Effects of a Math-Enhanced Curriculum and Instructional Approach on Students' Need for Post-secondary Remediation 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 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 measure of students' need for mathematical remediation at the post-secondary level did reveal results that held practical significance and supported use of the experimental treatment.

Introduction

The need for increased student achievement in mathematics in the United States is well documented. A report commissioned by the Committee for Economic Development (2003) found that most national measures of student achievement in math were generally disappointing. This study also found that student interest in math has declined, especially among high school seniors. In addition, the 2000 National Assessment of Educational Progress (NAEP) (National Center for Educational Statistics, 2004a) revealed that less than 20% of 12th graders were proficient in math. Moreover, in 2003, the mathematics performance of U.S. students aged 15 was assessed by the Program for International Student Assessment (PISA) and compared to math achievement of students from 39 other nations. Results of the PISA indicated that the mathematics scores of U.S. students ranked 9th behind such countries as Latvia, Hungary, and Russia (National Center for Educational Statistics, 2004b).

The current level of student achievement in mathematics in the state of Oklahoma is also of concern. Oklahoma ranked 41st in the nation on the 2005 NAEP scores for mathematics (National Center for Educational Statistics, 2005). In 2005, the Oklahoma state board of education reported that only 32% of students scored at the "satisfactory" or "advanced" performance levels for the algebra I end-of-instruction examination (Oklahoma State Board of

Education, 2005). So in Oklahoma and nationwide, "Improving the math and science skills of our young people is an important step towards maintaining innovation-led economic growth in the coming decades" (Committee for Economic Development, 2003, p. 1).

A strong need for remediation at the post-secondary level is but one of many manifestations of the lackluster achievement in mathematics by students in the United States. According to the National Center for Educational Statistics (2003), in the fall of 2000, 22% of post-secondary students were enrolled in remedial mathematics courses. Additionally, the Center reported that 71% of all Title IV, two and four year degree granting institutions offer at least one remedial course in mathematics. As one would expect, two-year, post-secondary institutions were most likely to offer remedial courses (98% indicated that they did); however, 80% of all public four-year universities also reported they offered at least one remedial course.

Remedial instruction is not only detrimental to individual students by increasing the amount of time necessary to complete a program of study it also results in a considerable drain on educational resources. One study (Mackinac Center for Public Policy, 2000) placed the cost of post-secondary level remediation in the United States at 16.6 billion dollars annually.

Secondary Agricultural Education

Agriculture has long been considered a natural context for teaching mathematics. Shepardson (1929) most eloquently expressed the relationship of agriculture to mathematics when he stated, "Agriculture is the meeting-ground to the sciences. Physics and chemistry lie at its base. To these elements biology adds its conception of organism. Mathematics is their common instrument" (p. 69).

Some teachers of mathematics have also supported the concept that agriculture could be a powerful context for teaching mathematics. To that end, Miller and Vogelzang (1983) found that, among a population of agricultural education teachers, teachers of mathematics, principals, and agricultural education students from 36 randomly selected schools in Iowa, the teachers of mathematics supported the inclusion and application of math concepts in agricultural education classes to a greater extent than the other groups studied.

That study identified 13 math concepts that were applicable to problems in agriculture and should be included in the agricultural education curriculum. The researchers also recommended that applied math concepts should be incorporated in new curriculum, and suggested that teachers of mathematics should provide assistance to agricultural education teachers in developing lesson plans which incorporated applied math (Miller & Vogelzang, 1983).

Shinn et al. (2003) summarized the value of problem-solving and teaching and learning in mathematics when delivered through an agricultural context:

> There are indications that student achievement in mathematics will increase when students become more engaged using inquiry-based, problem-solving learning strategies, particularly when coupled with highly qualified, caring teachers who deploy a

> contextualized curriculum that connects new ideas and skills to students' past knowledge and experience. (p. 23)

Agriculture has been recognized for many years as a viable context for teaching and learning mathematics. This combination of teaching through context and reliance on the problem-solving method (Parr & Edwards, 2004) could make secondary agricultural education a valuable curriculum venue for the teaching of mathematics, i.e., one in which student performance in mathematics is affected positively.

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).

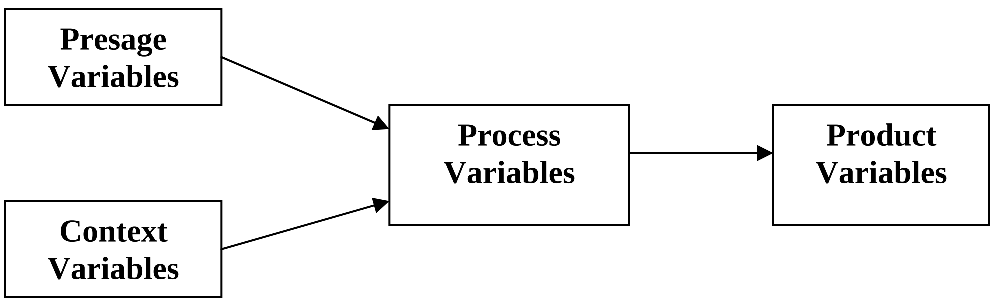

Figure 1. Model for the Study of Classroom Teaching. (Taken from Parr, Edwards, and Leising, in press, p. 4)

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*. Teacher 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. 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, thus ensuring less need for remediation in mathematics at the post-secondary level. 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.

Research Question 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 affect students' need for post-secondary math remediation? The following null hypotheses guided the study's statistical analyses: H_o There is no difference between the two study groups on a math placement test used to determine students' need for math remediation at the post-secondary level.

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 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 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 examination used to determine students' need for mathematics remediation, the ACCUPLACER (35 items), had an internal consistency reliability coefficient of 0.92 (Cronbach's alpha) (College Entrance Examination Board, 2002). This posttest measure 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 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 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).

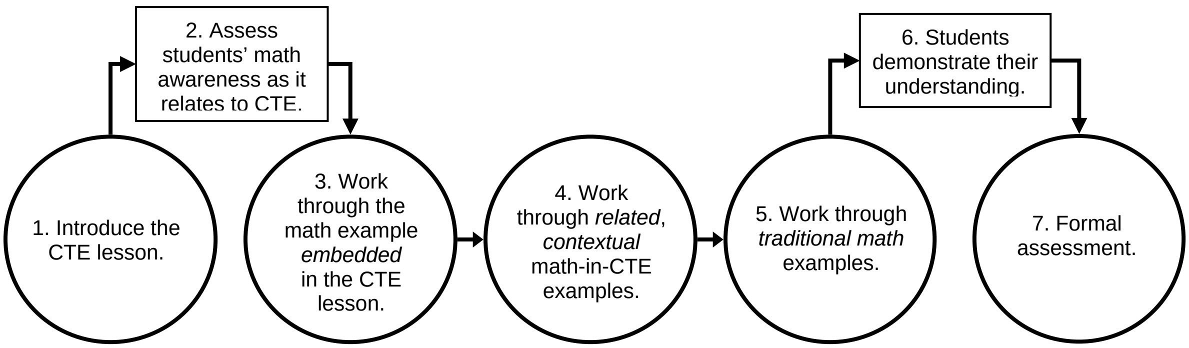

Figure 2. The NRCCTE Model: The Seven-elements of a Math-Enhanced Lesson (Stone III et al., 2005)

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 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.

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 aptitude. The control group mean score for this examination was 49.2119 with a standard deviation of 8.23297; the experimental group mean score was 43.4399 with a standard deviation of 8.00857 (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 aptitude at an *a priori* determined alpha level of .05 (p = .047; Table 2); the control group students scored significantly higher.

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	49.2119	8.23297	33.11	67.20
Experimental	16	43.4399	8.00857	28.67	57.25
Total	34	46.4957	8.52191	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 aptitude 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 need for math remediation at the post-secondary level using the ACCUPLACER examination (College Entrance Examination Board, 2002) after the treatment was completed. The control group mean score was 36.4602 with a standard deviation of 7.62071, and the experimental group mean score was 40.3914 with a standard deviation of 13.39890 (Table 3). An ANCOVA comparison of this measure revealed no significant difference in the need for math remediation between the groups following the treatment (p = .081) 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 ($\alpha = .126$). Effect size was calculated using Keppel's (1991) formula for Omega squared ($\acute{\omega}^2 = .062$), which is considered a "medium" effect (Cohen, 1977).

Table 3
Descriptive Statistics for Student Math Performance by Group on the ACCUPLACER Examination

	n	Mean	*SD*	Minimum	Maximum
Control	18	36.4602	7.62071	24.57	54.29
Experimental	16	40.3914	13.39890	21.43	74.29
Total	34	38.3102	10.74659	21.43	74.29

Note. The total number of classes that took the ACCUPLACER 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 4
Comparative Analysis of Student Math Performance by Group as Measured by the ACCUPLACER Examination with Pre-treatment Measure as a Covariate

Source	*SS*	*df*	*MS*	*F*	*p*
Pretest	484.625	1	484.625	4.701	.038*
Between Groups	334.934	1	334.934	3.249	.081
Within Groups	3195.611	31	103.084		
Total	3811.147	33			

*$p < .05$.

Conclusions

Concerning research question number one, 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.

Concerning research question two and the study's null hypothesis, this study found that within this particular population, a math-enhanced agricultural power and technology curriculum and aligned instructional approach did not significantly affect ($p < .05$) students' need for math remediation at the post-secondary level. 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' ACCUPLACER scores revealed results that held practical significance ($\acute{\omega}^2 = .062$). These results support the value of curriculum integration as endorsed by other researchers and scholars (Association for Career and Technical Education, 2006; Balschweid & Thompson, 2002; Bottoms & Sharp, n.d.; Childress, 1996; Edwards, 2004; Hernandez & Brendefur, 2003; Roegge & Russell, 1990; Wu & Greenan, 2003).

Recommendations, Discussion, and Implications

Parr (2004) called for further inquiry concerning the evaluation instrument employed in this study. The ACCUPLACER examination provided the only statistically significant ($p < .05$) finding of the pilot study. Albeit not significant at .05, that examination also demonstrated the largest effect size and measure of practical significance in this year-long study. This finding warrants additional research into the specific mathematical concepts measured by it, and why the context of agricultural power and technology may be a robust curriculum that assists in improving student learning for the type of mathematics the ACCUPLACER examination assesses.

In both the pilot and year-long studies, differences of practical significance between the control and experimental groups regarding student mathematics performance were found. However, only the pilot study demonstrated a statistically significant difference ($p < .05$). In contrast, students' performance on the pre-treatment measure to determine the equivalence of groups for general math ability was not significantly different in the pilot but was in this study. To that end, comparative analysis of the findings obtained from both investigations regarding student characteristics is warranted in an attempt to better examine factors that may have contributed to differences and similarities between the results of each investigation.

More than one-fourth of the students who participated in this study reported their ethnicity as Native American. So, further analysis of the data collected should be conducted to determine if any significant differences emerge when the performance of Native American students is compared to other ethnic groups. If significant findings were to emerge that supported the experimental treatment, then replications of this study in other states or regions with significant Native American populations may be warranted.

Additional research should be conducted regarding the mathematical abilities and aptitudes of secondary agricultural education teachers. To date, only a few studies have investigated the mathematical problem-solving abilities of secondary agricultural education teachers. Persinger and Gliem (1987) found that secondary agricultural education teachers scored below an expected level of competence on an examination measuring mathematical problem-solving in the context of agricultural mechanics. Hunnicutt and Newman (1995) discovered similar findings in a study conducted with agricultural education teachers in Alabama. Miller and Gliem (1994) determined that the method by which agricultural education teachers were taught mathematics had a greater influence on their mathematical abilities than the number of college level mathematics classes the instructors had completed. However, little has been reported about the relationship between agricultural education teachers' level of content knowledge for a particular core subject (e.g., math) and their ability to integrate that subject into their curriculum to the extent it positively affects student achievement.

Future investigations should be conducted to determine the efficacy of the *Math-in-CTE* model as developed by the NRCCTE (Stone III et al., 2005) for its usefulness in improving student achievement in other academic areas. For example, could this model, i.e., one that involves both pedagogy and process, be used to improve student achievement in science with the resulting equation?

(Pedagogy)(Process) = Student *Science* Performance

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 instructors' teaching abilities and levels of 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. So, 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?

This study also supports the findings of Hernandez and Brendefur (2003) in regard to factors necessary to produce high quality, integrated mathematics curriculum. Many of the essential factors outlined by Hernandez and Brendefur were a part of the process in which experimental agricultural education and mathematics teachers participated during the course of the study (i.e., intensive professional development, support from administrators, and meeting regularly in regional math cluster sessions).

Additionally, this study may negate the concerns asserted by some scholars (Bjork & Richardson-Klavhen, 1989; Carraher, 1986; Lave, 1988; Saxe, 1989) regarding knowledge that is bound too tightly in a particular context, thus limiting its transfer to new and novel settings. For example, it appeared that experimental group teachers who used the seven-element, math-enhanced lesson plan and aligned instructional approach enabled their students to better transfer the math skills they learned to the ACCUPLACER examination with a medium level of practical significance ($\acute{\omega}^2 = .062$). What is more, according to the *Publication Manual of the American Psychological Association*, 5th edition, (2001) failure to report effect sizes (i.e., practical significance) is one of seven common errors found in the design and reporting of research. The manual states further that,

> For the reader to fully understand the importance of your findings, it is almost always necessary to include some index of effect size or strength of relationship in your Results section. . . . The general principle to be followed, however, is to provide the reader not only with information about statistical significance but also with enough information to assess the magnitude of the observed effect or relationship. (pp. 25-26)

The results as measured by the ACCUPLACER examination also supported the assumptions of Carpenter and Lehrer (1999), Romberg (1994), and Shinn et al. (2003) regarding an improvement in student achievement when mathematics is taught in a context. Moreover, the seven-element, math-enhanced lesson plan format addressed both the "connections" and problem-solving process standards outlined by the National Council of Teachers of Mathematics (NCTM) (2004). The focus on agricultural power and technology as a context for teaching mathematics and the use of problems specifically in elements 3, 4, and 5 of the math-enhanced lesson plans provided evidence of congruence with those NCTM standards. In addition to meeting many of the NCTM standards, the agricultural power and technology curriculum provided a point of intersection between existing, embedded competencies and some of the math concepts identified by the Oklahoma Department of Education's Priority Academic Student Skills (PASS) for high school students (Parr, 2004).

The value of professional development for teachers and its relationship to student achievement (Gordon, 1999; Harwell, D'Amico, Stein, & Gatti, 2000; Kent, 2004) was also supported by the results of this study. It is important to note that experimental group agricultural education teachers and their math teacher partners participated in approximately 11 days of professional development. Moreover, a review of the agendas from those professional development sessions revealed a congruence with five factors identified by Borasi and Fonzi (2002) necessary for professional development that supports mathematics education reform.

Finally, findings of this study reflect the positions of many agricultural education scholars (Conroy, Trumbull, & Johnson, 1999; Miller & Vogelzang, 1983; Moss, 1988; National Research Council, 1988; Shepardson, 1929; Shinn et al., 2003) who supported the use of agriculture as a context for teaching and learning mathematics. Specifically, the model of teaching and learning posited by Dunkin and Biddle in 1974 (see Figure 1) provided a structure to describe and classify the various elements of this study. *Presage* variables were defined by Dunkin and Biddle as the characteristics of teachers that may have an influence on the teaching process. In this study, significant presage variables may have been the professional development sessions that teachers attended, and the emergence of communities of practice between the agricultural education and math teachers. *Context* variables, as defined by Dunkin and Biddle, are those conditions to which a teacher must adjust. Selected characteristics of the students who participated in the study, the Oklahoma agricultural power and technology curriculum, and the math embedded in that curriculum all qualified as context variables.

Process variables are defined as the actual activities that occur during the act of teaching. In this study, "The 7-Elements of a Math-Enhanced Lesson," i.e., the prescribed method for teaching the math-enhanced lessons, served as a significant process variable. Finally, the *product* variables of interest included changes in student behavior resulting from the interaction of all other variables. The study's primary product variable was the measure and comparison of students' mathematics performance on the ACCUPLACER examination following completion of the experimental treatment.

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