EFFECTS OF A MATH-ENHANCED CURRICULUM AND INSTRUCTIONAL APPROACH ON STUDENTS' ACHIEVEMENT IN MATHEMATICS: 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 that included intensive teacher professional development would develop a deeper and more sustained understanding of selected mathematics concepts than those students who participated in the traditional 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) and analysis of covariance (ANCOVA) were used to test the study's null hypothesis. The level of students' achievement as measured by a traditional test of math knowledge revealed results that held practical significance and supported the use of the experimental treatment. So, those who are charged with providing professional development for secondary agricultural education teachers are encouraged to consider introducing the seven-element approach to their students and teachers.

Introduction

In an era of standards-based reform in education, many believe the best way to raise student academic achievement is through improved teaching (Birman, Desimone, Porter, & Garet, 2000). To that end, Porter and Brophy (1988) maintained that student learning can be improved only if teachers' practices are of high standard; however, they concluded many teachers are not prepared to implement practices that reflect high standards. What is more, professional development for teachers could serve to fill the gap between standards-based reform and pre-service teacher preparation (Birman et al., 2000). Unfortunately, many times the professional development provided to teachers does not adequately prepare them for the rigors of standards-based student achievement (Corcoran, 1995; Darling-Hammond, 1996; Hiebert, 1999; Little 1993; Sparks & Loucks-Horsley, 1989).

In an effort to identify effective professional development for teachers, Birman et al. surveyed a sample of more than 1000 teachers who participated in the Eisenhower Professional Development Program. These researchers identified the following six factors aligned with effective professional development: (a) *Form*, was the activity planned as a traditional workshop or a reform activity; (b) *Duration,* how many hours were devoted to professional development; (c) *Participation,* were participants from the same or different schools; (d) *Content focus,* to what extent did the professional development activity focus on improving teachers' subject matter knowledge in mathematics or science; (e) *Active learning,* were teachers actively engaged in significant examination of teaching and learning; and, (f) *Coherence,* were teachers encouraged to continue a professional dialog after the professional development session. Results from this study indicated that effective professional development should provide activities that are longer in duration, involve collective participation, afford opportunities for active learning, encourage a deepening of teachers' content knowledge and provide opportunities for continued coherence (Birman et al., 2000).

The issue of professional development that supports school mathematics reform was addressed by Borasi and Fonzi (2002) in a monograph prepared for the National Science Foundation. The authors identified five factors that must be present in professional development programs in order for those programs to meet the needs of teachers of mathematics. Those factors are:

> (1) be sustained and intensive; (2) be informed by what we know about how people learn best; (3) center around the critical activities of teaching and learning rather than focus primarily on abstractions and generalities; (4) foster collaboration; and (5) offer a rich set of diverse experiences. (p. 114)

Notably, a congruence of opinion exists between those who posited factors necessary for effective professional development of teachers in general (Birman et al., 2000) and those who directed their efforts specifically at teachers of mathematics (Borasi & Fonzi, 2002).

The format used to deliver effective professional development for teachers of mathematics may be as important as the factors necessary; what is more, this conclusion may hold for all teachers who strive to improve student achievement in mathematics. Summer

institutes, study groups of teachers who meet on a regular basis, a series of workshops held during the school day or after school, and independent work done by the teacher are examples of effective formats for delivering professional development (Borasi & Fonzi, 2002). Moreover, most successful programs use a combination of formats based on the needs of the teachers involved (Borasi & Fonzi, 2002; Loucks-Horsley, Hewson, Love, & Stiles, 1998; Southern Region Educational Board, 2000).

Once the factors necessary for effective professional development are identified and put into practice, the question still remains, "Is professional development of teachers an effective means to improve student achievement?" To that end, Gordon (1999) found that professional development opportunities aimed at improving student achievement were prominent in successful schools. And, Kent (2004) concluded, "Therefore, linking improved teacher quality through effective professional development will ultimately lead to student success" (p. 432).

Harwell, D'Amico, Stein, and Gatti (2000) found similar results in a longitudinal study conducted in school District #2 in New York City. This study, conducted from 1988 to 1998, explored a variety of factors that influenced student achievement, particularly the role of teacher professional development. During the decade of observation, the percentage of District #2 students who achieved at or above grade level in mathematics rose from 66% to 82%. The researchers concluded that the professional development activities of the teachers may have had some effect.

Further, the use of intensive professional development was found to improve teacher self-efficacy years after the initial professional development session had occurred. For example, Watson (2006) found that teachers' self-efficacy regarding their use of the Internet remained high many years after the initial series of intense professional development sessions had concluded. What is more, some researchers (Mitchell, 2002; Wenger, 1998; White, 2002) have called for the use of "communities of practice" as a cost-effective method to deliver quality professional development for teachers.

Educational practitioners, researchers, and scholars (Gordon, 1999; Harwell et al., 2000; Kent, 2004) have posited that a significant relationship exists between the quality of professional development received by teachers and their future impact on student learning and achievement. However, in order to be effective, professional development must address the critical factors of form, duration, participation, content focus, active learning, and coherence (Birman et al., 2000). Accordingly, effective professional development can have a long term effect on how teachers view their self-efficacy (Watson, 2006). What is more, the use of communities of practice may be an effective way to provide valuable, sustainable, professional development for teachers, including agricultural educators who may be striving to improve their students' achievement in mathematics. Finally, some researchers (Chalmers & Keown, 2006; Mitchell, 2002; Wenger, 1988; White, 2002) have called for the use of "communities of practice" as a cost effective method to deliver quality professional development for teachers

Theoretical Framework

The underlying theoretical framework for this study relies on the model of teaching and learning developed by Dunkin and Biddle (1974) (Figure 1), that was derived from concepts first espoused by Mitzel (1960).

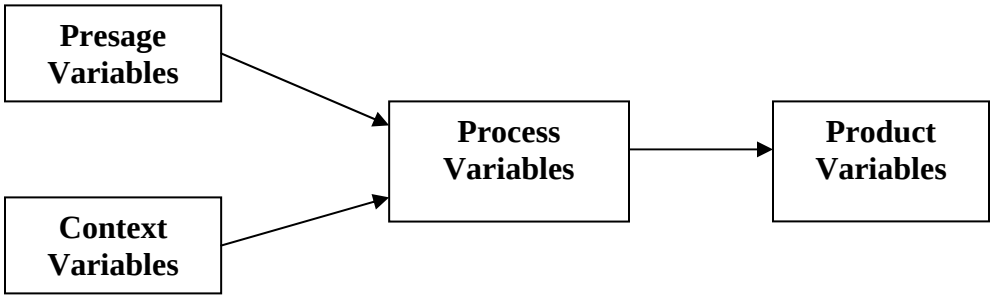

Figure 1. Model for the study of classroom teaching. (Taken from Parr, Edwards, and Leising, 2006, p. 83)

Dunkin and Biddle organized the variables that contribute to teaching and learning into four general classes. The characteristics of teachers that may be observed for their effects on the teaching process are called *presage variables*. Professional development for teachers would be classified as a significant presage variable along with other formative experiences, teacher properties, teacher-training experiences, and any other variable that may be controlled by teacher educators or school administrators are included as presage variables. *Context variables* are those conditions over which a teacher has little control. Pupil formative experiences, pupil properties, school and community contexts, and classroom contexts were variables identified by Dunkin and Biddle as context variables.

Process variables refer to those activities that take place in the classroom during the act of teaching. These variables include behaviors in the classroom demonstrated by the teacher and students, as well as the observable changes in pupil behavior. Finally, *product variables* describe the actual outcomes of teaching (i.e., student achievement in mathematics). The product variables of most interest are immediate pupil growth and long-term pupil effects (Dunkin & Biddle, 1974).

Park and Osborne (2004) used the Dunkin and Biddle model as theoretical support from which to explore the variables necessary to improve student reading, comprehension, critical thinking and motivation to read in the context of agriscience. After completing a review of literature, the researchers grouped the related literature into themes related to presage and context variables. This grouping of literature, based on variables described by Dunkin and Biddle, then allowed the researchers to posit a model for the study of reading in secondary agriscience. Park and Osborne made a strong case as to the utility of the Dunkin and Biddle model for examining the integration of academic and CTE courses, including effects that may be related to improving student academic achievement.

The model posited by Dunkin and Biddle is robust, and, therefore, provides a comprehensive and grounded approach for looking at many of the significant variables associated with the teaching and learning process. This model is also valuable as an aid to summarize research-based knowledge about the teaching and learning process, and it provides a transparent lens to view and interpret the results of this study.

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 develop a deeper and more sustained understanding of selected mathematical concepts than those students who participated in the traditional agricultural power and technology curriculum. The assumption was that students who received the experimental curriculum and instruction would be able to transfer their math learning to new and novel settings (Stone III, Alfeld, Pearson, Lewis, & Jensen, 2005) in their technical field and more broadly, including their performance on a standardized test of mathematics ability.

Research Questions and Null Hypothesis

The following research questions guided the study: (2) What were selected characteristics of students enrolled in and instructors teaching Agricultural Power and Technology in Oklahoma during the 2004-2005 school year? (b) What was the effect of a math-enhanced agricultural power and technology curriculum and aligned instructional approach on student performance as measured by a traditional test of student math ability? The following null hypothesis guided the study's statistical analyses: H_o There is no difference between the two study groups on math performance as measured by a conventional standardized test of math achievement.

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 one replication of a larger study (Stone III et al., 2005); the pilot being one of six replications and this study one of five replications 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). The Terra Nova CAT Basic Battery (46 items) that was used as a post-treatment measure for evaluation of general math ability has a reliability coefficient of 0.91 (Cronbach's alpha) (McGraw-Hill, 2000).

The design of this study was chosen based on its robust nature and 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."

The treatment in this study consisted of the *Math-in-CTE* model developed by the NRCCTE. 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, including agricultural education instructors, 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, a tractor, a plow) necessary to complete a task in their occupational area (Stone III et al., 2005).

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 2).

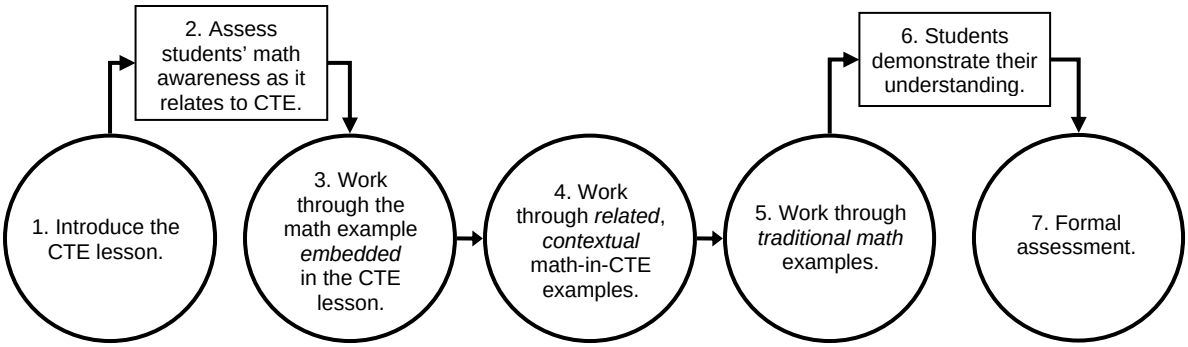

Figure 2. The NRCCTE Model: The seven-elements of a math-enhanced lesson (Stone III et al., 2005)

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 sustained professional development, and implementing the lessons. According to Dunkin and Biddle (1974), the abovementioned teacher professional development experiences were *presage* variables.

The experimental group agricultural education teachers and their math teacher partners participated in approximately 11 days of professional development over the course of this study The goal and objectives of the professional development component of this study's treatment were outlined at a Math-in-CTE Year 2 Planning Meeting held in Minneapolis, MN June 4-5, 2004 (National Research Center for Career and Technical Education, 2004):

> The overarching goal of the professional development aspect of the study is to prepare teachers to reinforce students' understanding and mastery of higher-level math concepts and skills by enhancing the math that already exists in the CTE curriculum. The professional development sessions will reinforce and build on the teachers' content and pedagogical knowledge. Math-enhanced lessons developed in year 1 of the study will be critiqued and improved. New lessons, based on the identification of mathematics concepts within specific CTE courses, will be developed in year 2 to further help teachers emphasize and enhance math as part of their CTE classroom instruction. (p. 9)

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 instruction") 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 (Young, 2006).

Findings

Selected characteristics of participating students and teachers were summarized using frequencies and percentages calculated from the study's questionnaires. The pre-treatment measure used to determine the equivalency of groups regarding students' general mathematical ability was analyzed using one-way analysis of variance (ANOVA). Due to finding a significant difference ($p = .047$) between the experimental and control groups based on results of the pre-treatment measure, comparative analysis of the posttest mathematics achievement measure was conducted using the analysis of covariance (ANCOVA) procedure.

Selected Characteristics of Students and Teachers

The student pre-treatment questionnaire revealed that the student participants 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 (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 4 of 5 teachers (78.1%) reported they were of European/Anglo descent.

Pre-treatment Analysis

In the fall of 2004, the two groups of student participants were tested using the Terra Nova CAT™ Survey Edition (CTB/McGraw-Hill) examination to determine the equivalence of groups in regard to their general math ability. The control group mean score for this examination was 49.21 with a standard deviation of 8.23; the experimental group mean score was 43.44 with a standard deviation of 8.01 (Table 1). A comparison of this data using a one-way ANOVA indicated that a significant difference in mean scores existed between the groups on general math ability at an *a priori* determined alpha level of .05 ($p = .047$; Table 2); the control group students scored significantly higher on the examination.

Table 1

Descriptive Statistics for Student Math Performance by Group on the Terra Nova Survey Examination (Pre-treatment Measure)

	n	Mean	*SD*	Minimum	Maximum
Control	18	49.21	8.23	33.11	67.20
Experimental	16	43.44	8.01	28.67	57.25
Total	34	46.50	8.521	28.67	67.20

Note. The total number of classes that took the Terra Nova Basic Survey 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 Student Math Performance by Group Means as Measured by the Terra Nova Survey Examination (Pre-treatment Measure)

	SS	*df*	*MS*	*F*	*p*
Between Groups	282.208	1	282.208	4.271	.047*
Within Groups	2114.349	32	66.073		
Total	2396.557	33			

*$p < .05$.

The use of a pre-treatment measure to determine equivalency of groups regarding general math ability prior to administration of the treatment is a method of reducing experimental error using statistical means rather than experimental (Keppel, 1991). As a pre-treatment measure, the test becomes a covariate and is useful in further refining experimental error and to adjust treatment effects when differences between the experimental and control groups are determined prior to the treatment (Keppel, 1991). Due to finding a significant difference between the experimental and control groups on the pre-treatment measure, analysis of the posttest math examination was done using the analysis of covariance (ANCOVA) procedure.

Posttest Analysis

To address the study's null hypothesis, student participants in both the experimental and control groups were tested on their general math ability using the Terra Nova CAT™ Basic Battery (CTB/McGraw-Hill) Level 21/22 Form A examination after the treatment was completed. The control group mean score was 44.97 with a standard deviation of 14.72, and the experimental group mean score was 46.17 with a standard deviation of 11.07 (Table 3). Although the experimental group students scored higher, an ANCOVA comparison of this measure revealed no significant difference in general math ability between the groups following the treatment ($p = .125$) at an *a priori* determined alpha level of .05 (Table 4). The null hypothesis was not rejected based on this analysis. Equality of variances was assured with a Levene's Test ($\alpha = .696$). Effect size was also calculated using Keppel's (1991) formula for Omega squared ($\acute{\omega}^2 = .031$); a "small" effect (Cohen, 1977) was revealed.

Table 3

Descriptive Statistics for Student Math Performance by Group on the Terra Nova Basic Battery Examination

	n	Mean	*SD*	Minimum	Maximum
Control	18	44.97	14.74	19.57	76.09
Experimental	14	46.17	11.07	21.74	60.14
Total	32	45.50	13.06	19.57	76.09

Table 4

Comparative Analysis of Student Math Performance by Group as Measured by the Terra Nova Basic Battery Examination with Pre-treatment Measure as a Covariate

Source	*SS*	*df*	*MS*	*F*	*p*
Pre-treatment Measure	2079.080	1	2079.080	18.847	.000*
Between Groups	275.997	1	275.997	2.502	.125
Within Groups	3199.090	29	110.313		
Total	5289.569	31			

*$p < .05$.

Note. Degrees of freedom differ for the Terra Nova Basic Battery Examination when compared to the pre-treatment measure due to the random assignment of the three mathematics posttests to two classrooms in the experimental group with small numbers of students, which prevented all three measures being administered in those classrooms.

Conclusions

This study found that the student participants were mostly male and of European/Anglo descent. However, one-in-four students 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.

Within this particular population, a math-enhanced agricultural power and technology curriculum and aligned instructional approach did not result in a significant increase ($p < .05$) in student performance as measured by a traditional test of student math ability (i.e., Terra Nova CAT™ Basic Battery) ($p = .125$). Although no significant difference was detected for the study's null hypothesis, the post-treatment measure of student math achievement did show a positive effect in favor of the experimental group (Table 3). What is more, the comparison of students' Terra Nova CAT™ Basic Battery performance revealed results that held practical significance ($\acute{\omega}^2 = .031$).

Implications and Discussion

Although no significant differences were detected for the study's null hypothesis, the post-treatment measure of student math achievement did show a positive effect in favor of the experimental group (Table 3). It is important to note that experimental group agricultural education teachers and their math teacher partners participated in approximately 11 days of professional development over the course of this study. Moreover, a review of the agendas from those professional development sessions (Young, 2006) revealed congruence with five factors identified by Borasi and Fonzi (2002) necessary for professional development that supports school-based mathematics education reform.

One positive outcome of the intensive professional development associated with this study was the emergence of communities of practice. The construct "community of practice" as used in this study is consistent with the theory espoused by Wenger (1998) and described in educational practice by Yamagata-Lynch (2001). Although Yamagata-Lynch suggested that "community of practice" be used as a metaphor for analyzing current practices, she also promoted the idea of examining the advantages and disadvantages of using "communities of practice" as tools for crafting educational environments, including learning contexts that hold promise for improving student achievement. So, the identification of factors inherent to the design of this study that resulted in the transformation of teacher teams as described by Parr (2004) into communities of practice is worthy of additional inquiry.

Further, would the development of "communities" early in teachers' professional careers result in the establishment of communities of practice that, in turn, create vibrant and effective schools where the quality of student learning is exemplary? Using the concept of communities of practice as a tool for designing effective educational environments, research regarding the development of communities of practice among pre-service agricultural education teachers and pre-service academic teachers may be warranted.

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