

HANDS-ON ACTIVITIES VERSUS WORKSHEETS IN REINFORCING PHYSICAL SCIENCE PRINCIPLES: EFFECTS ON STUDENT ACHIEVEMENT AND ATTITUDE

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Abstract

A posttest-only control group experimental design with a counter-balanced replication was used to determine the effects on cognitive achievement (both immediate and delayed) and attitude toward the subject matter of a hands-on activity versus a worksheet in reinforcing physical science principles. The experimental results were stable across both replications, regardless of the subject matter (Ohm 's Law or incline plane). For both the Ohm 's Law and the incline plane replications, there were no significant ($p \geq .10$) differences in immediate or 11-day delayed cognitive achievement posttest scores between students participating in a hands-on reinforcement activity or a worksheet reinforcement activity. Thus, it was concluded that the two methods were equally effective in reinforcing student subject matter learning. For both replications, students participating in the hands-on reinforcement activity had a significantly more positive ($p \leq .10$) attitude toward the subject matter than did students in the worksheet group. It was concluded that hands-on activities were superior to worksheets in developing positive student attitudes toward academic subject matter.

Change is occurring rapidly in all dimensions of society, including agriculture and education (National Research Council, 1988; Adams and Hamm, 1994). According to Hughes and Barrick (1993), public school agricultural education must continue to change in order to meet the needs of both students and society.

One recent change in agricultural education is the increased emphasis on agriscience (Camp, 1994). Buriak (1989, p.4) defined agriscience 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) supported this definition by stating that, "The emphasis [of agriscience] is on the principles of science that undergird agriculture."

According to Lee (1994), one of the primary purposes of agriscience is to provide students with a hands-on, application-oriented science education. 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. 1-2) 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, almost all 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).

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.

Problem Statement

The science education literature is not conclusive regarding the effects of laboratory activities on student cognitive achievement in science. However, the literature does support the premise that hands-on activities promote a more positive student attitude toward science.

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 purpose of this study was to determine the effects on both student cognitive achievement and attitude of a hands-on activity when compared with

a worksheet activity in reinforcing physical science principles. The following null hypotheses concerning student cognitive achievement were formulated for testing at the .10 alpha level:

H_{o1} : In the Ohm's Law instructional area, there will be no significant difference in either immediate or delayed cognitive achievement posttest scores between students completing a hands-on activity and students completing a worksheet activity,

H_{o2} : In the incline plane instructional area, there will be no significant difference in either immediate or delayed cognitive achievement posttest scores between students completing a hands-on activity and students completing a worksheet activity.

Since the literature supported the effectiveness of hands-on activities in developing positive student attitudes toward science, the following directional hypotheses were formulated for testing at the .10 alpha level:

H_{a1} : In the Ohm's Law instructional area, students completing a hands-on activity will have a significantly more positive attitude toward the subject matter than will students completing a worksheet activity.

H_{a2} : In the incline plane instructional area, students completing a hands-on activity will have a significantly more positive attitude toward the subject matter than will students completing a worksheet activity.

The .10 alpha level was selected a priori based on the researchers' evaluation of the relative consequences of committing a Type I or a Type II error.

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, (e) instrumentation.

Population and Sample

The population for this study included all Arkansas students enrolled in "Agricultural Science and Technology" classes within a 50 mile radius of Fayetteville, Arkansas during the spring 1996 semester. 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 may not be generalized beyond these subjects. 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. Eighteen students were excluded because of individual absences. Attitudinal data from one class (26 students) were not usable because students did not complete the item indicating whether they were in the hands-on or the worksheet group.

All seven Agricultural Science and Technology classes participated in and provided usable data for the incline plane experiment. Because of individual absences, data from 28 of the students were excluded from the analyses of student achievement, while data from 19 of the students were excluded from the analyses of student attitude.

Experimental Design

This study was conducted using a modified posttest-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, KR-21 = .68; (b) Ohm's Law delayed cognitive posttest, KR-21 = .92; (c) Ohm's Law attitude instrument, coefficient alpha = .93; (d) incline plane immediate cognitive posttest, KR-21 = .93; (e) incline plane delayed cognitive posttest, KR-21 = .95; and (f)

incline plane attitude instrument, coefficient alpha = .95.

Experimental Procedures

Prior to the main experiment, the researchers randomly assigned the students in each class 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 attitude and 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 researchers and validated by a panel of experts. The classroom teacher and one researcher alternated in the supervision of students as they completed the hands-on and worksheet activities. All students were provided with identical calculators.

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 multimeter (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. Students completed a data sheet as part of the hands-on activity.

The incline plane worksheet consisted of 20 incline plane drawings. The data necessary for calculating the theoretical mechanical advantage (TMA), actual mechanical advantage (AMA) or efficiency (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. Students 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. Students completed a data sheet as they worked with the incline plane.

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 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, .99; and (d) incline plane delayed posttest, .86.

Student attitudes toward each subject matter area were measured using modified versions of the Attitude Toward Any School Subject instrument (Purdue Research Foundation, 1986). Both instrument versions used in this study consisted of 20 attitudinal statements concerning the subject matter area to which students responded using a 1 to 7 Likert-type scale (1 = strongly disagree; 7 = strongly agree). Individual responses to each statement were summated to arrive at an overall attitude measure. The possible range of scores was from 20 to 140, with higher scores representing more positive attitudes. The coefficient alpha reliability estimates for the attitude instruments used in the main study were .91 for the Ohm's Law instrument and .90 for the incline plane instrument.

Results

The results of the one-way multivariate analysis of variance (MANOVA) used to test the first null hypothesis revealed no significant differences on immediate or delayed Ohm's Law cognitive achievement posttest scores for students in the hands-on or worksheet groups, $F(2, 83) = 0.03$, $p = .98$. Thus, H_{o1} was not rejected. Descriptive statistics related to cognitive achievement in the Ohm's Law subject matter area are presented in Table 1.

The results of the one-way MANOVA used to test the second null hypothesis revealed no significant difference between the hands-on or worksheet groups on either immediate or delayed incline plane cognitive posttest scores, $F(2, 101) = 0.30$, $p = .74$. Thus, H_{o2} was not rejected.

Table 1. Immediate and Delayed Ohm's Law Cognitive Achievement Posttest Scores

| Group | <u>Immediate cognitive posttest</u> | | | <u>Delayed cognitive posttest</u> | | |
|-----------|-------------------------------------|------|------|-----------------------------------|------|------|
| | n | X | SD | n | X | SD |
| Hands-on | 48 | 73.5 | 17.9 | 48 | 62.7 | 21.5 |
| Worksheet | 38 | 73.2 | 17.1 | 38 | 63.2 | 21.3 |

Note: Possible range of scores for each test was 0 - 100.

Descriptive statistics related to cognitive achievement in the incline plane subject matter area are presented in Table 2.

The one-way analysis of variance (ANOVA) used to test the first directional hypothesis indicated that students in the hands-on group had a significantly more positive attitude toward the Ohm's Law subject matter area than did the students in the worksheet group, $F(1, 69) = 5.55, p = .01$. Thus, H_{a1} , was retained. Descriptive statistics related to student attitude toward the Ohm's Law subject matter area are shown in Table 3.

The one-way ANOVA used to test the second directional hypothesis indicated that students in the hands-on group had a significantly more positive attitude toward the incline plane subject matter area than did those students in the worksheet group, $F(1, 111) = 3.89, p = .03$. Based on these results, H_{a2} was also retained. Descriptive statistics on student attitude toward the incline plane subject matter area are presented in Table 4.

Conclusions, Discussion and Recommendations

The experimental treatments, hands-on instructional activities in both the Ohms law and inclined plane subject matter areas, produced no statistically significant differences when compared with the use of traditional worksheets on the dependent variable, "student learning," on either immediate or delayed post-test achievement

measures. Thus, it was concluded that students learned the subject matter equally well with either the hands-on or work sheet instructional approaches.

However, the experimental treatment, hands-on instructional activity, did produce significantly more positive attitudes toward the subject matter when compared to the use of traditional worksheets. Students' attitudes about the subject matter were more positive when learning took place utilizing the hands-on activities compared with the work sheet instruction. These results were stable across both subject matter areas.

These findings support the conclusions of Hofstein and Lunetta (1982), which were based on their review of the science education literature. Agricultural educators, and indeed all educators, should expand the use of hands-on instructional activities to enhance student affective outcomes. Producing positive attitudes toward learning is an important educational outcome in its own right. The long-term impact of increasing student satisfaction toward learning may be to effect such broad educational outcomes as reduced school drop-out rates.

While no differences were found among learners on achievement from the treatments, effects based on student differences such as age, gender, learning styles, and academic ability were not assessed. It is possible that hands-on activities, while producing no overall effects, may have

Table 2. Immediate and Delayed Incline Plane Cognitive Achievement Posttest Scores

| Group | <u>Immediate Cognitive Posttest</u> | | | <u>Delayed Cognitive Posttest</u> | | |
|-----------|-------------------------------------|------|------|-----------------------------------|------|------|
| | n | X | SD | n | X | SD |
| Hands-on | 50 | 66.1 | 23.0 | 50 | 54.9 | 22.7 |
| Worksheet | 54 | 63.4 | 21.4 | 50 | 51.3 | 24.1 |

Note: Possible range of scores for each test was 0 - 100.

Table 3. Student Attitude Toward the Ohm's Law Subject Matter Area, by Group

| Group | n | X | SD |
|-----------|----|-------|------|
| Hands-on | 39 | 102.8 | 18.2 |
| Worksheet | 31 | 91.7 | 21.4 |

Note: Possible range of scores was 20 - 140.

Table 4. Student Attitude Toward the Incline Plane Subject Matter Area, by Group

| Group | n | X | SD |
|-----------|----|-------|------|
| Hands-on | 55 | 103.6 | 19.6 |
| Worksheet | 58 | 95.6 | 23.5 |

Note: Possible range of scores was 20 - 140.

differential effects across unique student groups. Possible effects on both achievement and attitude should be studied by group. Further, since this study was of a short duration and on only two units of subject matter, the question of whether a long-term study might produce similar results should be asked. Would a longer term, over more units of instruction, magnify the differences in attitudes toward the subject matter between the two

treatments, or are any differences the result of a novelty effect with a new (to the students) teaching procedure which might be mitigated over time? Would a study over more units of instruction, which may allow students the opportunity to develop increased knowledge and comfort levels with alternative modes of instruction, produce differential results on the immediate and delayed achievement assessments?

Finally, questions of other, but similar, treatments arise. What would be the effect on student attitudes and achievement when comparing other teaching approaches such as cooperative versus individual versus group instruction? What would be the effect on student attitudes and achievement when comparing instructional techniques such as discovery versus reinforcement instruction? Would increasingly complex subject matter be more likely to produce differences (or greater differences) in student outcomes? These questions bear further study.

Since this study in agricultural education supports research findings from science education, science education may have promise for informing practice in agricultural education, and vice versa. Agricultural educators should consider their role in the larger education community to learn from and contribute to improving instruction for all learners. Thus, agricultural educators should explore instructional practices in other areas such as science education as a means to improve their instruction.

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