The Effects of an Integrated, Activity-Based Science Curriculum on Student Achievement, Science Process Skills, and Science Attitudes

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ABSTRACT

This study investigated the effect of an integrated, activity-based science curriculum, on science achievement, science process skills, and attitudes toward science. The research involved seventh grade students using the Integrated Science (IS) curriculum as the experimental group and seventh grade students using a traditional science curriculum as the control group. The IS curriculum developed connections between different content areas of science, technology and mathematics in ways to improve science literacy for students while the traditional curriculum focused on Life Science.

The instruments included the Iowa Test of Basic Skills (ITBS), the South Eastern Regional Vision for Education (SERVE) Science Process Skills Test, and the SERVE Science Attitude Survey. Analysis of Covariance (ANCOVA) was used for data analysis.

In the experimental group, 532 seventh grade ITBS Science scores were matched to same student sixth grade scores with 450 matches obtained in the control group. The experimental group had a significantly higher ITBS Science adjusted posttest mean compared to the control group with means of 238.3 and 232.2 respectively. The effect size ($f=1.026$) would be considered large according to J. Cohen (1988).

In the experimental group 531 Process Skill Test matches were made pretest to posttest while 398 matches were made in the control group. The experimental group adjusted posttest mean score was significantly higher than the control with means of 14.51 and 13.68 respectively. The effect size ($f=.9285$) was large. Differences in individual process skills were also evaluated and significant differences were found between the experimental and control groups.

Students were given the SERVE Attitude Survey as a pretest and posttest. The attitude adjusted posttest means of the experimental and control groups were not significantly different.

Purpose of the Study

The purpose of this study was to investigate the effect of an integrated, activity-based science curriculum program on science achievement, science process skills, and attitudes toward science. It compared the performance of seventh grade students using an integrated activity-based curriculum to seventh grade students using a traditional science curriculum.

Introduction

Improving science literacy has received attention as a national priority for many years. Extensive federal funding of science and mathematics programs (Suter, 1992) has occurred in an attempt to solve the problem of U. S. students lagging behind their international counterparts (Finn & Ravitch, 1995; Jones, Mullis, Raizen, Weiss, & Weston, 1992; National Center for Education Statistics, 1999; Suter). Many science educators and science agencies in the U. S. are demanding that science education produce a science literate public (American Association for the Advancement of Science [AAAS], 1989; National Research Council [NRC], 1996).

Many states now include performance-based science assessment in their student assessment programs to determine the extent to which students can apply and use science knowledge (Finn & Petrilli, 2000). These new accountability initiatives are being implemented at the same time student attitudes towards science are steadily declining from elementary to high school (Peng, Wright, & Hill, 1995).

The NRC (1996), a division of the National Academy of Science, published *National Science Education Standards* to assist school systems in designing and implementing science programs that would foster scientific literacy for all K-12 students. This document outlines what all students should know and be able to do in science in order to become scientifically literate. *National Science Education Standards* call for major changes in science education programs. The *National Science Education Standards* are based on the premise that science is an active process. Learning science involves actively engaging students in science activities that require scientific thinking and reasoning.

Treatment and Control

An integrated approach to science teaching is one method that has been identified as a method of improving science achievement and literacy (Harman & McColskey, 1997; AAAS, 1989; Aldridge, 1992). The integrated approach to science is a major component of the Integrated Science (IS) curriculum program, the program that was investigated in this study. In the IS curriculum, each of the content standards recommended by the *NSE Standards* (NRC, 1996) is covered at increasingly higher levels of difficulty in grade six through grade eight. The spiraling curriculum found in the IS program was modeled after the recommendations of the NSTA Scope, Sequence, and Coordination Project's recommendations for middle school curriculum (Aldridge). The IS curriculum also emphasizes the connections between science, technology, and mathematics an essential component for improved science literacy (AAAS, 1989).

The IS curriculum also stresses student involvement in hands-on science activities that engage scientific thinking and reasoning. Many researchers have shown that an activity-based approach to science instruction will improve science achievement (Harmon & McColskey, 1997; Hill, 2002; Howard, 1995; Ruby, 2001; Yager & Weld, 1999).

The IS program was developed in 1991-1992 with funding from the University of Alabama and private corporate sponsors. It included schools in Alabama and Florida. The program began with instruction provided to only seventh grade students with eighth grade instruction being added in the 1992-1993 school year and sixth grade instruction in the 1993-1994 school year. (Love, 1997)

The traditional science curriculum program used in the control group consisted of a textbook emphasis with lecture and demonstration being the primary method of instruction. This curriculum had a major focus of life science for seventh grade students and included topics such as: life, heredity and evolution, simple living things, plants, animals, the human body and health, and ecology (Daniel, Ortleb, & Biggs, 1995).

The IS and the traditional curriculum were similar in that they both contained seventh grade science content. They both dealt with life science topics such as characteristics of living things and characteristics of human body systems. The programs were very different in that the IS curriculum also examined content from other science subject areas such as earth and space science, physics, chemistry, and engineering and how these disciplines are interrelated. The use of mathematics to solving scientific problems is also a component of the IS program. The IS curriculum also emphasizes the use of activities as a method for students to learn content. Teachers are directed to conduct at least 2 investigations a week with students.

Research on the Integrated Science Curriculum Program

Harmon and McColskey (1997) examined the first cohort of eighth grade students that had been involved in IS for all three years of middle school science (i.e., sixth, seventh, and eighth grades). Researchers found that significantly more students reported doing hands-on activities and working in cooperative groups than non-IS students. IS students also showed significantly more positive attitudes toward their science classroom experience and toward their science teacher. However, there was no significant difference between the two groups in attitudes toward science and future expectations of science participation.

In a study of 205 IS eighth grade students and 120 non-IS eighth grade students, McColskey (1995) found that IS students showed significantly more positive attitudes toward science than did non-IS students. Significantly fewer IS than non-IS students indicated that science was boring, significantly more IS students found science interesting, and significantly more IS students found science assignments interesting.

Bryant, Jeong, Maxwell, and Raney (1999) conducted a study of the relationship between IS and student scores on the Science Subtest of the SAT. When the schools were matched based on economic and social variables, schools using IS showed significantly higher SAT scores than non-IS schools. Also, schools participating in IS showed increased improvement in SAT scores during the second and third years of enrollment, indicating that the longer students remained in the IS curriculum, the higher their score on the SAT science test.

Research Design

A quasi-experimental, nonequivalent control group design was used in this study (Campbell & Stanley, 1963). This design is appropriate as the experimental and control groups consisted of pre-existing classes. Pre-experimental sampling equivalence could not be guaranteed. A pretest and posttest were utilized and group equivalence was established through the use of ANCOVA data analysis.

The independent variable in this study was student participation in the IS curriculum program versus the use of a traditional science curriculum. Three dependent variables were identified to characterize student performance: science achievement, science process skills, and attitudes toward science.

Sample

Seventh grade students involved in the IS program from three schools in north Louisiana comprised the experimental group. The experimental group consisted of 531 students who completed both the pretest, the posttest, and received IS instruction from seven newly trained IS seventh grade teachers, teaching IS for the first time. The seven teachers selected to participate in the experimental group had received training during an IS summer training session. Summer training included instruction in the use of hands-on activities, classroom management, and other implementation strategies.

Students involved in a traditional science curriculum program from four schools in north Louisiana participated as the control group for the project. Seven science teachers taught these seventh graders from these schools and 398 students completed both the pretest and posttest. Two of the control group teachers only taught one class of seventh grade science resulting in a lower number of students in the control group.

Instrumentation

The instruments used in this study were selected to measure three aspects of student performance in science. Science achievement was measured using the Science Subtest of the ITBS. This test is a nationally normed standardized test. This test measured student knowledge of science content and the ability of students to use scientific reasoning skills to answer questions and solve problems on science related passages.

To demonstrate equivalent forms reliability on the ITBS a correlation was conducted by Riverside Publishing between Form K given in the Spring of 1992 and Form L given in the Fall of 1992. The correlation between the two forms on the science test for 949 students was 0.65 and for a different group of 1400 students was 0.54. The correlation between the forms on the composite score was 0.89 for the 949 students and 0.86 for the 1400 students (Riverside Publishing, 1997).

The SERVE Process Skills Test was developed for the IS curriculum program by SERVE for teacher use in determining the process skills level of their students. This test consisted of items obtained from two science process skill tests, the Performance of Process Skills (POPS) Test for Middle Grade Students (Mattheis & Nakayama, 1988) and the Assessment Ideas for Science in Six Domains (AISSD) (Yager & Kellerman, 1992).

The majority of the items for the SERVE Process Skills Test were taken from the POPS test (Mattheis & Nakayama, 1988). Four science educators experienced in test construction and science process skills reviewed the POPS test. The responses of the four reviewers were consistent on almost all items in terms of indicating the correct answer and keying to a process skill objective. The concurrence of the raters was taken as evidence of content validity and objectivity of scoring. The test was administered to 1,402 students to determine test reliability. A mean of 9.77 and a standard deviation of 4.16 were obtained for students on the test. Total scores ranged from 1 to 20 with a standard error of measurement of 2.08. Total test reliability, as computed by the Kuder-Richardson formula (KR-20) was equal to .75. Item difficulty indices ranged from .28 to .71 with an average of .49 and were above .30 for 90% of the items (Mattheis & Nakayama, 1988).

The remaining items of the SERVE Process Skills Test were taken from the Process Domain section of the AISSD (Yager & Kellerman, 1992). The validity of the items in this section was established by comparisons with other process skills tests. The reliability of the process test items was within a range of 0.82 – 0.90 using the test-retest method. The difficulty of these items had a range of 0.42 – 0.58 (Yager & Kellerman).

The SERVE Science Attitude Survey consisted of items designed to determine student science attitudes. The survey was given by SERVE to 1,248 IS and non-IS middle school students in Palm Beach, Florida, at the request of IS directors. A principle factor analysis of the sample with orthogonal rotation yielded five factors accounting for 94% of the variance. These factors were: Factor 1 – general science attitude (10 items), Factor 2 – science classroom attitude (9 items), Factor 3 – science teacher attitude (5 items), Factor 4 – participation in hands-on/group activities (4 items), and

Factor 5 – future expectations of science participation (4 items) (McColskey & Harmon, 1997).

Data Collection

Students in experimental and control group schools were given the SERVE Process Skills Test and Attitude Survey as a pretest and again as a posttest. A week for test administration was established for each school with teachers determining the specific day of administration depending on individual scheduling considerations.

Student ITBS Science Scores for all seventh grade students in the control and experimental schools were obtained from each school involved in the study. The sixth grade ITBS Science scores were matched to the seventh grade science scores for each student. Since all seventh grade students at each school participated in the project, all seventh grade scores with matching sixth grade scores were used for analysis.

Data Analysis

Pretest and posttest data from this study were analyzed using the SPSS computer program (SPSS 12.0 Inc., 2003). An ANCOVA was used to determine if significant differences existed between seventh grade ITBS Science means of the experimental group and control group using the sixth grade ITBS Science score as the covariate.

An ANCOVA was conducted on the Process Skills test to determine if significant differences existed between the experimental and control groups with the pretest responses used as a covariate. The process skills of students were further examined by individual process skill using ANCOVA with the pretest responses used as a covariate.

Student responses to the SERVE Attitude Survey were in a Likert scale format with responses ranging from a positive attitude towards science being indicated with a high number on a scale of one to five and a negative attitude toward science being indicated with a low number on a scale of one to five. Student responses on all attitude survey items were summed and a mean attitude score was calculated for each student. An ANCOVA was conducted on the student attitude scores to determine if significant differences existed between the experimental and control groups with the pretest responses used as a covariate.

Results of Data Analysis

The ITBS Science adjusted posttest mean of the experimental group was significantly higher than the ITBS Science adjusted posttest mean of the control group. Results of adjusted posttest means are shown in Table 1. The F value of 14.26 was significant at $p < .001$. The f value was calculated using Eta squared as recommended by Cohen (1988) as the appropriate evaluation of effect size for ANCOVA. According to Cohen, an f = 0.10 represents a small effect, an f = .25 represents a medium effect, and an f = .40 represents a large effect. Eta squared = .513 and f = 1.026 represented a large effect.

Table 1: ITBS Pre, Post, and Adjusted Posttest Means by Group

Group	n	Pretest Means	Posttest Means	Adjusted Posttest Means	F
Experimental	532	223.98	236.39	238.34[a]	14.26**
Control	450	229.46	234.50	232.20[a]	

[a] Evaluated as covariates appeared in the model: PreScience = 226.49
**$p < .001$

The Science Process Skills Test adjusted posttest mean of the experimental group was significantly higher than the control group adjusted posttest mean. Results of adjusted posttest means are shown in Table 2. The F value of 7.56 was significant at $p < .01$. Eta squared = .463 and f= 0.928 represented a large effect.

Table 2: SERVE Science Process Skills Pre, Post, and Adjusted Posttest Means by Group

Group	n	Pretest Means	Posttest Means	Adjusted Posttest Means	F
Experimental	531	13.55	15.03	14.51[a]	7.56**
Control	398	12.02	12.98	13.68[a]	

[a.] Evaluated as covariates appeared in the model: Pretest Skill Score = 12.90
**$p < .01$

The posttest science attitude adjusted mean of the experimental and control groups were not significantly different. Results of adjusted posttest means are shown in Table 3. The F value of 2.28 was not significant at the 0.05 level.

Table 3: Science Attitude Survey Pre, Post, and Adjusted Posttest Means by Group

Group	n	Pretest Means	Posttest Means	Adjusted Post Means	F
Experimental	531	3.362	3.411	3.445[a]	2.28
Control	398	3.511	3.431	3.386[a]	

[a.] Evaluated as covariates appeared in the model: Pretest Attitude = 3.427

Science Process Skills were also evaluated by individual process skill. The Process Skill: *Identifying Experimental Questions* posttest adjusted mean of the experimental group was significantly higher than the adjusted mean for the control group. Results of adjusted posttest means are shown in Table 4. The F value of 6.65 was significant at $p < .05$. Eta squared = 0.032 and f= 0.182 represented a small effect. Both groups, did however, show a numerical decline in this process skill when the posttest mean was compared to the pretest mean.

Table 4: Science Process Skill: Identifying Experimental Questions Pre, Post, and Adjusted Posttest Means by Group

Group	n	Pretest Means	Posttest Means	Adjusted Posttest Means	F
Treatment	531	0.7985	0.7213	0.710[a]	6.65*
Control	398	0.6281	0.5829	0.597[a]	

[a.] Evaluated as covariates appeared in the model: Pretest Objective 1 = .7255

*$p < .05$

The Process Skill: *Identifying Variables* posttest adjusted mean of the experimental group was significantly higher than the adjusted mean of the control group. Results of adjusted posttest means are shown in Table 5. The F value of 16.11 was significant at $p < .001$. Eta squared = 0.151 and f= 0.422 represented a large effect.

Table 5: Science Process Skill: Identifying Variables Pre, Post, and Adjusted Posttest Means by Group

Group	n	Pretest Mean	Posttest Mean	Adjusted Mean	F
Experimental	531	2.211	2.693	2.671[a]	16.11***
Control	398	2.078	2.276	2.306[a]	

[a.] Evaluated as covariates appeared in the model: Pretest Objective 2 = 2.154
***p < .001

The Process Skill: *Formulating Hypotheses* posttest adjusted means of the experimental group and the control group were not significantly different. Results of adjusted posttest means are shown in Table 6. The $\underline{F}$ value of 2.20 was not significant at the .05 level.

Table 6:Process Skill: Formulating Hypotheses Pre, Post, and Adjusted Posttest Means by Group

Group	n	Pretest Means	Posttest Means	Adjusted Posttest Means	F
Experimental	531	1.298	1.311	1.288[a]	2.20
Control	398	1.168	1.194	1.223[a]	

[a.] Evaluated as covariates appeared in the model: Pretest Objective 3 = 1.242

The Process Skill: *Designing Investigations* posttest adjusted mean of the experimental group was significantly higher than the adjusted mean of the control group. Results of adjusted posttest means are shown in Table 7. The $\underline{F}$ value of 8.42 was significant $\underline{p} < .01$. Eta squared = 0.146 and f= 0.413 represented a large effect.

Table 7: Science Process Skill: Designing Investigations Pre, Post, and Adjusted Posttest Means by Group

Group	n	Pretest Means	Posttest Means	Adjusted Posttest Means	F
Experimental	531	1.083	1.211	1.191[a]	8.42**
Control	398	0.952	1.025	1.052[a]	

[a.] Evaluated as covariates appeared in the model: Pretest Objective 4 = 1.027
**$p < .01$

The Process Skill: *Graphing Data* adjusted posttest means of the experimental group and the control group were not significantly different. Results of adjusted posttest means are shown in Table 8. The F value of 3.163 was not significant at the .05 level.

Table 8: Science Process Skill: Graphing Data Pre, Post, and Adjusted Posttest Means by Group

Group	n	Pretest Means	Posttest Means	Adjusted Posttest Means	F
Experimental	531	1.269	1.343	1.331[a]	3.16
Control	398	1.093	1.209	1.224[a]	

[a.] Evaluated as covariates appeared in the model: Pretest Objective 5 = 1.194

The Process Skill: *Interpreting Data* posttest adjusted means of the experimental group were significantly higher than the adjusted mean of the control group. Results of adjusted posttest means are shown in Table 9. The F value of 12.76 was significant at $p < .001$. Eta squared = 0.141 and f= 0.405 represented a large effect.

Table 9: Science Process Skill: Interpreting Data Pre, Post, and Adjusted Posttest Means by Group

Group	n	Pretest Means	Posttest Means	Adjusted Posttest Means	F
Experimental	531	1.264	1.576	1.547[a]	12.76***
Control	398	1.088	1.271	1.310[a]	

[a.] Evaluated as covariates appeared in the model: Pretest Objective 6 = 1.188
***$p < .001$

Discussion of Findings

In the area of science achievement, the ANCOVA results for the ITBS Science scores showed that the seventh graders involved in the IS activity-based science program had a significantly higher adjusted posttest mean compared to students in a traditional science program. Student sixth grade scores on the ITBS were used as the covariate in the ANCOVA in order to adjust for preexisting differences in science achievement. The experimental group students achieved a six point higher adjusted posttest mean on the ITBS Science test compared to control group students. This was consistent with findings by Bryant et al. (1999) in their comparative study of Alabama schools using IS and Alabama schools not using IS. They found that when schools were matched based on economic and social variables, schools using the IS curriculum had significantly higher science achievement than non-IS schools. They also found that IS schools showed increased improvement in science achievement during the second and third year using the program. Similar positive results in student achievement was found with 9th grade students involved in an activity-based science program (Freedman, 2001).

Meta-analysis studies of activity-based programs support the findings of this study in the area of student achievement. Shymansky, Hedges, Woodworth and Berg (1990), in a meta analysis of 81 activity-oriented science programs, found a significant improvement in science achievement by students involved in science inquiry. Wise (1996) found that inquiry oriented science strategies were more effective than traditional strategies. In the meta analysis of 122 studies on cooperative learning, Marzono, Pickering, and Pollock (2001) found that students using cooperative learning strategies had improved achievement with an effect size of 0.73.

The ANCOVA results for the Science Process Skills test scores showed that students involved in the IS program had a significantly higher adjusted posttest mean compared to students in a traditional science program. Similar results were found in the student impact study of IS students conducted by Harmon and McColskey (1997)

On the process skill of *Identifying Experimental Questions*, both groups showed a decline in pretest to posttest mean and, overall, they scored lower on this process skill than any other process skill tested. The experimental group did show a significantly higher posttest adjusted mean compared to the control group but with a low effect size for the comparison. The decline in both groups may have resulted from this process skill being of high difficulty and being at a formal operational level. Other studies have indicated that most seventh grade students do not function at a formal operational level (Norman, 1992; Renner & Marek, 1990).

In the area of student attitude towards science, no significant difference was found between students involved in the IS program compared to students involved in a traditional science program. This result is consistent with research on science attitude and activity-based programs. The research indicates that attitude may be more of a reflection of classroom and school environment than of the science curriculum (Freedman ,1997; Shymansky, Yore, and Anderson, 2000).

No significant differences in attitude or awareness in science was found by Shymansky, Yore, and Anderson (2000) in a study of student responses in the Third International Mathematics and Science Study of students taught with constructivist, student interactive science teaching strategies. Ebenezer and Zoller (1993) interviewed 72 randomly selected students that had been involved in an activity-based program. They found that classroom teacher behavior variables had more influence on student attitude than curriculum variables.

This study examined three areas of student behavior in order to evaluate the effectiveness of the IS program: science achievement, science process skills, and student attitude toward science. Howard (1995) also examined these three components of student performance in an activity-based science curriculum involving 2875 fourth graders in Kentucky. He reported a significantly higher science achievement, science process skill attainment, and science attitude of students involved in the activity-based curriculum. Howard’s study examined science ability of younger students and used a larger sample. However, he did not utilize any measures that would eliminate preexisting differences between groups.

Harmon and McColskey (1997) conducted a student impact study of the first cohort of students completing three consecutive years of IS. They equated IS and non-IS students by using a matched pairs design of 121 matches of IS to non-IS students of similar race, gender, and academic ability. While Harmon and McColskey found significantly higher scores on science process skills and on student attitude towards their science teacher, they failed to find any significant difference in science achievement between IS and non-IS students.

Conclusions

The participants in this study using the IS curriculum program had significantly higher scores in the areas of science achievement and science process skills when compared to students using a traditional science curriculum. IS students had significantly higher scores on the specific science process skills of Identifying Experimental Questions, Identifying Variables, Designing Investigations, and Interpreting Data. Based on these findings and the research reviewed it can be concluded that students in the IS program had improved science achievement and improved process skill development.

In the area of science attitudes, students in the IS program showed no improvement compared to the control group. This result is surprising considering the increase student involvement in science activities and the increase in social interaction that is stressed in the IS program. Improved IS student attitude was found with students that had been involved in the IS program for all three middle school years (Harmon & McColskey, 1997). Based on these findings it might be expected that the students in this study might show improved attitudes towards science after being involved in the program for longer than one year.

That IS students did not show improved attitudes toward science also points to the importance of continued support and training of IS teachers as they implement the IS program. Research indicated that student attitude is primarily influenced by teacher interaction and class environment. Teachers need continued support and training to ensure that they are creating a class environment that will produce more positive attitudes toward science by their students.

These findings are important to science teachers because they show that activity-based instruction does produce improved student achievement. Activity-based instruction requires more instructional time and a different type of classroom environment to be effective. Many administrators must be convinced that the changes they see in science classrooms are supported by research on improved science achievement for students. These classes look different, students behave differently, and different types of material are covered during lessons. This study increases the evidence that activity-based instruction is worth the instructional time needed and will improve student performance in science.

In *Project 2061: Science for All Americans* it is stated that schools and teachers do not need teach more and more content, but focus on the essentials to science literacy and teach those concepts more effectively. The IS curriculum is one that works to make the connections between the different content areas of science, technology, and mathematics. These are the areas needed for improved science literacy in students. By making the connections between science content, technology, and mathematics and by involving students in real-world science activities, students can begin developing the skills and processes needed to be truly science literate.

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