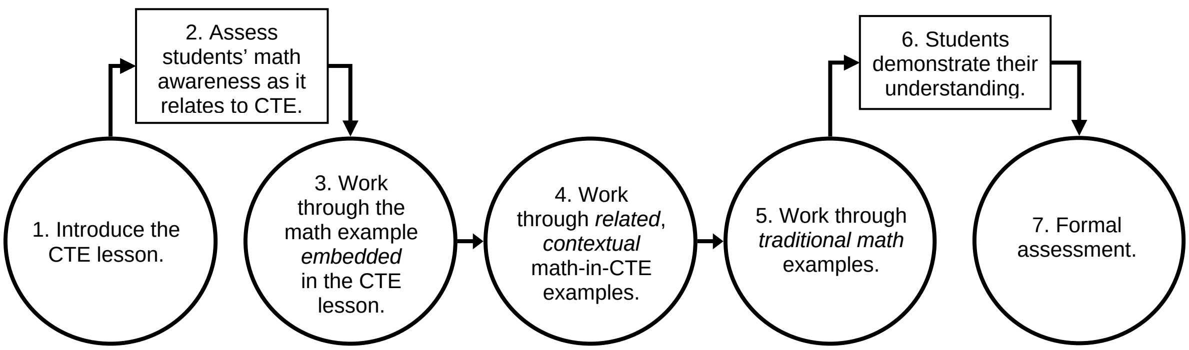

Figure 1. The NRCCTE model: The seven-elements of a math-enhanced lesson. From a published report of a year-long study of Math-in-CTE by J.R. Stone, C. Alfeld, D. Pearson, M. Lewis, and S. Jensen, 2005, St. Paul: University of Minnesota. Reprinted with permission.

The development of math-enhanced APT 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 APT 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 APT classes by using the same curriculum and teaching method(s) (i.e., "traditional") they had used previously. Because of 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.

The ODCTE's online agricultural mechanics competency examination was administered upon completion of the study's treatment. Teacher and student questionnaires were also administered so that selected characteristics of both groups could be described. Campus-based testing liaisons administered and collected all student questionnaires and examinations. The final day of posttreatment testing was reserved for measuring students' technical competence in APT. This test was administered online via the Internet in participating schools' computer laboratories. The examination was a measure of students' technical competence in APT.

Findings

Selected characteristics of students and teachers were summarized with frequencies and percentages calculated from the study's questionnaires. The posttreatment measure to determine students' APT competence was analyzed by using one-way analysis of variance (ANOVA).

Selected Characteristics of Students and Teachers

The student pretreatment questionnaire revealed that the students were mostly male (77.5%) and of European/Anglo descent (62.9%). 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 (31.9%), 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 four of five teachers (78.1%) reported they were of European/Anglo descent; the remainder indicated they were Native Americans.

Posttreatment Analysis

In the spring of 2005, the two groups of students were tested by using the ODCTE's online agricultural mechanics competency examination to determine their APT competence. The control group mean score for this examination was 45.55 (*SD* = 5.62); the experimental group mean score was 44.31 (*SD* = 4.82) (Table 1). A comparison of this data with a one-way ANOVA indicated that no significant difference in mean scores existed between the groups on technical competence 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 Online Agricultural Mechanics Competency Examination

	n	*M*	*SD*	Min	Max
Control	18	45.55	5.62	33.20	57.18
Experimental	16	44.31	4.82	34.85	52.40
Total	34	44.97	5.22	33.20	57.18

Note. The total number of classes that took the online agricultural mechanics competency examination differ compared with the total number of agricultural education teachers who participated in the study (*N* = 32) because two control-group teachers taught two sections of APT. Thus, two sections (i.e., classes) were tested for each of those teachers.

Table 2
Comparative Analysis of Students' Technical Competence by Group as Measured by the ODCTE's Online 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 of the 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 APT curriculum and aligned instructional approach did not significantly diminish ($p < .05$) students' attainment of technical skills in APT; so, the null hypothesis was not rejected.

Recommendations, Implications, and Discussion

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's Agriculture Mechanics examination (42 items) was the test used to assess students' technical competence at posttreatment. Similarly, no significant difference ($p < .05$) in students' technical competence between groups was detected following the experimental treatment (Parr). So, findings from both the one-semester pilot and this year-long study indicated that the contextualized, math-enhanced high school APT curriculum and aligned instructional approach could be a practical method of increasing students' academic skills in mathematics (Parr, Edwards, & Leising, 2006; Young, Edwards, & Leising, 2007) without diminishing their acquisition of technical skills. Accordingly, teachers who teach APT 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 improve their mathematics achievement. What is more, based on the findings of this study, teachers should not fear a diminishment in students' technical competence, assuming a similar curriculum and instructional approach are followed.

Future investigations should be conducted to determine the efficacy of the Math-in-CTE model as developed by the NRCCTE for its usefulness in improving student achievement in other academic areas without experiencing a loss in technical competence 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 without diminishing their acquisition of technical skills? (Pedagogy)(Process) = Improved Student *Science* Performance

No significant difference was detected for the study's null hypothesis; that is, , the teaching of 17 mathematics-enhanced lessons did not diminish students' attainment of technical competence. However, one might ask at what point is competence jeopardized? Is there a tipping point"? Future research should be carried out to determine the point at which the teaching of additional mathematics-enhanced lessons would have an adverse effect on students' technical 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 can 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 represented a wider array of teaching abilities, levels of motivation, and school contexts?

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