SELECTED EFFECTS OF A CURRICULUM INTEGRATION INTERVENTION ON THE MATHEMATICS PERFORMANCE OF SECONDARY STUDENTS ENROLLED IN AN AGRICULTURAL POWER AND TECHNOLOGY COURSE: AN EXPERIMENTAL STUDY

Brian Parr, Assistant Professor
Auburn University
M. Craig Edwards, Professor
James G. Leising, Professor and Assistant Director
International Agricultural Programs
Oklahoma State University

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 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 38 high schools in Oklahoma (18 experimental classrooms; 20 control classrooms). Students were enrolled in an APT course in the spring of 2004. 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 hypotheses. The math-enhanced curriculum and aligned instructional approach did not significantly affect (p > .05) a student's mathematics ability as measured by a traditional test of student math knowledge or by an "authentic" assessment of student ability to use math to solve workplace problems. Thus, the study's null hypotheses were not rejected. However, because of incomplete implementation of the treatment as reported by some experimental teachers coupled with an intervention time frame of only one semester, a one-year replication of the study is recommended.

Introduction

The importance of making learning relevant to the student by teaching from a contextual perspective is not a new concept, but it is one that may have never reached its full potential. In fact, this idea is supported by research done in the early to mid 20th century by Jean Piaget. Piaget's (1977) position on contextualized learning is apparent in the following passage:

> a sufficient experimental training [in science] was believed to have been provided as long as the student had been introduced to the results of past experiments or had been allowed to watch demonstration experiments conducted by his teacher, as though it were possible to sit in rows on a wharf and learn to swim merely by watching grown-up swimmers in the water. (p. 705)

John Dewey presented his stance on contextualized learning in 1897 when recording his pedagogical creed. Dewey stated, "I believe that education which does not occur through forms of life, or that are worth living for their own sake, is always a poor substitute for the genuine reality and tends to cramp and deaden" (1959, p. 23). Dewey believed very strongly in the importance of curriculum integration and that negative consequences were associated with separating knowledge from its application. His perspective was described clearly when he stated,

> 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)

Alfred North Whitehead recognized the need for the integration of curriculum as early as 1929. Whitehead asserted, "The solution which I am urging is to eradicate the fatal disconnection of subjects which kills the vitality of our modern curriculum. There is only one subject matter for education, and that is Life in all its manifestations" (p. 10).

In 1947, *A Handbook on Teaching Vocational Agriculture* identified agricultural education as an integral component of public secondary school education that contributed to the general objectives and philosophy of a student's education (Cook, 1947). The author identified how agricultural education contributed to the "seven cardinal principles of an education" (p. 50). For example, "Vocational agriculture instruction develops abilities in constructive thinking and problem solving which enables the student to have a better command of the fundamental processes" (p. 5). This book was written over half a century ago, yet some of the recommendations for successful education programs are nearly identical to those posited today by many educators and education scholars.

The importance of contextualized learning has been a very prominent topic in agricultural education for the past two decades. The National Research Council (NRC) brought this topic to the forefront transparently in 1988. The NRC published the book, *Understanding Agriculture: New Directions for Education*, and in it called for the integration of sciences into the agricultural education curriculum. The book described changes needed for the then current program of secondary vocational agriculture. The NRC determined that vocational agriculture needed to broaden the educational opportunities that it afforded to reflect a new definition of agriculture, including aspects ranging from traditional production agriculture to agricultural science concepts far removed from the farm or production setting. This assessment of agricultural education led to changes in curricula that involved integrating more academics into course offerings and to repurposing a program that no longer focused primarily on vocational training but instead would also serve to improve student academic learning and preparation.

Conceptual/Theoretical Framework

If secondary agricultural education is to remain effective in graduating well-prepared and highly qualified graduates, programs must include a strong emphasis on traditional academic skills (National Research Council, 1988). Newcomb (1995) supported this position when he stated, "The need to have students graduate with the demonstrated capacity to think at the higher levels of Bloom's taxonomy is more urgent than ever. The nature of the world we live in demands it" (p. 4). Moreover, it is essential that modern agricultural education programs develop well-rounded individuals capable of adapting to an ever-expanding agricultural industry and to the changing world in which we live (National Research Council).

One approach to developing this type of graduate is described as "facilitative instruction that motivates students to learn" (Bodilly, Ramsey, Stasz, & Eden, 1994, section 2, ¶1). Facilitative instruction, as it is described here, involves applying scientific principles in an agricultural context that requires some degree of problem solving. By using this type of instruction, not only will students be better motivated to learn, but also the transfer of learning can be boosted significantly (Eggebrecht et al., 1996). Eggebrecht et al. asserted that, "If learning has value, students should be able to transfer the knowledge they acquire in school to the world beyond the classroom" (p. 5). Eggebrecht and colleagues assembled a team of researchers to identify possible instructional methods that would increase the transfer of learning by students. The team discovered that transfer of knowledge was greatly enhanced when multiple contexts for learning were used. Newcomb, McCracken, and Warmbrod (1993) supported their posit by asserting that students were much more inclined to learn things they could put into practice immediately. Further, Newcomb et al. defended the use of real-life problems as teaching tools by making the argument that the natural process by which students learn should be identified and harnessed for use in the classroom. What is more, Johnson, Wardlow, and Franklin (1997) found that students' attitudes about the subject matter were more positive when learning took place using hands-on activities rather than worksheet-based instruction. These researchers even opined that the improved student motivation achieved through curriculum integration may reduce high school drop-out rates.

According to Bottoms and Sharp (n.d.), integration of academic and vocational studies holds great potential for enhancing student learning in critical academic, technical, and personal areas. To that end, they stated,

> Integration is how people learn in the real world. In the school-based scenarios, concepts, issues, and ideas flow in many directions; few of them are related to the real world. Students learn more quickly and easily if information is given in context. (p. 41)

Phipps and Osborne (1988) contended that most educators would agree that information gathered because it is necessary to solve a problem is learned more permanently. These problems could be presented to the student through the use of agriculture as the learning context. This view about student learning is constructivist in its approach (Brown, 1998). Brown concluded that student-centered teaching, project-oriented instruction, problem-based learning, and contextual teaching and learning are currently promoted as strategies for implementing constructivism and that these approaches also reflect the philosophy on which academic and vocational integration is based. This philosophy implies that education must forge connections between knowledge development and its application in the world.

For example, research performed at the Hodgson Vocational Technical High School in Delaware revealed that providing a context for learning mathematics not only improved student achievement but also provided math teachers with familiar examples that could be used in the course of teaching their subject matter (Ancess, 2001). Ancess stated, "Math teachers visited shop [vocational] classrooms and while there they taught math that corresponded to shop units so that students learned math when they needed to know it for their shop projects" (p. 74). Further, the author explained, "In their own classrooms, math teachers began to use shop references to teach math" (p. 74). According to the New Castle County Vocational Technical District, the following year saw an increase of 13% on the Delaware math assessment for students involved in the delivery of integrated curriculum and instruction when compared to the previous year's student performance (Ancess).

Finally, several studies (Balschweid, 2001; Enderlin & Osborne, 1992; Hitz & Scanlon, 2001; Johnson et al., 1997; Roegge & Russell, 1990) have been conducted in agricultural education to determine the effects of contextual learning on student attitudes toward subject matter. However, experimental research that measured the effects of contextualized teaching and learning on student achievement for a core academic course is very limited. So, the question addressed by this study was, can an agricultural power and technology (APT) course provide students with a contextualized, mathematics-enhanced curriculum and instructional approach that increases their mathematics achievement?

Purpose

The purpose of this study was to empirically test the posit that students who participate in a contextualized, mathematics-enhanced high school APT curriculum and aligned instructional approach would develop a deeper and more sustained understanding of selected mathematics concepts than students who participated in the traditional curriculum.

Research Questions and Null Hypotheses

The following research questions guided the study:

1. What were the selected characteristics of students enrolled in and instructors teaching APT in the state of Oklahoma during the spring 2004 semester?
2. What was the effect of a mathematics-enhanced APT curriculum and aligned instructional approach on student performance as measured by (a) a traditional test of student math knowledge and by (b) an "authentic" assessment of student ability to use math to solve workplace problems?

The following null hypotheses guided the study's statistical analysis:

H_o1: There is no difference between the two study groups on math performance as measured by a conventional, standardized test of math achievement.

H_o2: There is no difference between the two study groups on math performance as measured by a "real world" or problem-based test.

Methods and Procedures

This study used a posttest only control group experimental design (Campbell & Stanley, 1963). Thirty-eight agriculture teachers were recruited to participate in the study. Before teachers agreed to take part in the study, researchers explained that each teacher would be randomly assigned to either an experimental or control group to increase the probability of equality among the two groups of students who would provide data for analysis. Subsequently, classrooms were randomly assigned to either the experimental or control group. The assignment involved intact groups of students; thus, the "unit of analysis" was the classroom. In addition to the random assignment to groups, the two groups (experimental and control) were assessed to determine level of equivalence concerning basic mathematics aptitude (Campbell & Stanley; Tuckman, 1999) prior to the treatment. The two groups were not significantly different (p > .05) based on their performance on the Terra Nova CAT™ Basic Battery Examination that was administered prior to the experiment. This design was chosen primarily on the basis of its robust nature concerning validity. According to Tuckman (1999), this type of experimental design provide[s] completely accurate controls for all sources of internal validity" (p. 161).

The Terra Nova CAT™ Survey Edition, (CTB McGraw-Hill; 25 items) examination was used to determine students' general mathematics ability posttreatment. This test holds a reliability coefficient of .84 (Cronbach's alpha). The WorkKeys Applied Mathematics Assessment (American College Testing; 33 items) was used to determine student math aptitude as applied to workplace problems. It has a .88 (KR-20) reliability estimate (B. Ziomek, personal communication, December 2, 2004). These examinations were very similar in format to the "pencil and paper" standardized tests used often to assess student mathematics achievement. According to Campbell and Stanley (1963),

> . . . in research on teaching, one is interested in generalizing to a setting in which testing is a regular phenomenon. Especially if the experiment can use regular classroom examinations as *O*s, but probably also if the experimental *O*s are similar to those usually used, no undesirable interaction of *testing* and *X* would be present. (p. 18)

The experimental intervention (or treatment) embedded in this design required the preparation of agriculture teachers to develop and implement a math-enhanced curriculum in the context of an APT course. The experimental group agriculture teachers had math teacher "partners" to assist them in developing math-enhanced lesson plans in the context of

APT and on how to enhance student understanding of the embedded mathematics in the lessons.

Eighteen agriculture teachers and their math teacher partners were randomly assigned to the experimental group, and 20 agriculture teachers were assigned to the control group. Initially, two additional teachers were randomly assigned to the experimental group, but both teachers chose not to participate in the study prior to the first professional development meeting. The experimental group teachers implemented a math-enhanced APT curriculum and instructional approach. The control group teachers taught the traditional APT curriculum (Oklahoma Department of Vocational and Technical Education, 2000) and were instructed to use the same instructional approach they used in the past. This approach yielded an overall N of 447 APT students (experimental n = 206; control n = 241) who provided data for analysis at the classroom level.

This study was part of a larger investigation that included the collection of data concerning other aspects of student achievement. Therefore, each student was randomly assigned (within the class) to one of three posttest measures. This random assignment was performed for at least two purposes. First, the administration of multiple posttests to each student could have introduced a level of test fatigue that may have had negative effects on student performance (Enderlin & Osborne, 1992). Second, this decision was made to reduce the expense of posttesting while protecting the integrity of posttest results. For these reasons, the number of students who took the pretreatment measure of math equivalence (N = 447) does not match the number of students who took the two posttest measures (Terra Nova Survey, n = 147; WorkKeys, n = 130) reported in this study. Approximately one-third of the student participants took each examination.

The partnering of high school math teachers with agricultural power and technology teachers encouraged instructors to function as a team. The pairs of teachers (agriculture and math) spent five days together in professional development during the fall of 2003. The purpose of this activity was to create mathematics-enhanced lessons in the context of agricultural power and technology. The role of math teachers was to work with their agriculture teacher partners to identify and develop content as well as design lesson activities to more fully contextualize mathematics terminology, principles, and concepts embedded in the curriculum.

Prior to developing the math-enhanced lessons, a panel of experts was convened to identify specific mathematics constructs that were present in the Oklahoma APT curriculum. It was determined that there were nine constructs in the existing curriculum that aligned with state and national mathematics standards (Parr, 2004). The teacher teams were charged with developing a lesson to address one of the identified constructs, which would result in 18 lessons. The development of two lessons per construct gave teachers a choice of which lesson they would teach to address each of the nine constructs. Following the review of lesson rough drafts, it was determined that two of the lessons were very similar and should be combined. So ultimately, 17 lessons were developed that emphasized selected math concepts embedded in the APT curriculum. During the spring 2004 semester, math teachers continued to collaborate with agriculture teachers concerning specific questions related to the math-enhanced lessons and to facilitate teachers' reflections about lessons taught.

The treatment was defined as a series of math-enhanced learning experiences (i.e., lessons) designed to raise the embedded, contextualized mathematics found in the APT curriculum to a level of explicit instruction intended to facilitate student learning of selected mathematics competencies and to improve a student's ability to transfer that competence to new and novel settings (Stone III, Alfeld, Pearson, Lewis, & Jensen, 2005). It was intended that the treatment be delivered as a series of nine lessons during the spring 2004 semester, each of which addressed a specific math construct. For example, a lesson that explained the proper method of area calculation when constructing a greenhouse or agricultural mechanics facility addressed a construct that aligned with state and national mathematics education standards (e.g., National Council of Teachers of Mathematics' [NCTM] Geometry Standard for Grades 9-12). The lessons were to be taught using the prescribed math instructional model (Figure 1). This teaching approach was supported by mathematics education literature (e.g., Bickmore-Brand, 1993). Agriculture teachers were expected to deliver their lessons without any outside assistance from math teacher partners or other math education professionals during the act of teaching.

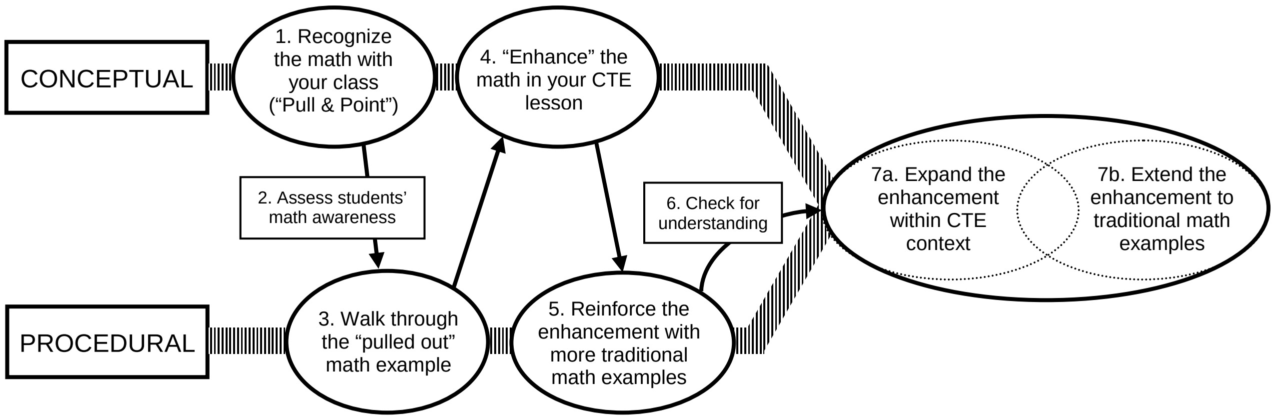

Figure 1. The National Research Center for Career and Technical Education's Model: The "7 Elements" of a math-enhanced lesson, (Prescribed teacher behaviors during the act of teaching math-enhanced lessons.) *Note*. From "Unpublished draft report of Year 1 of Math-in-CTE study" by J.R.Stone III, C. Alfeld, D. Pearson, M. Lewis, & S. Jensen, 2004, St. Paul, MN: University of Minnesota. Reprinted with permission.

A concise view of the treatment implemented in this study and a listing of each facet is presented in Table 1. The elements of the treatment described were delivered only to experimental group teachers and students. Control group teachers were instructed to make no changes relative to the teaching of mathematics in their agricultural power and technology classes.

Table 1
Overview of the Treatment

Experimental Group Teachers	*Experimental Group Students*
Preparation Phase	**Preparation Phase**
Math and agriculture teacher collaboration and professional development Teachers participated in: - Team building activities - Curriculum mapping - Lesson plan development and refinement - Peer evaluations of lessons that provided feedback to other teachers - Training in seven-step instructional approach	Students were told that their class would participate in the study and the need for questionnaires and testing was explained Permission (i.e., "passive consent") was obtained from students and their parents
Presentation Phase	**Presentation Phase**
Implementation of the seven-step instructional approach - Presentation of curriculum materials developed in professional development meetings Continued collaboration/reflection between math and agriculture teachers throughout the semester - Debriefing following each math-enhanced lesson Observation of math-enhanced lesson by researcher - Researcher observed and scripted one lesson presentation per teacher	Students received math-enhanced lessons delivered through the seven-steps (or elements) approach

Note. From *Effects of a math-enhanced curriculum and instructional approach on the performance of secondary education students enrolled in an agricultural power and technology course: An experimental study.* (p. 56), by B.A. Parr, Unpublished doctoral dissertation, Oklahoma State University: Stillwater. Adapted with permission.

Frequencies and percentages were calculated for selected personal characteristics of student and teacher participants in the study. One-way analysis of variance (ANOVA) was used to compare experimental and control groups' classroom means to test the research hypotheses.

Findings

Selected Characteristics of Students and Teachers

Student participants were asked to respond to questions that described selected personal characteristics. The questionnaire revealed that the majority of students were male (84.4%) and of European/Anglo descent (58.5%). One-fourth of the students reported their ethnicity as Native American. About one-third (31.8 %) of the student participants were seniors in high school, a similar number (34.5%) were juniors, and about one-fourth (26.4%) were sophomores; the remaining students were either freshmen (6.1%) or did not respond to the question of grade level. Most of the students (82.7%) were between the ages of 16 and 18 at time of the experiment; the majority held selfreported grade point averages ranging from 2.6 to 4.0 (72%).

The data collected about agriculture teacher participants revealed that 86.8% of the teachers were male and 2.6% were female; 10.8% elected not to report their gender. The data also indicated that 73.7% of teachers identified themselves as being of European/Anglo descent, 15.8% were Native American, and 10.8% did not report their ethnicity.

Pretreatment Analysis

The Terra Nova CAT™ Basic Battery (CTB/McGraw-Hill) examination was used as a pretreatment measure to establish the equivalence of groups regarding general mathematics aptitude. This test was chosen because it is a nationally-normed and reliable test of math skills with an internal reliability coefficient of .91 (Cronbach's alpha) (McGraw-Hill, 2000). No significant difference (p = .074) was detected concerning students' math aptitude.

Posttest Analysis

Means were calculated by group for the purpose of comparative statistical analysis following the treatment. One-way analysis of variance (ANOVA) was used to compare the experimental and control groups' classroom means to test the study's research hypotheses.

To address null hypothesis one, an analysis was conducted on student math performance by group (control and experimental) on a general math aptitude examination (i.e., the Terra Nova Survey) taken by students after the treatment was administered. The control group posted a mean score of 11.70 on this measure (SD = 3.12); the mean score of the experimental group was 11.77 (SD = 3.01) (Table 2). Although the experimental group demonstrated a slightly higher score, analysis of this examination revealed no significant difference (p = .946) in general math ability between groups at an *a priori* determined alpha level of .05 (Table 3). Based on this analysis, the null hypothesis was not rejected.

Table 2
Descriptive Statistics for Student Math Performance by Group on the Terra Nova Survey Examination

	n	*M*	*SD*	*SE*	Min	Max
Control	20	11.70	3.12	.70	6.33	16.00
Experimental	18	11.77	3.01	.71	7.67	20.00
Total	38	11.73	3.02	.49	6.33	20.00

Table 3
Comparative Analysis of Student Math Performance by Group Means as Measured by the Terra Nova Survey Examination

	SS	*df*	*MS*	*F*	*p*
Between Groups	.044	1	.044	.005	.946
Within Groups	338.080	36	9.391		
Total	338.124	37			

To address null hypothesis two, an analysis was conducted on student math performance by group (control and experimental) on an examination to measure students' ability to use math to solve workplace problems (i.e., WorkKeys) taken by students after the treatment was administered. The control group mean score for this examination was 73.23 (*SD* = 2.93), and the experimental group mean was 73.69 (*SD* = 3.92) (Table 4). Although the experimental group demonstrated a slightly higher score, analysis of this examination revealed no significant difference (p = .681) in level of performance between the groups following the treatment at an *a priori* determined alpha level of .05 (Table 5). So, the null hypothesis was not rejected.

Table 4
Descriptive Statistics for Student Math Performance by Group on the WorkKeys Examination

	n	*M*	*SD*	*SE*	Min	Max
Control	20	73.23	2.93	.65	68.50	80.83
Experimental	18	73.69	3.92	.92	68.00	80.33
Total	38	73.45	3.39	.55	68.00	80.83

Table 5
Comparative Analysis of Student Math Performance by Group Means as Measured by the WorkKeys Examination

	SS	*df*	*MS*	*F*	*p*
Between Groups	2.017	1	2.017	.171	.681
Within Groups	423.839	36	11.773		
Total	425.855	37			

To assess the study's fidelity of treatment, data regarding instructional delivery were collected through a posttreatment questionnaire that queried experimental teachers about the number of math-enhanced lessons they actually taught during the spring 2004 semester. Teachers were asked to teach at least one lesson supporting each of the nine math constructs that were identified as being embedded in the APT curriculum. Sixteen of the 18 experimental teachers responded to this question. It was reported that the average number of math-enhanced lessons actually taught by the respondents was slightly more than five (Parr, 2004).

Conclusions

Conclusions were based on analysis of data as related to the research question: What was the effect of a mathematics-enhanced APT curriculum and aligned instructional approach on student performance as measured by (a) a traditional test of student math knowledge (i.e., the Terra Nova Survey) and by (b) an "authentic" assessment of student ability to use math to solve workplace problems (i.e., WorkKeys)? In this particular population, a mathematics-enhanced APT curriculum and aligned instructional approach did not result in a significant increase (p > .05) in student mathematics performance as measured by either examination. So, the experiment's null hypotheses were not rejected.

Recommendations for Future Research and Practice

Perhaps the short time period over which this study was conducted (i.e., one semester) did not allow sufficient opportunity for significant differences in student math achievement to emerge as measured by the tests described. Because the average number of math-enhanced lessons taught per experimental teacher was slightly more than five (out of a possible nine), perhaps an increase in this number would result in improved student performance. So, a similar intervention should be extended over a longer experimental period (i.e., one academic year) (Stone III et al., 2005). Extending the length of treatment may demonstrate significant ($p < .05$) increases in student performance that were not found in one semester. (To that end, a similar study was conducted over the course of a full school year during 2004-2005; see Young, 2006.)

Additional investigations should be conducted regarding the testing instruments used in this study. Through an item analysis procedure, content of the examinations could be analyzed to determine whether specific mathematics concepts or principles were taught more effectively than others by using a contextualized, mathematics-enhanced curriculum and aligned instructional approach delivered through an APT course.

Results of this study demonstrated that professional development for teachers supporting their use of contextualized teaching and learning methods did help instructors recognize opportunities for doing such and to gain knowledge and skills needed to accomplish that task. The professional development activities delivered through this study helped to create functional interdisciplinary teacher teams (Hernandez & Brendefur, 2003) that developed and delivered contextualized curriculum and instruction in the context of agricultural power and technology. However, consistent with the observations of other researchers (Enderlin & Osborne, 1992; Thompson, 1998; Warnick & Thompson, 2002), there is a large resource investment associated with such activities, including a substantial time commitment required of teachers. For that reason, school administrators who may be considering this type of professional development for their teachers should set aside sufficient resources to support it. For example, resource allocations should include staff release time for the purpose of team building and curriculum development sessions involving both career and technical and general education teachers (Garet, Porter, Desimone, Birman, & Yoon 2001).

Discussion and Implications

This study was conducted as part of a larger experiment that also included a comparison of student performance as measured by a mathematics placement test used to determine a student's need for mathematics remediation at the postsecondary level. Data analysis revealed that the experimental treatment described did significantly affect a student's need for postsecondary mathematics remediation (i.e., students in the experimental classrooms performed significantly better ($p < .05$) than the control group students) (Parr, 2004; Parr, Edwards, & Leising, 2006). Moreover, results from a different study site (i.e., another state), one in which the curriculum context was horticulture, found that those experimental group students performed significantly better on the WorkKeys examination (Stone III et al., 2005). Do these findings indicate that the potential a curriculum context holds for significantly affecting a student's math performance is related to the kind or "level" of mathematics learning one is attempting to influence? For example, it is known that the examination assessing a student's need for postsecondary math remediation stressed algebraic problem solving, but the WorkKeys test emphasized more "applied mathematics" (i.e., pre-algebra computations and related problem solving). Additional data analysis and inquiry is needed to answer this and related questions.

References

Ancess, J. (2001). Teacher learning at the intersection of school learning and student outcomes. In A. Lieberman & L. Miller (Eds.), *Teachers caught in the action: Professional development that matters* (pp. 61-78). New York: Teachers College Press.

Balschweid, M. A. (2001). Teaching biology using agriculture as the context: Perceptions of high school students. *Proceedings of the 28th Annual National Agricultural Education Research Conference*, New Orleans**,** LA. (National Agricultural Education Research Conference, CD-ROM, December 12, 2001 release.)

Bickmore-Brand, J. (1993). Implications from recent research in language arts for mathematical teaching. In J. Bickmore-Brand (Ed.), *Language in mathematics* (pp. 1-9). Portsmouth, NH: Heinemann.

Bodilly, S., Ramsey, K., Stasz, C., & Eden, R. (1994). *Integrating academic and vocational education: Lessons from early innovators*. RAND Corporation. Retrieved January 12, 2009, from www.rand.org/publications/RB/RB8005/

Bottoms, G., & Sharpe, D. (n.d.). *Teaching for understanding through integration of academic and technical education*. Atlanta: Southern Regional Education Board.

Brown, B. A. (1998). *Integration of academic and vocational education myths and realities.* Retrieved January 17, 2008, from http://eric.ed.gov/ERICDocs/data/ericdocs2sql/content_storage_01/0000019b/80/15/32/71.pdf

Campbell, D. T., & Stanley, J. C. (1963). *Experimental and quasi-experimental designs for research.* Chicago: Rand McNally.

Cook, G. C. (1947). *A handbook on teaching vocational agriculture* (5th ed.). Danville, IL: Interstate.

Dewey, J. (1959). In M. S. Dworkin (Ed.), *Dewey on education*. New York: Teachers College Press.

Eggebrecht, J., Dagenais, R., Dosch, D., Merczak, N. J., Park, M. N., Styer, S. C., et al. (1996, May). Reconnecting the sciences. *Educational Leadership, 53*(8) 88-90.

Enderlin, K. J., & Osborne, E. W. (1992). Student achievement, attitudes, and thinking skill attainment in an integrated science/agriculture course. *Proceedings of the 19th Annual National Agricultural Education Research Meeting* (pp. 37-44), St. Louis, MO.

Fishman, S. M., & McCarthy, L. (1997). *John Dewey and the challenge of classroom practice*. New York: Teachers College Press.

Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., & Yoon, K. S. (2001, Winter). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal, 38*(4), 915-945.

Hernández, V. M., & Brendefur, J. L. (2003). Developing authentic, integrated, standards-based mathematics curriculum: [More than just] an interdisciplinary collaborative approach. *Journal of Vocational Education Research, 28*(3), 259-283. Retrieved January 12, 2009, from http://scholar.lib.vt.edu/ejournals/JVER/v28n3/pdf/v28n3.pdf

Hitz, W. H., & Scanlon, D. C. (2001). Effects of instructional methodologies on student achievement, attitude and retention. *Proceedings of the 28th Annual National Agricultural Education Research Conference*, New Orleans, LA. (National Agricultural Education Research Conference, CD-ROM, December 12, 2001 release.)

Johnson, D. M., Wardlow, G. W., & Franklin, T. D. (1997). Hands-on activities versus worksheets in reinforcing physical science principles: Effects on student achievement and attitude. *Journal of Agricultural Education, 38*(3), 9-17.

McGraw-Hill. (2000). CAT™ Prepublication: Technical bulletin. Monterey, CA: McGraw-Hill.

National Research Council. (1988). *Understanding agriculture: New directions for education.* Danville, IL: Interstate.

Newcomb, L. H. (1995, December). The genius of the agricultural education model for nurturing higher order thinking. *The Agricultural Education Magazine, 68*(6), 4, 6.

Newcomb, L. H., McCracken, J. D., & Warmbrod, J. R. (1993). *Methods of teaching agriculture* (2nd ed.). Danville, IL: Interstate.

Oklahoma Department of Vocational and Technical Education. (2000). *Agricultural power and technology: Welding instructor's manual*. Stillwater, Oklahoma: Curriculum and Instructional Materials Center.

Parr, B. A. (2004). *Effects of a math-enhanced curriculum and instructional approach on the performance of secondary education students enrolled in an agricultural power and technology course: An experimental study.* Unpublished doctoral dissertation, Oklahoma State University, Stillwater.

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

Phipps, L. J., & Osborne, E. W. (1988). *Handbook on agricultural education in public schools* (5th ed.). Danville, IL: Interstate.

Piaget, J. (1977). Science of education and the psychology of the child. In H. E. Gruber & J. J. Voneche (Eds.), *The essential Piaget: An interpretive reference guide.* New York: Basic Books.

Roegge, C. A., & Russell, E. B. (1990). Teaching applied biology in secondary agriculture: Effects on student achievement and attitudes. *Journal of Agricultural Education, 31*(1), 27-31.

Stone, J. R., III, Alfeld, C., Pearson, D., Lewis, M., & Jensen, S. (2004). *Unpublished draft report of Year 1 of Math-in-CTE study* [since revised]. St. Paul, MN: University of Minnesota.

Stone, J. R., III, Alfeld, C., Pearson, D., Lewis, M. V., & Jensen, S. (2005). Building academic skills in context: Testing the value of enhanced math learning in career and technical education (Pilot Study). St. Paul, MN: National Research Center for Career and Technical Education, University of Minnesota.

Thompson, G. (1998). Implications of integrating science in secondary agricultural education programs. *Journal of Agricultural Education, 39*(4), 76-85.

Tuckman, B. W. (1999). *Conducting educational research* (5th ed.). New York: Thompson.

Warnick, B., & Thompson, G. (2002). Perceptions of Oregon science teachers regarding the integration of science into the agricultural education curriculum. *Proceedings of the 29th Annual National Agricultural Education Research Conference*. (CD-ROM, December 11, 2002 release, Las Vegas, NV.)

Whitehead, A. N. (1929). The *aims of education and other essays.* New York: Macmillan.

Young, R. B. (2006). *Effects of a math-enhanced curriculum and instructional approach on the performance of secondary education students enrolled in year-long agricultural power and technology course: An experimental study.* Unpublished doctoral dissertation, Oklahoma State University, Stillwater.

BRIAN PARR is an Assistant Professor in the Department of Curriculum and Teaching at Auburn University, 212 Wallace Center for Adult and Vocational Education, Auburn, AL 36849-5212. E-mail: bap0007@auburn.edu

M. CRAIG EDWARDS is a Professor in the Department of Agricultural Education, Communications, and Leadership at Oklahoma State University, 448 Agricultural Hall, Stillwater, OK 74078-6032. E-mail: craig.edwards@okstate.edu

JAMES G. LEISING is a Professor and the Assistant Director of International Agricultural Programs, Student Academic Outcomes Assessment and Outreach Division of Agricultural Sciences and Natural Resources at Oklahoma State University, 139 Agricultural Hall, Stillwater, OK 74078-6026. E-mail: james.leising@okstate.edu