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METHOD OF REINFORCEMENT AND STUDENT GENDER: EFFECTS ON ACHIEVEMENT IN AGRISCIENCE EDUCATION

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Abstract

A randomized post-test-only experimental design with a counter-balanced internal replication was conducted to determine the effects of reinforcement method (worksheet or hands-on activity) and student gender on immediate and delayed cognitive achievement in two physical science subject matter areas (Ohm's Law and simple machines). Students enrolled in seven purposively selected Agricultural Science and Technology classes (N = 132) in five school districts participated in the study.

The experimental results were stable across both subject matter areas. The main effect of method of reinforcement produced no significant differences in either immediate or delayed cognitive posttest scores. There was no significant interaction between the two main effects (method of reinforcement or gender). However, there were significant differences in both immediate and delayed cognitive posttest scores based on the main effect of gender, with females scoring higher than males on each of the four posttests.

Introduction

Agricultural education programs in the public schools are changing in order to meet the needs of both students and society (Hughes and Bar-rick, 1993). One recent change is an increased emphasis on instruction in agriscience (Camp, 1994). According to Buriak (1989, p.4), agriscience is defined as, "Instruction in agriculture emphasizing the principles, concepts, and laws of science and their mathematical relationships supporting, describing, and explaining agriculture." Lee (1994, p.2) stated that in agriscience education, "the emphasis is on the principles of science that undergird agriculture."

One of the primary purposes of agriscience is to provide students with a hands-on, application-oriented science education (Lee, 1994). Such a purpose is consistent with the constructivist approach to science education, which emphasizes the importance of concrete physical experiences in learning science concepts and principles (Brooks and Brooks, 1993; Fensham, 1992). Agricultural educators have traditionally espoused a "hands-on" approach to teaching and learning (Newcomb, McCracken and Warmbrod, 1993; Phipps and Osborne, 1988). Yet, in traditional programs, many of the hands-on activities have been intended to allow students to develop the procedural and psychomotor skills deemed necessary for success in agricultural occupations (Johnson, 1989). Agricultural educators have placed considerably less emphasis on the use of hands-on activities as a method for teaching and/or reinforcing student learning of science principles.

According to Enderlin and Osborne (1992, n.p.), "Changes are needed in agricultural education in order to increase students' inquiry skills and understanding of science principles as they relate to agriculture." Lee (1994, pp. l-2) echoed this sentiment when he stated that, "Agriscience and technology require [instructional] approaches that are different from traditional agricultural education." One such instructional approach could well be the use of hands-on activities to reinforce student learning of science principles (Osborne, 1993).

Theoretical Framework

In recent years, many major science curriculum development projects have promoted hands-on, practical activities as both an effective and enjoyable way for students to learn science content (Hodson, 1990). After a quarter of a century, the phrase "hands-on science" is part of the everyday vocabulary of science educators, particularly those at the elementary and middle school levels (Flick, 1993).

Proponents of hands-on science claim that it has several advantages when compared to more traditional forms of science instruction. According to LeBuffe (1994, p. 10), the use of hands-on activities "makes science vivid, meaningful and fun for most students." Wasserstein (1995) found that when middle school students were asked to identify their most memorable school work, a higher percentage identified hands-on science (27%) than any other topic or activity.

Although hands-on science is generally associated with elementary and middle schools, some researchers believe that a hands-on approach to teaching science is also needed at the secondary school level. According to Piburn and Baker (1993):

> Especially in the upper grades, the increasing abstraction of science content is unpleasant to students. We recommend that a conscious effort be made to identify content that has some meaning within their [the students'] everyday lives. This content should be relatively concrete and subject to physical manipulation, and teachers should be cautious, even in the highest grades, about introducing advanced axiomatic or theoretical concepts into the curriculum. (pp. 404-405)

Lehman (1989) studied a national sample of secondary school chemistry teachers and students to determine their perceptions concerning the effectiveness of laboratory activities in promoting student learning in the affective, psychomotor, and cognitive domains, as well as in the area of science process skills. A majority of respondents in both the teacher and student groups perceived that laboratory activities were effective in promoting cognitive learning (63.6% and 75.3%, respectively). Fewer teachers and students perceived laboratory activities to be effective in enhancing affective (34.1% and 22.1%, respectively), psychomotor (20.5% and 26.6%, respectively), or science process skills (20.5% and 11.5%, respectively) learning. Lehman (p. 5 13) concluded that, "Both teachers and students most frequently perceived cognitive advantages of laboratory activities. The notion that laboratories help students understand the abstract concepts and principles introduced in class was frequently expressed."

Despite the perceptions of both teachers and students, some critics have questioned the effectiveness of laboratory activities in promoting cognitive learning in science (Hodson, 1990; Hofstein and Lunetta, 1982; and Tobin, 1990). Based on their review of the science education research literature, Hofstein and Lunetta (1982, p. 202) concluded that, "Most research studies have shown no significant differences between the instructional methods [laboratory instruction vs. other methods] as measured by standard paper-and-pencil tests in science achievement." On the other hand, Hofstein and Lunetta did state that sufficient research evidence exists to support the role of laboratory activities in promoting positive attitudes toward science.

Researchers have found significant differences between male and female students in science achievement. In a meta-analysis of 77 studies conducted between 1980 and 199 1 among middle and high school students, DeBaz (1994) found a significant gender effect favoring males in overall science achievement.

Focusing on overall gender differences in science achievement may obscure differences between males and females in specific fields of science. In an analysis of data from the National Educational Longitudinal Study (NELS:88), Lee and Burkam (1996) found a large advantage for males on the physical science subtest and a modest advantage for females on the life science subtest. These researchers concluded that laboratory activities are beneficial for achievement among females in the physical sciences. Oakes **(1990)** has also noted that females are more likely to benefit from cooperative and hands-on learning activities while males benefit more from traditional instructional activities.

These same differences by gender also exist in students' out-of-school science-related experiences. Using data from the National Assessment of Educational Progress (NAEP) for students in grades seven and 11, Blosser (1990) concluded that male students were more likely than female students to report having attempted to fix electrical or mechanical devices. Conversely, females were more likely than males to have attempted diagnosing problems with an unhealthy plant or animal.

Shepardson and Pizzini (1994) noted that the attitude of girls toward science is one of the factors that influences the achievement of females in science courses as well as their decision to participate in science careers. Citing the under-representation of women in scientific careers, they posited that the nature of the learning situation (i.e. method of instruction) may contribute to the development of positive attitudes of girls toward science, as well as improve their educational achievement, thus, increasing participation of women in these careers.

Problem Statement

Research in science education is not conclusive regarding the effects of laboratory activities on student cognitive achievement in science. However, evidence does suggest that gender is related to both student achievement in science and student preference toward method of instruction. While research in science education can inform the agricultural education profession as it moves toward a more science-based curriculum, specific research involving agricultural education teachers and students is needed. It is only through such research that the effectiveness of instructional practices in agriscience can be evaluated.

Purpose and Hypotheses

The primary purpose of this study was to determine the effects of two methods of reinforcement in the teaching/learning process on student cognitive achievement in two instructional areas. The study also sought to determine the effects of gender, and the interaction of gender and method of reinforcement on student cognitive achievement. Nondirectional null hypotheses concerning student cognitive achievement were formulated for testing at the 10 alpha level and are summarized as follows:

H_{o1}: In the **Ohm's** Law instructional area, there will be no significant differences on either immediate or delayed cognitive achievement posttest scores based on (a) method of reinforcement, (b) gender, or (c) the interaction of method of reinforcement and gender.

H_{o2}: In the incline plane instructional area, there will be no significant differences on either immediate or delayed cognitive achievement posttest scores based on (a) method of reinforcement, (b) gender, or (c) the interaction of method of reinforcement and gender.

Methods

This section describes the methods used in conducting the study. Specific details include descriptions of the: (a) population and sample, (b) pilot-test(c) experimental design, (d) experimental procedures, and (e) instrumentation.

Population and Sample

The population for this study included all "Agricultural Science and Technology" classes within a 50 mile radius of Fayetteville, Arkansas during the spring semester of 1996. Agricultural Science and Technology is an introductory agricultural education course intended for, and primarily enrolling, students at the ninth grade level; however, students above the ninth grade, who have not taken the course previously, may also enroll (Arkansas Department of Education, 1992).

Seven Agricultural Science and Technology classes (from five different school districts) were purposively selected to participate in this study. The teacher of each selected class was personally contacted and agreed to participate in the study. Since these classes were selected in a purposive manner, the results of this study should not be generalized to other populations. However, the results of this study may inform decision makers in similar situations.

The total enrollment for the seven classes participating in this study was 132 students. However, due to school assemblies and individual absences, not all classes or students were included in the analyses. For the Ohm's Law experiment, two Agricultural Science and Technology classes (a total of 28 students) in two different schools did not participate because of unscheduled school assemblies which occurred during the experimental treatment period. All seven Agricultural Science and TTechnology classes participated in and provided usable data for the incline plane experiment.

Experimental Design

This study was conducted using a modified, post-test-only, control group experimental design as described by Campbell and Stanley (1966). The design was modified by incorporating a counter-balanced internal replication and a delayed posttest. According to Campbell and Stanley (1966) the posttest-only control group design controls for all threats to internal validity. Because purposive sampling was used, these results are not generalizable to other populations. Thus, questions of external validity are not pertinent.

Pilot-Test

The instructional materials, experimental procedures and research instruments used in this study were pilot-tested in two Agricultural Science and Technology classes not selected for inclusion in the main study. As a result of the pilot-test, the following changes were made: (a) the number of class periods for the Ohm's Law experiment was reduced from three to two, and (b) minor changes were made in the Ohm's Law immediate cognitive posttest. No other changes were deemed necessary based on the pilot-test.

Reliability estimates obtained on the instruments as used in the pilot-test were as follow: (a) Ohm's's Law immediate cognitive posttest, RR-21 = .68; (b) Ohm's Law delayed cognitive posttest, RR-21 = .92; (c) incline plane immediate cognitive posttest, KR-21 = .93; and (d) incline plane delayed cognitive posttest, KR-2 1 = .95.

Experimental Procedures

Prior to the main experiment, the researchers randomly assigned the students within each of the seven classes into one of two groups (A or B), using the official roll for each class and a table of random numbers. For the first experiment (Ohm's Law), students in the "A" group completed the worksheet activity, while students in the "B" group completed the hands-on activity. In the replication (incline plane experiment), students in the "A" group completed the hands-on activity, while students in the "B" group completed the worksheet activity.

A total of six, 50 minute periods of instruction and testing was required in each class to complete the study. The first five class periods were scheduled consecutively. These class periods were used to provide group instruction, apply the control and experimental treatments, and administer the immediate cognitive posttests. The delayed cognitive posttests were administered on the sixth class period (which occurred 16 days after the beginning of the experiment in each school).

The regular agriculture teacher provided all formal classroom instruction, following standardized lesson plans developed by the researcher and validated by a panel of experts. The classroom teacher and the researcher alternated in the supervision of students as they completed the hands-on and worksheet activities. All students were provided with identical calculators for use during each day of the study.

On the first day, each class received a 15 minute illustrated lecture on Ohm's Law and its mathematical formula. For the last 30 minutes of this class period, students in Group A remained in the classroom and completed an Ohm's Law worksheet, while students in Group B went to another location and completed a series of hands-on activities related to Ohm's Law.The Ohm's Law worksheet consisted of 15 electrical circuit drawings. Each circuit drawing had two of the three circuit values (voltage, amperage or resistance) given. Students completed the worksheet by using the two known values and the Ohm's Law formula to calculate and record the unknown circuit value.

The Ohm's Law hands-on activity consisted of 12 stations through which the students were rotated. Each station consisted of a battery, a resistor, hook-up wires and a digital multi meter (DMM). Two of the three circuit values were given, and student was required to use Ohm's Law and the known circuit values to calculate the unknown value. Once the unknown value was calculated, the student inserted the DMM into the circuit and obtained the actual value. The student then compared the calculated and actual values to verify Ohm's Law. During the second class, the Ohm's Law immediate posttest was administered to the students.

On the third class period, the entire class was taught an introductory lesson on simple machines, with primary emphasis on the concepts of and formulas for calculating the theoretical mechanical advantage (TMA), actual mechanical advantage (AMA) and efficiency (E) of an incline plane. The class was taught using a lecture-discussion and demonstration format, and lasted the entire period.

On the fourth class period, students in Group B remained in the classroom and completed an incline plane worksheet. Students in Group A went to another location and completed a series of hands-on activities related to incline planes.

The incline plane worksheet consisted of 20 incline plane drawings. The data necessary for calculating the TMA, AMA or E for each incline plane were also provided. Students completed the worksheet by calculating and recording the unknown value requested in each problem.

The incline plane hands-on activity involved the use of an apparatus constructed by the researchers. The incline plane apparatus was adjustable so that three discrete base height positions could be selected. The student used a weight, tape measure and scale to collect the data necessary to calculate the TMA, AMA and E of the incline plane at each of the three base heights. One apparatus and a complete set of materials were provided for each student. On the fifth class period, students completed the incline plane immediate posttest.

On the sixth class period (16 days into the experiment), students completed the delayed cognitive posttests for both the Ohm's Law and the incline plane subject matter areas. Students were not notified in advance that the delayed cognitive posttests were to be administered.

Instrumentation

The Ohm's Law and incline plane immediate and delayed cognitive posttest instruments were developed by the researchers and validated by a panel of experts. Both Ohm's Law cognitive posttests consisted of different forms of a test having 17 mathematical word problems (in a multiple choice format with four response alternatives) and eight true-false items. Both incline plane cognitive posttests consisted of different forms of a test having 25 mathematical word problems in a multiple choice format (each with four response alternatives). The KR-21 reliability estimates for the cognitive achievement instruments used in the main study were as follow: (a) Ohm's Law immediate posttest, .80; (b) Ohm's Law delayed posttest, .79; (c) incline plane immediate posttest, .88; and (d) incline plane delayed posttest, .86.

Results

Descriptive statistics for the Ohm's Law experiment and the incline plane replication are presented in Tables 1 and 2, respectively. Cognitive post-test scores were converted to a loo-point basis prior to analysis.

Table 1. Descriptive Statistics for Cognitive Achievement on Ohm's Law Subject Matter by Method, Gender, and Method x Gender

Method	Immediate post-test			Delayed post-test		
Gender	n	Mean	SD	n	Mean	SD
Hands-on	53	73.74	17.37	48	62.67	21.51
Worksheet	44	73.36	16.97	38	63.16	21.33
Male	68	71.47	18.57	62	59.48	22.36
Female	29	78.48	12.35	24	71.67	15.46
Hands-on						
Male	37	71.24	19.73	34	58.47	23.28
Female	16	79.50	8.99	14	72.86	11.76
Worksheet						
Male	31	71.74	17.40	28	60.71	21.56
Female	13	77.23	15.86	10	70.00	20.15

Table 2. Descriptive Statistics for Dognitive Achievement on Incline Plane Subject Matter by Method, Gender. and Method x Gender.

Method	Immediate post-test			Delaved post-test		
Gender	n	Mean	SD	n	Mean	SD
Hands-on	55	66.47	22.96	50	54.88	22.47
Worksheet	61	64.20	21.61	54	51.33	24.07
Male	76	61.16	22.01	71	48.84	23.08
Female	40	73.10	20.60	33	62.06	21.77
Hands-on						
Male	36	62.78	22.17	34	50.94	22.33
Female	19	73.47	23.37	16	63.25	21.97
Worksheet						
Male	40	59.70	22.05	37	46.92	23.88
Female	21	72.76	18.31	17	60.94	22.20

The data from the experiment (Ohm's Law) and the replication (incline plane) were analyzed using 2 x 2 factorial analysis of variance (ANOVA) procedures to determine if significant differences existed between the main effects of method ofreinforcement (hands-on or worksheet), gender, or the interaction of the main effects. Results for the Ohm's Law analyses for both the immediate post-test and the delayed post-test (Table 3) indicated that neither the main effect of method nor the interaction of method and gender were significant ($p > 0.10$). The analyses did reveal significant differences ($p < 0.10$) in both immediate and delayed post-test scores for the main effect of gender with females achieving higher scores than males (Table 3).

The results of the analyses for the incline plane replication (Table 4) were consistent with the Ohm's Law experiment. Neither the main effect for method nor the interaction of method and gender were significant ($p \geq 0.10$). Significant differences ($\rho \leq 0.10$) existed in both immediate and delayed post-test scores for the main effect of gender, with females achieving higher scores than males.

Because no significant differences were found for the main effect of method of reinforcement, or the interaction of method and gender, for either the Ohm's Law or the incline plane experiments, the associated null hypotheses were not rejected. However, since differences were found for the main effect of gender, the null hypotheses of no differences by gender were rejected.

Secondary analyses were performed to rule out potential rival hypotheses involving interactions between method of reinforcement, gender and the classroom unit in which the individual subjects were enrolled. Since no significant interaction effects were found ($p \geq 0.$ lo), it was concluded that these rival hypotheses did not confound the results of the study.

Table 3. Factorial ANOVA for Ohm's Law Cognitive Achievement Tests

	Immediate post-test			Delayed post-test		
Source	df	F	ρ	df	F	ρ
Method	1,93	0.05	.82	1,82	0.00	.95
Gender	1,93	3.24	.08	1,82	5.41	.02
Method x Gender	1,93	0.13	.72	1,82	0.25	.62

Table 4. Factorial ANOVA for Incline Plane Cognitive Achievement Tests

	Immediate post-test			Delayed post-test		
Source	df	F	ρ	df	F	ρ
Method	1,112	0.20	.66	1,100	0.60	.44
Gender	1,112	7.84	,006	1,100	7.55	,007
Method x Gender	1,112	0.08	.78	1,100	0.03	.86

Conclusions, Discussion, and Recommendations

The results of this study were consistent across both the experiment and the replication. Hands-on and worksheet reinforcement methods were equally effective in supporting learning and retention of subject matter, In addition, the method of reinforcement had no differential effects by gender. However, differences on both the immediate and delayed post-tests were noted for the main effect of gender, with females scoring higher than males. The reader should keep in mind that, because of subject selection methods used in this study, results are not generalizable to any larger population.

The result of no effect for method on cognitive achievement in science is consistent with science education literature, as summarized by Hoffstein and Lunetta (1982). Since professionals in agricultural education have historically noted that hands-on instruction is a unique strength of the program, additional research is warranted. This study should be replicated to determine if these results are stable across different subject matters, populations, teachers, and extended instructional periods in agricultural education.

The science education literature indicates that males have higher academic achievement than females in physical sciences (Lee and Burkam, 1996), and that females benefit most by hands-on instruction in the physical sciences (Oakes, 1990). However, the findings of this study of gender and reinforcement method conducted in agricultural education do not support the findings from the science education literature.

Further study is needed to clarify these findings, especially those which are inconsistent with research in science education. Females scored higher than males across subject matter and method of reinforcement, which is inconsistent with research findings among students of the larger school population. Thus, the question arises of whether gender differences among students in this study are representative of gender differences in agricultural education or in the larger student population. Does agricultural education attract female students of higher science abilities than the larger student population, or does it attract males of lower abilities? While this study cannot answer these questions, it does provide potential hypotheses for future investigations. Perhaps examination of data from national longitudinal studies could begin to provide answers to these important questions.

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