The Nature of Student Science Projects in Comparison to Educational Goals for Science[1]

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ABSTRACT. The objective of this research was to determine if student science projects in Ohio were meeting educational goals for science as recommended by the American Association for the Advancement of Science, the National Science Teachers Association, and the Ohio Department of Education. In addition, five methods were examined to determine if each had a positive effect on science projects in meeting these educational goals. Teachers from the Diocese of Toledo with students completing science projects in The Ohio Academy of Science's District 2 were asked to rate projects for each aspect of eight educational goals for science defined by this study. Science projects were rated overwhelmingly and consistently positive on each goal. Modeling of skills in the classroom was found to be significantly linked to six of the eight goals for science education. In addition, there was evidence to suggest that participating at a district science fair and supportive help also improved these ratings.

OHIO J. SCI. 96 (4/5): 81-88, 1996

INTRODUCTION

Science Fairs have become very popular in northwest Ohio; 624 students from 42 schools were registered to participate in the Northwest District Science Day in 1995. Science Day was especially popular with Catholic schools in this area. Students from Catholic schools made up 85% of the participants at the 1992 Northwest District Science Day (Czerniak 1996). Since schools were allowed to send only their best students to Science Day, there were many more than 624 students, mostly from Catholic Schools, who completed a science project in northwest Ohio during the 1994-95 school year.

This popularity of science projects is supported by The Ohio Academy of Science. The Academy recommends science projects for all students "regardless of any academic standing or handicap" (Mann 1990, p. 10). Many students participating in science fairs do so because they are required by a teacher to complete a science fair project and many report that their science fair project counted toward their course grade in science (Czerniak and Lumpe 1996). Completing a science project and attending a science fair were purported to have many positive affects for students and their future in science (Mann 1990), however, there exists little research on science fair projects (Slisz 1989).

RECENT RECOMMENDATIONS FOR SCIENCE EDUCATION

Several recent publications were reviewed in order to define a set of educational goals for science which would apply to student science projects. The first was *Science for all Americans*, part of the American Association for the Advancement of Science's Project 2061 (1990). The second report for science education reviewed was *Science/Technology/Society* (STS), endorsed by the National Science Teachers Association (1990). The third reform considered was *Ohio's Science Model Competency Based Program* published by the Ohio Department of Education (1994). Many Ohio schools revised their course of study to conform to the guidelines recommended by Ohio's science model. The three publications had similar ideas leading to the common goal of scientific literacy for students in our schools and all three made recommendations for science that were applicable to student science projects.

EDUCATIONAL GOALS FOR STUDENT SCIENCE PROJECTS

After considering opinions, recommendations, and educational research, we compiled a list of educational goals for science that could apply to student science projects.

1. *Exploration of a real world issue important to the student*: Student science projects will be based on, or centered around, an issue/problem from the world, local or global, that the student finds to be significant.
2. *Hands-on/minds-on*: Student science projects will actively involve the student in "doing" science through observing, measuring, predicting, manipulating equipment, doing experiments, and collecting data.
3. *Scientific knowledge*: Student science projects will teach concepts from the three content domains: life, physical, and earth/space.
4. *Scientific inquiry*: Student science projects will allow students the opportunity to form questions and hypotheses which explore the natural world, to test their own ideas, and to propose solutions to problems.
5. *Higher order thinking*: Student science projects will give students the opportunity to practice higher order thinking skills such as problem solving, using logic, making decisions, forming evidence based conclusions, designing, and creativity/imagination.

[1]Manuscript received 29 February 1996 and in revised form 7 September 1996 (#96-05).

6. *Habits of mind*: Student science projects will allow students to see the value of science and develop curiosity/interest, skepticism, and open mindedness about science.
7. *Integration*: Student science projects will allow students to experience the interrelatedness of the sciences and of science with other disciplines.
8. *Social skills*: Student science projects will allow the student to practice interpersonal skills needed to complete a task, including communication of scientific ideas (written and verbal) and citizenship.

LITERATURE REVIEW

One logical question that came about in reference to these reform reports was whether student science projects were useful in fulfilling some of these new goals for science education. The Ohio Academy of Science believed that they were useful (Mann 1990) as did Gifford and Wiygul (1992). While there were no studies found that directly tested student science projects designed for science fairs, individual student research projects (Tytler 1992) and project-based science classes (Krajcik et al. 1994, Krajcik 1993, Blumenfeld et al. 1991) have been shown in studies to address many of the goals of these reforms for science.

The second question was whether there were methods that would improve the ability of student science projects to meet the eight educational goals. One method to consider is cooperative learning since project-based science is collaborative (Krajcik 1993). Also, Fay (1991) found cooperative group projects integrated into the science class to be successful experiences for students. In Ohio, teams of students are allowed to enter the District, State, and International Science Fairs.

Another factor to consider is teacher modeling of the process skills involved in inquiry which are necessary for a research project. "In order to develop a good project most students will require considerable guidance from their teacher" (Rivard 1989, p. 201). Project-based science, as was recommended by Krajcik (1993), takes place daily in the classroom. "The pursuit of a problem that is of the student's own choosing is a cooperative venture that implies a different student-teacher relationship than the normal autocratic one" (Tytler 1992, p. 410). Including more inquiry learning into the classroom might make student projects more effective at addressing scientific literacy for students.

Three other factors that may affect the success of science projects in addressing the above eight goals are attending science fairs, support of parents, and grade level. In the fall of 1994, science educators in both Catholic and non-Catholic schools received a letter from the Northwest District Science Day chairpeople promoting the educational benefits to students attending the district science fair (Czerniak et al. 1994). Success at this Science Day was found to be linked to parental support (Czerniak 1996). It was also found by Czerniak and Lumpe (1996) that 72% of the entrants in the 1992 Northwest District Science Day were from the 7th and 8th grade. This is supported by the fact that the Diocese of Toledo developed pupil performance objectives in their Course of Study aimed at student science projects for eighth grade students (Diocese of Toledo 1994).

PURPOSE

Our primary focus was to determine whether student science fair projects meet the eight educational goals for science listed above and are a valuable part of a school's science curriculum. We also looked at other factors which might have affected the frequency of student science projects in meeting these educational goals. These factors are; (1) team versus individual projects; (2) teacher modeling of projects; (3) student support by parents and other adults; (4) school attendance at a regional science fair; and (5) grade level. The specific questions addressed by this study are:

1. Do student science projects meet each of the eight educational goals for science?
2. Are there relationships between student science projects meeting each of the educational goals for science and the five factors employed in science fairs?

METHODS

To determine if science projects could meet the science education goals for students in grades 7-12, we focused on schools experienced with student science fair projects. This study was limited to the Catholic Diocese of Toledo's schools within the six counties of District 2 (northwest Ohio) of The Ohio Academy of Science. This study was conducted through a two page questionnaire. Science teachers responded to items designed to assess student science projects completed by their students. A copy of the questionnaire can be seen in Fig. 1.

The questions were designed to match each of the eight goals and five methods for science as defined in this study. The questions were then examined by several professional educators in the field of science. The reviewers' comments were used to develop questions for each goal and method thereby providing a level of validity. The experts' opinions were in agreement that the final version of the questionnaire was worded appropriately and that the content of the questions matched these goals for science education. Since each of the items addressed a separate issue and the scores on the items could not be summed for a total test score, reliability was tested through stability for each of the eight goals and five methods. The questions were grouped into subscales for each goal and method. The test-retest correlation coefficients ranged from 0.46 to 0.90 with an average of 0.69 for all subgroups.

The surveys were administered to all science teachers in the Catholic Diocese of Toledo in the weeks following the district science fair when all projects were completed and the experience was still fresh in their minds. Since the district science fair was in late March, the initial mailing was sent to schools in April. A follow-up letter was sent three weeks after the initial mailing.

The results of the surveys were examined to see how each goal was rated by the science teachers. The frequency

Survey for science teachers *about student* science projects.

Directions: Please fill in the appropriate information in the first box. The following questions, 1-31, ask about your experience with student science projects for the 1994-95 academic year. For each statement decide whether you: strongly agree; agree; are unsure; disagree; or strongly disagree. Then check the corresponding box at the right.

Gender (M/F) ______________ For what grade level(s) do you teach science projects? ____________
Do you (or does your school) require students to complete a science project?
a. no, b. yes all science students, c. yes but only honors science students. d. other (describe) ____________

Students in your class a. must do an individual project. b. must do a team project.
c. may choose to do a team or an individual project. d. may choose to not do a project.
Number of students in your class who completed a team project: ______ boys ______ girls.
Number of students in your class who complete an individual project: ______ boys ______ girls.
Number of students in your class who chose to not complete a project: ______ boys ______ girls.

Are students in your class required to present their project beyond the local school level? (yes/no) ____________
Number of students in your class who presented their science project beyond the local school level:
________ boys on teams ________ boys individually ________ girls on teams ________ girls individually.

	strongly agree	agree	unsure	disagree	strongly disagree
1. Students in my class choose an issue or problem as a topic for their science project.					
2. Students in my class choose a topic for their science project from real world/local issues or problems.					
3. Students in my class choose a topic of personal interest for their science project.					
4. While doing science projects, students in my class use one or more of the following skills: observing, measuring, predicting, or manipulating equipment.					
5. Students in my class do experiments with controlled variables while working on their science project.					
6. Students in my class collect data while working on their science project.					
7. Students in my class learn life, physical, or earth/space science concepts about their topic while doing their science project.					
8. Students in my class form their own questions about the natural world while working on their science project.					
9. Students in my class form their own hypotheses about the natural world while working on their science project.					
10. Students in my class test their own ideas about the natural world while working on their science project.					
11. Students in my class do science projects which involve proposing a solution to a problem.					
12. Students in my class use logical reasoning/thinking skills while working on their science project.					

Please turn this form over and complete the questions on side two.

FIGURE 1. *Survey for science* teachers *about student* science projects.

	strongly agree	agree	unsure	disagree	strongly disagree
13. Students in my class make decisions while working on their science project.					
14. Students in my class form conclusions based on data from their science project.					
15. Students in my class design their own project or experiments.					
16. Students in my class display creativity and/or imagination while working on their science project.					
17. Doing a science project teaches students in my class the value of science.					
18. Doing a science project encourages students in my class to be curious about science.					
19. Doing a science project makes science interesting to students in my class.					
20. Students in my class are more skeptical about scientific facts/theories after doing a science project.					
21. Students in my class are more open minded about science after doing a science project.					
22. Students in my class use more than one area of science while working on their science project. (Biology, Chemistry, Physics, etc.).					
23. Students in my class use skills from disciplines other than science while working on their science project (e.g. English, Art, Social Studies, etc.)					
24. Students in my class work with other people to complete a task while working on their science project.					
25. Students in my class use their writing/ composition skills to share their scientific ideas with others while working on their science project.					
26. Students in my class use their speaking skills to share their scientific ideas with others while working on their science project.					
27. Students in my class see how to be involved in society as a citizen while working on their science project.					
28. Students in my class are encouraged to work on their science project in cooperative groups.					
29. I used examples to show students how to conduct a successful science project.					
30. The type of work students need to do on their science project is like the type of work they need to do in my science class.					
31. Students in my class receive supportive help from their parents or other adults on their science project.					

Thank you very much for taking time to help in this study.

Comments:

FIGURE 1. *Continued.*

of responses in each category: strongly agree, agree, unsure, disagree, and strongly disagree, was reported for each question. A statistical analysis was also completed to address the use of methods. A question by question comparison between district science fair participants and non-participants was conducted using a Mann-Whitney U-test for independent, ordinal data. This comparison was also used to compare projects completed by students in grades 7-8 to those in grades 9-12. Because the three factors of level of team cooperation, modeling, and support by adults were measured on the same Likert scale, a Spearman correlational analysis was conducted to identify links between these factors and the achievement of each goal.

RESULTS

In order to better understand the ratings that teachers gave to student science projects in comparison to the educational goals for science as defined in this study, the participants are first described. This section describes the schools who responded to the questionnaire and the population of students who completed student science projects.

Schools

The questionnaire was mailed to 54 schools in the Diocese of Toledo. Thirty-nine of these schools responded (72%) returning a total of 49 questionnaires. The response rate among Diocese schools known to attend the Northwest District Science Day was 91% therefore, many of the non-responding schools did not complete student science projects. Most of the schools responding (76%) were 7th and 8th grade schools. This is reasonable in that 81% of the schools who were sent the questionnaire were 7th and 8th grade schools. Only 13% of the schools returned an incomplete questionnaire stating that their students did not complete science projects this year. This left 41 usable questionnaires from 34 schools whose students completed science projects in the 1994-95 school year.

Of the 34 schools whose students completed science projects, 94% said science projects were a requirement for their students. Most of these schools required students to complete an individual project (79%). Only 6% said their students must do a team project, and 9% let their students choose either a team or an individual project. The remaining 6% allowed their students to choose not to complete a project. Of the schools that required projects, 31% also required their best students to participate in a science fair beyond the local level.

Student Population

Teachers also reported the numbers of students completing a science project in the 1994-95 school year in several categories. The total number of students reported to have completed a project in their class this year was 1,930. Of this number, 87% of students completed an individual project and 13% completed a team project. Females made up 54% of the total students participating in a science project. Only 25 % of students completing a project participated in a science fair beyond the local level and of this number most (92%) exhibited an individual project and again 54% were female.

Ratings Of Science Projects

The ratings that the teachers gave to student science projects were overwhelmingly positive. One exception to this pattern was question 20: "Students in my class are more skeptical about scientific facts/theories after doing a science project." This was the only question to not receive any strongly agree responses and had a majority of unsure responses. A complete listing of response frequencies is in Table 1.

Methods Affecting Ratings

Teams

From the 41 responses received, only 5 were from schools whose students only completed team projects. Thirty-two responses were from schools whose students completed only individual projects. This is reflected in the high frequency of disagree and strongly disagree responses to question 28: "Students in my class are encouraged to work on their science project in cooperative groups" (see Table 1).

When the ratings on these questions were correlated with the ratings on each educational goal using Spearman's Rho, the correlation coefficients were low, (see Table 2). The ratings of the goals, questions 1-27 were clustered near the positive end of the scale (see Table 1), and the ratings on team projects, question 28, were clustered at the low end of the scale (see Table 1). There was not a large enough spread across the ratings range to show a strong correlation between team science projects and the goals for science.

Modeled In Class

There were two questions, 29 and 30, that asked teachers if they modeled skills necessary to complete a successful science project through examples or the type of work students did in class. Both of these questions received very high ratings (see Table 1). When the ratings on these questions were correlated with the ratings on questions 1-27 (educational goals), using Spearman's Rho, the correlation coefficients were significantly positive for 6 of the 8 goals, (see Table 2).

Supportive Help

Question number 31 asked teachers if their students received supportive help from their parents or other adults. This question also received high ratings (see Table 1). When the ratings on this question were correlated with the ratings on questions 1-27 (educational goals), using Spearman's Rho, the correlation coefficients were low (see Table 2). Only two significant relationships were found, goal 5, higher-order thinking and goal 8, social skills. Again there was not a large enough spread across the ratings range to show a significant correlation between supportive help and the goals for science.

Science Fairs

Thirty teacher responses from the 41 had at least one student who participated in a science fair beyond the local level. The remaining eleven responses were placed in the group that did not participate in a fair beyond the local level. These two groups were compared through a Mann Whitney U test (see Table 3). Only two goals, higher order thinking and habits of mind, were found to be rated differently by these two groups of teachers. Both goals were rated higher by teachers from schools that participate in a district science fair.

Grade Level

Most of the questionnaires received, 33 out of 41, were from 7th and 8th grade schools. Eight responses were from high schools. These two groups were compared through a Mann Whitney U test. Any differences in the goals were not large enough to be significant.

Table 1

Response frequencies by question for Goals 1-8 and and Methods 1-3.

		Strongly Agree (%)	Agree (%)	Unsure (%)	Disagree (%)	Strongly Disagree (%)
Goal 1.	Question 1.	44	44	7	2	2
	Question 2.	12	61	7	17	2
	Question 3.	51	37	7	2	2
Goal 2.	Question 4.	90	10	0	0	0
	Question 5.	73	24	2	0	0
	Question 6.	85	10	2	2	0
Goal 3.	Question 7.	66	32	2	0	0
Goal 4.	Question 8.	34	61	5	0	0
	Question 9.	44	49	7	0	0
	Question 10.	46	37	15	2	0
	Question 11.	46	37	10	7	0
Goal 5.	Question 12.	61	34	2	2	0
	Question 13.	61	39	0	0	0
	Question 14.	66	29	5	0	0
	Question 15.	39	51	5	5	0
	Question 16.	45	50	5	0	0
Goal 6.	Question 17.	44	44	10	2	0
	Question 18.	49	46	2	2	0
	Question 19.	44	44	7	2	2
	Question 20.	0	32	51	15	2
	Question 21.	7	61	32	0	0
Goal 7.	Question 22.	17	54	15	15	0
	Question 23.	61	39	0	0	0
Goal 8.	Question 24.	27	49	15	10	0
	Question 25.	59	39	0	2	0
	Question 26.	66	34	0	0	0
	Question 27.	7	34	46	10	2
Method 1.	Question 28.	7	20	5	54	15
Method 2.	Question 29.	58	33	5	5	0
	Question 30.	41	46	5	7	0
Method 3.	Question 31.	46	44	7	2	0

TABLE 2

Spearman Correlation Coefficients for Methods 1, 2, and 3 by Goals 1-8.

Goal	Teams	Modeling	Supportive Help
1. Real World Issues	.1040 p = .517	.4208* p = .006	.1507 p = .347
2. Hands-On/Minds-On	.0441 p = .784	.1385 p = .388	.0384 p = .812
3. Scientific Knowledge	.0536 p = .739	.1664 p = .298	.0614 p = .703
4. Scientific Inquiry	.0376 p = .816	.5368* p = .000	.7046 p = .199
5. Higher Order Thinking	.0462 p = .774	.6158* p = .000	.3290* p = .036
6. Habits Of Mind	.0307 p = .849	.5628* p = .000	.3016 p = .055
7. Integration	.1244 p = .438	.3174* p = .043	.2161 p = .175
8. Social Skills	.1005 p = .532	.5977* p = .000	.4710* p = .002

n = 41, * significant at 0.05.

DISCUSSION

Science projects were rated overwhelmingly and consistently positive on each of the eight educational goals for science as defined by this study. In the minds of teachers, science projects are an effective way to address the new educational goals for science. The rating frequencies show that teachers think science projects are especially effective in incorporating hands-on/minds-on science with the goal of scientific knowledge being rated second highest. Teachers also rated science projects well on using scientific inquiry and higher order thinking skills through explorations of real world issues important to the student. The goal of integration was rated highly although it is ironic that teachers felt the sciences were not integrated nearly as well in a science project as were other disciplines such as English.

While teachers also rated science projects highly on the remaining goals, they did have some misgivings on some parts of them. Under the goal of social skills, students were sharing scientific ideas verbally and in writing. Less often, students were working with other people to complete a task and teachers were very unsure if students were learning citizenship. Three of the five parts of habits of mind were rated high: value, curiosity, and interest in science. Teachers were less sure if their students

TABLE 3

Mann Whitney U Test for Method 4 versus Goals 1-8.

Goal Cases	School participates in District Fair n = 30 Mean Rank	School does not articipate in District Fair n = 11 Mean Rank		
1. Real World Issues	21.47	19.73	z = 0.4214	p = .6735
2. Hands-On/Minds-On	21.40	19.91	z = 0.4534	p = .6502
3. Scientific Knowledge	22.43	17.09	z = 1.5311	p = .1258
4. Scientific Inquiry	22.82	16.05	z = 1.6212	p = .1050
5. Higher Order Thinking*	23.60	13.91	z = 2.3258	p = .0200
6. Habits Of Mind*	23.25	14.86	z = 2.0071	p = .0447
7. Integration	22.08	18.05	z = 1.0121	p = .3115
8. Social Skills	22.45	17.05	z = 1.2954	p = .1952

*significant at 0.05

were more open minded after completing a science project and they were very unsure that students were more skeptical. The question about skepticism was the only part of any goal to not receive any high ratings. Perhaps the word skepticism, which sounds negative, or teacher misunderstanding of the value of skepticism, is behind the low ratings. These teachers were enthusiastic about science projects and might not have wanted to rate them high on something that sounds negative or perhaps this is one area were science projects are not effective.

Instructional Methods

While the results in this section were not as overwhelmingly positive, some inferences can be made. There is evidence that several of the five methods hypothesized did have an influence on how highly science projects were rated by teachers.

Cooperative learning is highly recommended in the literature. It is especially recommended for improving higher order thinking skills, and attitudes (habits of mind). In spite of all the arguments for cooperative learning, teachers do not encourage it; in most cases teachers required that students complete individual projects. This resulted in a very small percentage of schools whose students completed team projects. Even when team projects were rated more positively than individual projects, the small size of the total sample and the fact that very few teachers encourage group work made it difficult to prove any of these differences. It would be interesting to find the reason behind teachers' reluctance to use cooperative learning. Additional research in this area to show a relationship between team projects and educational goals may help teachers to see this as a valuable method for students.

Valuable experience may be gained in class through examples given by the teacher and the type of work students do in class. Nearly all of the teachers reported that they use these types of modeling; 91% use examples and 87% have their student do work in class like the work students do on science projects. These high ratings may in part be due to self reporting. Teachers may hesitate to report that they do not help students with science projects through modeling. Even so, modeling was found to be directly related to achieving the goals for science. The correlation between these types of modeling and each goal was significant for six of the eight goals. Perhaps teachers who see value for students in science projects incorporated the skills used when completing these science projects into their daily teaching. Either way, the goals for science are achieved in science projects and in the classroom.

Supportive help was also rated highly by teachers. This is an area with which teachers are familiar, but they may not see the full extent of the support students receive from their parents and other adults. The correlation coefficients between supportive help and each of the educational goals were insignificant on all but two goals (higher order thinking and social skills). Again, the small sample size and the concentration of high scores on both support and on each goal made it difficult to show a significant correlation between the two. The fact that two goals were found to be related to supportive help suggests that a larger sample may show that the other goals are also related to supportive help. A rating scale that resulted in a wider range of scores would also be helpful in showing a relationship.

Science fairs are highly recommended although there is little research on this subject. In this study, from the sample of 41, only 11 schools participated in a science fair beyond the local level. In spite of the small sample, two goals were still found to be rated significantly higher by schools attending a district science fair. The two goals linked to science fair participation were goal 5 (higher order thinking) and goal 6 (habits of mind). One explanation for these differences may be that teachers who most strongly believe science projects are valuable encourage their students to work harder and encourage them to go to a science fair. A larger sample with more schools that participate in a district science fair may be able to show more of these goals positively related to science fair participation.

It was expected that differences would not be found in teacher ratings based on grade level and this was found to be true in this sample. Teachers from grades 9-12 did not rate science projects higher than did teachers from grades 7-8. The experience of older students may not be necessary to be more successful with a science project based on the educational goals for science.

While this study shows that teachers clearly feel that science projects are effective in meeting educational goals for science, it may be worthwhile to study these science projects directly. Teachers' opinions are valuable but may be biased by their strong support of science projects. More information may be obtained through an individual evaluation of a cross section of different types of student science projects. Students themselves may also have opinions on the value of science project that would be informative. Data collected directly by the researcher would be more reliable than data collected from many different teachers. Direct observation of a selection of science projects would also be a way to increase the sample size of team projects, non-fair projects, and 9-12 grade projects. An expanded rating scale to better show differences from agree to strongly agree is also recommended.

Science projects appear to be an important part of science education. Teachers feel that student science projects are meeting the educational goals for science. Experience through modeling the necessary skills in the classroom has the strongest relationship to science projects meeting these goals. Participation in a science fair beyond the local level, and supportive help from parents and other adults may also improve the effectiveness of student science projects By utilizing these methods, more teachers may be able to address the goals of the National Science Teachers Association, the Ohio Department of Education, the Ohio Junior Academy of Science, and the Diocese of Toledo.

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