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ABSTRACT

This study investigated the use of a hands-on laboratory program as a means of improving attitude toward science and increasing achievement levels in science knowledge among students in a ninth grade physical science course. Using a posttest-only control group design, a curriculum referenced objective final examination was used to measure student achievement in science knowledge, and a post-test Q sort survey was used to measure attitude toward science. A t test compared the treatment and control groups' differences in achievement and in attitude toward science. ANCOVA was used to determine the effect of the laboratory treatment on the dependent achievement variable with attitude toward science as the co-variable. The findings showed that: (a) students who had regular laboratory instruction scored significantly higher ($p<.05$) on the objective examination of achievement in science knowledge than students who had no laboratory experiences; (b) female students who had regular laboratory instruction scored significantly higher ($p<.05$) on the objective examination of achievement in science knowledge than female students who had no laboratory experiences; (c) female and male students within the treatment group did not differ significantly on the objective examination of achievement in science knowledge. This study recommends that science instruction include a regular laboratory experience as a demonstrated viable and effective instructional method for science teachers. This model of science instruction has been shown to be effective with all students of diverse backgrounds, especially females, who live within large, urban centers. (Contains 30 references.) (Author/YDS)

The Influence Of Laboratory Instruction On Science Achievement And Attitude Toward Science Among Ninth Grade Students Across Gender Differences

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Abstract

This study investigated the use of a hands-on laboratory program as a means of improving attitude toward science and increasing achievement levels in science knowledge among students in a ninth grade physical science course. Using a posttest-only control group design, a curriculum referenced objective final examination was used to measure student achievement in science knowledge, and a post-test Q sort survey was used to measure attitude toward science. A t test compared the treatment and control groups' differences in achievement and in attitude toward science. ANCOVA was used to determine the effect of the laboratory treatment on the dependent achievement variable with attitude toward science as the co-variable. The findings showed that: (a) students who had regular laboratory instruction scored significantly higher ($p < .05$) on the objective examination of achievement in science knowledge than students who had no laboratory experiences; (b) female students who had regular laboratory instruction scored significantly higher ($p < .05$) on the objective examination of achievement in science knowledge than female students who had no laboratory experiences; (c) female and male students within the treatment group did not differ significantly on the objective examination of achievement in science knowledge. This study recommends that science instruction include a regular laboratory experience as a demonstrated viable and effective instructional method for science teachers. This model of science instruction has been shown to be effective with all students of diverse backgrounds, especially females, who live within large, urban centers.

Introduction

The investigation of science achievement and attitude toward science has been a significant area of study for many researchers in science education. It has long been assumed that males achieve higher scores in measures of science knowledge than females. For example, the National Assessments of Educational Progress, reported in 1979 that the performance of males is typically above that of females in science knowledge. In addition, females held a less positive attitude toward science, and they participated in far fewer science activities than did males. However, females, in general, expressed the desire to have opportunities to have experience with scientific materials (Matyas, 1985). Indeed, most school science curricula builds on activities such as manipulation of science equipment which males are more likely than females to have experienced (Sjøberg, 1993). Performance differences among female students in cognitive measures of science knowledge continue to be significant at the high school level (Shymansky, Hedges, & Woodworth, 1990), and results from the Third International Mathematics and Science Study (TIMSS, 1998) indicate that, for middle school years, differences in female achievement were pervasive in science for most countries, especially in physics, chemistry, and earth science.

Weinburgh (1995), in her extensive meta-analysis of the literature from 1970-1991, concluded that research indicates that gender may influence student attitude toward science. Gender is the single variable that has been shown to have consistent influence on attitude toward science, with the result that males have a more positive attitude toward science than do females. This is so in spite of the fact that females get higher grades in science than do males. These findings also have a strong parallel in mathematics classes (Eccles, 1989). The American Association of University Women reports that studies continue to show that females exhibit a less positive attitude toward science than do their male counter parts (AAUW, 1992).

In their landmark study, Schibeci and Riley (1986), seeking a causative relationship between attitude toward science and achievement in science, found that gender had an influence on the correlation between the two. Females had a less positive attitude toward science and lower achievement scores than did males. However, Weinburgh (1995) reports that conflicting results from the studies in her meta-analysis make it difficult to determine if there are differences for females in attitude toward science or whether there are correlations between attitude toward science and achievement in science. The AAUW (1992) reports difference in gender related results when attitude toward science and achievement are measured using teacher made, as opposed to standardized, instruments. Kahle (1996) hypothesizes that differences for females in attitude toward science and achievement are the result of differential treatment and instruction that females and males receive in the classroom. She notes that these differences are most pronounced in the use of science equipment, materials, and manipulatives, with males having had more opportunity to use science equipment and perform experiments than females. McComas (1996) suggests that evidence is accumulating that females' attitude toward science can be changed by instruction.

Seeking to identify obstacles to equity for females in science, Kahle (1988) opines that science has a masculine image perpetuated by who studies science, the way it is presented, and how science teaching is practiced. It is this masculinity, she reasons, that is the prime reason females tend to avoid the subject at school. Documenting studies done in the United States, Great Britain, and Australia, Kahle found that, when compared to males, fewer females handle science equipment, perform science experiments, and participate in science-related activities. These lack of experiences may account for a large portion of the differences noted in science achievement of females because they cause a lowering of females' self confidence in their science abilities. In a parallel study in mathematics, Eccles (1985) found that females who have more hands-on learning experiences and opportunities can develop greater confidence in their abilities, more interest in studying mathematics, and more interest in pursuing careers in mathematics and science-related fields. Females should be encouraged to take more precollege science courses, particularly physical science (Linn, De Benedictis, Delucchi, Harris, & Stage, 1987). Jenkins and McDonald (1989) suggest the use of teaching strategies and techniques that provide students, especially females, with the opportunity to practice observing, measuring, and hypothesis testing because of the probability that they lack such exposure and science experiences. The strategies that employ a clear emphasis on the "doing of science" and the use of hands-on experiences have been proven successful intervention techniques (Thomas, 1986; Lock, 1992; Anderson, 1993; Doran, Boorman, Chan, & Hejaily, 1993; Sjøberg, 1993). These activities enable all students, especially females, to see relevance in the application of science, therefore making science important for them to learn. Increasing these experiences for all students, especially females, appears to boost their attitude toward science and their achievement (Simpson and Oliver, 1990; Shakeshaft, 1995). Hill, Pettus, and Hedin (1990) cite that a contributing factor to the under representation of females in science-related fields is that they exhibit high levels of mathematics and science anxiety, often a result of lack of school experiences with science activities. Greenberg-Lake (1991) suggests that females are more likely deprived of active learning experiences than their male counterparts. Thus, as they grow up, females lose confidence in their abilities, and lose interest in challenging courses of study, especially in mathematics and science. This loss of self-esteem takes place at a critical point in a female's life - near the beginning of adolescence. Orenstein (1994) concurs, noting that a female's adolescence is marked by a loss of confidence in herself and her abilities, especially in mathematics and science. Orenstein also notes that this loss of confidence precedes a drop in achievement.

One teaching practice that limits females' participation in classroom science is allowing them to opt out of complex hands-on experiments (AAUW, 1992). Kahle (1996) also notes that obstacles to achievement in science may be based upon failure to participate in the classroom. She states that the negative attitude toward certain science topics (e.g. physical sciences) of females may be based on lack of experience in these areas.

There are strategies to overcome and to remove the obstacles to gender equity in science education. Matyas (1985) recommends countering the lack of science-based experimental activities in the classroom by having a wider variety of science experiences available for all students, particularly females and those with higher ability. Kahle (1985) examined case studies to identify instructional strategies and teaching behaviors to improve retention and achievement of females in science classes. She found that teachers who were successful in encouraging females in school to become women in science had certain characteristics. They maintained attractive, well-equipped classrooms, actively involved all students (females and males) in science experiments and activities in class, and made use of laboratory-based science teaching. The attitude toward science of all the students was positively affected by these in-class experiences. In a later paper, Kahle (1988) suggests means to change the masculine image of science and to enhance equitable opportunities for females in science. Laboratory groups should be structured so <u>all</u> members of the group have opportunities to <u>do</u> science. Females prefer a teaching style that makes use of pupil-centered experiments and activities. Other studies and reports corroborate the notion that programs involving active learning, inquiry-based, hands-on strategies increased science achievement of all students (Hill, Pettus, & Hedin, 1990; Greenberg-Lake, 1991; Lock, 1992; McLaren & Gaskell, 1995). We need to remove "exclusionary pedagogical techniques" found in traditional science classrooms and include a gender-fair approach to science teaching that is inclusive, representative, and integrated by allowing females to "do the lab" (AAUW, 1992).

Finally, there are overwhelming reasons for investigating science achievement and attitude toward science among females. Thomas (1986) has succinctly characterized the following scenario: (1) females express a lower interest and affinity for science; (2) the extent to which students like science is a critical determinant in pursuing a science career or major; and (3) increasing the interest and participation of females in science would increase the utilization of a great national resource. There is compelling evidence that course taking is strongly associated with the likelihood of increasing science proficiency between the 8th and 12th grade (U. S. Department of Education, 1997). If we share the view that females' differences in interest, participation, and achievement in science are societal rather than biological (Shakeshaft, 1995), then there is a need for studies that produce the hard data necessary to transform these views into realities.

Purpose

The purpose of this study is to examine the relationship among laboratory instruction, attitude toward science, and achievement in science knowledge across gender differences for students enrolled in a ninth grade physical science course in a large urban high school. The study emanates from the hypothesis that attitude toward science has an impact on achievement in science knowledge, rather than the reverse. It suggests a model of instruction that proposes that laboratory experiences have a positive influence on students' attitude toward science across gender, and that this positive attitude influences achievement in science knowledge. This study, therefore, investigates the use of a laboratory program in a ninth grade physical science course as a means of improving students' attitude toward science and increasing achievement levels in science knowledge.

The following null hypotheses were tested:

1. There is no significant difference in the mean performance on achievement in science knowledge across gender at the end of ninth grade physical science between students receiving laboratory instruction and those not having laboratory instruction as measured by departmental final examination scores.
2. There is no significant difference in the mean performance on a posttest of attitude toward science across gender between ninth grade physical science students receiving laboratory instruction and those not having laboratory instruction as measured by the Q sort attitude survey.
3. There is no significant difference in the mean performance on achievement in science knowledge across gender in ninth grade physical science between students receiving laboratory instruction and those not having laboratory instruction after these groups have been statistically equated with respect to the co-variable, attitude toward science.

Design and Procedures

The study reports an investigation of the relationship among laboratory instruction, attitude toward science, and achievement in science knowledge of ninth grade physical science students. The investigation used the posttest-only control group design. In this model, the subjects from a multi-racial and multi-ethnic student population of ninth graders were randomly assigned to physical science classes which comprised the treatment and the control groups. The assignment of specific classes of students to the treatment or control groups was done after the random assignment of the students to their physical science classes. Therefore, the randomization criterion for a true experimental study was met. The randomization of the two groups controlled for threats to internal validity such as selection bias, statistical regression, testing, and instrumentation used since the groups were equal (Huck, Cormier, & Bounds, 1974). The threat of subject mortality was limited because there was no reason to assume that more subjects might leave one group than the other.

The population tested was assigned to two groups. One group, T_R, represented students undergoing the treatment of laboratory experiences, and the other group, C_R, represented the corresponding students not having the treatment. The treatment group was given 36 regularly scheduled, weekly laboratory activities as part of their five period per week physical science course, while the control group received traditional, teacher-centered instruction with no laboratory experience during the school year. The laboratory experience consisted of an activity in which students interact with materials and equipment to observe and to record phenomena. These activities were performed by students in groups, cooperatively. All classes adhered to the established school district course of study, used the same textbook, and were taught the same body of content knowledge. This set of laboratory experiences was considered to have an impact on student achievement and attitude toward science when compared with no laboratory experience for the control group. Near the close of the school year an objective final examination measuring achievement in science knowledge, and an attitude toward science survey were given to both groups as posttests.

To determine the initial equivalence of the two groups on prior knowledge of science, an analysis was undertaken of the scores on the school district's Test of Science which is given at the end of the previous grade (grade eight). This instrument, which had been used districtwide for several years, was reported by the school district's testing office as consistently yielding normal distributions of student scores, thereby assuring reliability of the instrument. The treatment and control group populations were compared in this measure with a resultant $\underline{F}$ (2, 293) = .77. This value indicates that no significant difference existed in the mean performance in science knowledge among the two groups of beginning ninth grade physical science students. Thus the T_R and C_R groups may be considered to be equivalent in science knowledge prior to the experimental treatment.

Additionally, a test of homogeneity of variance between the two groups was done using Bartlett's chi-square test. The $\underline{F}$ = .75 result was less than the critical F value of 3.84 (1,269), $p <$ .05, thus supporting the assumption that the treatment and control groups represented random samples drawn from a normally distributed population.

Instrumentation

Student achievement in science knowledge was measured using their score on a final examination. The final examination was the curriculum-referenced test for physical science developed for, and used by, the school district to measure achievement in the physical science course. The final examination contained 60 questions measuring the following curricular objectives with the number of items of each shown in parentheses: force, work, and energy (11); motion (11); magnetism and electricity (11); waves (4); light and color (8); sound (6); and heat (9). This test, developed from a commercial bank of items and some items written by local teachers, was based upon the district curriculum. According to the district's Office of Assessment, several years of use of these instruments testing students in the district had yielded normal distributions, indicating how well the students in a particular classroom or school have done on the course objectives being taught in the city high school classrooms. This information provides evidence of construct validity and reliability of the test. Student attitude toward science was measured using the Q sort, a technique for scoring an attitude survey. In the Q sort, fifty cards, each containing a single adjective that students could use to describe their attitude toward science was given to the student to sort (Humphrey, 1975). Using a Science Attitude Sort form, the student recorded the numbers of the cards in columns along a continuum ranging from most disagree (-5) to most agree (+5). Each form was then scored according to the weights assigned to the adjectives as shown in Table 1. A perfect score equaled 100 points.

Results

The performance of the treatment and control groups on the science achievement final examination was compared using a t test, an appropriate technique for a two-sample analysis. An alpha level of .05 was used for all statistical tests. The students who received the laboratory program (treatment), did significantly better (M = 26.81, SD = 7.86) in achievement in science knowledge than did their counterparts in the control group (M = 23.80, SD = 7.80), t (170) = 2.47, p = .015. This finding is supported when these groups are compared using attitude toward science as a covariable as shown in Table (2). Here an analysis of covariance (ANCOVA) demonstrated that the students participating in the laboratory program performed significantly better, F (1,169) = 4.78, p < .05 in science achievement when compared to those not participating in the laboratory program when these means are adjusted for attitude toward science. There was no significant difference found between these two groups on their attitude toward science as measured by the Q-sort, t (170) = 1.39, p = .17 although the mean obtained for the T_R group (M = 63.6, SD = 13.9), was greater than that of the C_R group (M = 60.7, SD = 12.9).

Further analyses were undertaken to determine the influence of the treatment across gender differences both within and between groups. Within the treatment group, science achievement, attitude toward science, and science achievement with attitude toward science as a covariable between male and female students were compared as before. When scores on the final examination measuring achievement in science of female students within the treatment group (M = 26.25, SD = 6.51), were compared with the scores of male students within the treatment group (M = 27.37, SD = 9.07), the obtained t (101) = - .72, p = .47 indicated that no significant difference in performance existed across gender within the treatment group. These within group results are consistent when the means are adjusted for attitude toward science (F (1, 102) = 1.55, p = .217) as shown in Table 3. This evidence suggests that males and females participating in the hands on laboratory program achieve about equally. Also, when the between group findings are examined, it can be seen that female students who participated in the hands-on laboratory program (M = 26.25, SD = 6.51), scored significantly better in science achievement t (80) = 2.23, p = .029 than did the female students in the control group (M = 22.30, SD = 9.52). Again, when these means are adjusted for attitude toward science the between group results for female students are consistent (F (1, 81) = 3.79, p = .05) as shown in Table 4. No significant differences were reported in attitude toward science between or within groups. While this was somewhat disappointing to this researcher, it did not diminish the positive effect of the laboratory program on student achievement in science.

Conclusions

The results of an objective measure of achievement in science knowledge, the curriculum referenced final examination, provided evidence that the laboratory program influenced achievement. A significant difference in achievement was found between the females who received the treatment (T_R) and the females who comprised the control group and did not have a laboratory experience (C_R). It is reasonable to assume that this difference was due to the experimental treatment and that a hands-on laboratory program is a significant factor in increasing achievement in science knowledge among all students, especially females. Additionally, the similarity in final examination scores among female and male students within the treatment group appears to mitigate the gender gap in science achievement. The statistical analysis failed to show any significant differences between the treatment and control groups' attitude toward science.

This study adds to the growing body of evidence that laboratory activity has an effect on student achievement in science knowledge and also influences their attitude toward science. The model of instruction that laboratory influences attitude toward science and increases achievement in science knowledge in a ninth grade physical science course is a viable one. The proposed instructional model supports the model developed by Schibeci and Riley (1986).

The results also add specificity as to what teachers can do to improve student acquisition of science knowledge for all students, especially females, and to make science more exciting for them. The proposed model of instruction which includes a laboratory program was determined to be a valuable one for teachers to use in the classrooms of large urban schools as supported by significant differences in achievement scores.

Recommendations and Implications for Science Teaching

It is recommended that science instruction include a regular laboratory experience as a demonstrated viable and effective instructional method for science teachers. Based upon the findings presented in this study, hands-on laboratory, as a part of the science curriculum, offers a prescriptive method for raising achievement levels and may promote positive attitude toward science among all science students enrolled in ninth grade physical science. The model of science instruction proposed here has been shown to be effective with students of diverse backgrounds who live within large, urban centers. The model is also effective across gender differences. It is ever important to counter the obstacles in science education that impinge on gender equity in science instruction. At every level of our educational system, when free choices are made, female participation in science decreases (Sjøberg, 1993). We must attempt to counter the notion that science is not for females.

Although differences in achievement scores and attitude toward science for females have been recognized, nothing substantial has been done to redress these differences over the past two decades (Weinburgh, 1995). Strategies that allow females the opportunity to experience science and to reduce their lack of exposure to science equipment, materials, and activities must be encouraged and fostered. More research is needed to examine in-class instructional strategies for improving all students' attitude toward science and achievement in science, especially females. Efforts should be made to separate the analyses of attitude toward science data by gender, as recommended by Rennie and Parker (1987), because of the different patterns of responses made by females and males to the instrument items.

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Table 1.

Q Sort Adjectives and Accompanying Weights

Positive Adjectives	Negative Adjectives	Weighted Score
Capable	Stupid	5
Able	Failure	5
Trustworthy	Incompetent	3
Confident	Imbecile	3
Aware	Dishonest	3
Wise	Wrong	2
Understand	Unsatisfactory	2
Success	Unaware	2
Successful	Lazy	2
Smart	Insincere	2
Sincere	Inadequate	2
Qualified	Impossible	2
Observant	Foolish	2
Honest	Disqualified	2
Clever	Disappointment	2

table continues

Positive Adjectives	Negative Adjectives	Weighted Score
Achievement	Careless	2
Working	Uncertain	1
Remember	Misunderstand	1
Possible	Inattentive	1
Correct	Inactive	1
Certain	Idle	1
Busy	Forget	1
Ahead	Doubtful	1
Active	Behind	1
Accurate	Awkward	1

Table 2

Analysis of Covariance for Final Examination with Posttest Attitude Toward Science as the Covariate for Treatment and Control Groups of all Students.

Source	DF	ADJ SS	MS	F	P
Attitude	1	563.19	563.19	9.63	0.002
Achievement	1	279.41	279.41	4.78	0.030
Error	169	9886.08	58.50		
Total	171	10823.32			

ADJUSTED MEANS		
Group	N	M
Treatment	103	26.648
Control	69	24.033

Table 3

Analysis of Covariance for Final Examination with Posttest Attitude Toward Science as the Covariate for Females and Males within the Treatment Group

Source	DF	ADJ SS	MS	F	P
Attitude	1	590.51	590.51	10.39	0.002
Achievement	1	87.90	87.90	1.55	0.217
Error	100	5685.16	56.85		
Total	102	6308.12			

ADJUSTED MEANS		
Group	N	M
Males	52	25.88
Females	51	27.75

Table 4

Analysis of Covariance for Final Examination with Posttest Attitude Toward Science as the Covariate for Females Between Groups

Source	DF	ADJ SS	MS	F	P
Attitude	1	130.99	130.99	2.22	0.14
Achievement	1	223.19	223.19	3.79	0.05
Error	79	4655.06	58.92		
Total	81	5082.88			

ADJUSTED MEANS		
Group	N	M
Treatment	52	26.078
Control	30	22.598

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