Longitudinal Impact of an Inquiry-Based Science Program on Middle School Students' Attitudes Toward Science

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ABSTRACT: This study examined the long-term impact of the Summer Science Exploration Program (SSEP), a 2-week inquiry-based science camp, conducted at Hampshire College Amherst, MA from 1992 to 1994. The goal of the program was to stimulate greater interest in science and scientific careers among middle-school students. One hundred fifty-eight students were selected from a pool of applicants to attend the program using stratified random sampling procedures. In 1996, 22 participants were selected to participate in follow-up interviews using stratified random sampling procedures. Two quantitative surveys, the Science Opinion Survey and the Career Decision-Making Revised Surveys, were administered to 79 SSEP students and 35 students who applied but were not accepted (the control group). Pretest and posttest scores were analyzed for any significant change over time. Additionally, a cohort of over 500 students who were enrolled in the same grades and public schools that SSEP students attended completed the two surveys in both 1992–1994 and 1996–1997. The interviews and surveys suggested that SSEP students maintained a more positive attitude towards science and a higher interest in science careers than students who applied to the program but were not selected. *Sci Ed* **86:**693–705, 2002; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/sce.10039

INTRODUCTION

The American Association for the Advancement of Science (AAAS) (1993) and the National Research Council (NRC) (1996) endorse science curricula that actively engage students in science using an inquiry-based approach. This approach has shifted the focus of science education from the traditional memorization of facts and concepts in separate specific disciplines to inquiry-based learning in which students seek answers to their own questions. The pedagogy advocated for is an inquiry approach, in which students are

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actively engaged using both science processes and critical thinking skills as they search for answers.

Many studies conducted with middle and high school students found that inquiry-based science activities had positive effects on students' science achievement, cognitive development, laboratory skills, science process skills, and understanding of science knowledge as a whole when compared to students taught using a traditional approach (Chang & Mao, 1998; Ertepinar & Geban, 1996; Geban, Askar, & Ozkan, 1992; Mattheis & Nakayama, 1988; Padilla, Okey, & Garrand, 1984; Purser & Renner, 1983; Saunders & Shepardson, 1987; Schneider & Renner, 1980; Wollman & Lawson, 1978). Perhaps, as Hodson (1990) suggested, inquiry-based learning is a more effective way for students to learn science. Additionally, studies have shown that students who use an inquiry approach have improved attitudes towards both science and school while other studies show more negative attitudes resulting from traditional methods (Gibson, 1998a, 1998b; Jaus, 1977; Selim & Shrigley, 1983; Shrigley, 1990).

Most research on middle and high school inquiry-based science programs examined students' achievement test scores or process skills as their comparison measures. However, the long-term impact on students' attitudes towards science and interest in science careers has not been explored. For example, Chang and Mao (1998) compared the impact of 2 weeks of traditional lecture-type instruction to 2 weeks of inquiry-based instruction on secondary students' achievement in earth science. They found that students who were taught using the inquiry-based instructional method scored significantly higher on an achievement test than those who were taught using the traditional lecturing approach. Similarly, Padilla, Okey, and Garrand (1984) studied the impact of a 14-week unit on integrated process skills (controlling variables, interpreting data, formulating hypothesis, defining operationally, and experimenting) on middle school students. In contrast, the control group received no direct instruction on integrated process skills. After 14 weeks they found that middle school students in the treatment group had significantly higher scores in process skills than the control group. Both studies demonstrated positive impact immediately following the treatment program, but the long-term outcome was not assessed.

Some short-term studies have shown that students who use an inquiry approach have improved attitudes towards science. These same studies show negative attitudes resulting from traditional methods. For example, Selim and Shrigley (1983) compared two instructional modes, discovery and expository, for teaching science knowledge to fifth grade students. The treatment period was 21 days. After the treatment period, they found that students taught by teachers using the discovery approach (an inquiry approach) had a more positive science attitude than the control group who were taught by teachers using the traditional lecture approach.

In summary, the above studies indicate that students who learn science using an inquiry approach score higher on science achievement tests, have improved science process skills, and have more positive attitudes towards science, when compared to students taught using a traditional approach. However, all of these studies investigated the influence of inquiry-based science in comparison to traditional science at the end of a treatment period, which ranged from 2 weeks to 1 school year. A review of the literature suggest that few studies if any have been done that explore the long term impact of inquiry-based science instruction on students' attitudes towards science and interest in science careers.

Background

The purpose of this study was to evaluate the long-term effects of an inquiry-based program, the Summer Science Exploration Program (SSEP), conducted at Hampshire College from 1992 to 1994. The goal of the program was to increase middle school students' interest

in science and scientific careers. Over a 5-year time span, surveys were conducted to measure attitudes towards science and career interests among SSEP participants before they came to Hampshire College and several years later during the 1996–1997 school year. The same surveys were given to the classmates of SSEP participants throughout the study period to measure attitudes toward science among their peers.

SSEP focused directly on students. This was a summer science camp operated on the Hampshire College campus for students entering grades seven and eight. Over a 3-year period, a 2-week summer program was offered to a total of 158 middle-school students. SSEP students were selected from three urban school districts in Western Massachusetts. These districts were chosen for their proximity to Hampshire College, their demonstrated need for science education support, the demographics of their student population. Also, there was a successful partnership history on several earlier projects.

Application and screening procedures were used to ensure a balance in ability, gender, and ethnicity. Students were stratified by these factors to assure an equal number of females and males of different abilities and different ethnicities had the opportunity to participate in the summer science camp. Participants were then randomly selected from each of the stratified groups. Stratified random selection was used for two reasons. First, Hampshire College could not, in good conscience, devise a rational procedure for choosing one student over another. Second, Hampshire College wanted to test the effectiveness of these programs with students of all levels of ability and interest, not just the best and brightest or those interested in science.

The SSEP provided students with the opportunity to explore different biological and health related subjects through inquiry-based learning. Students who participated in this program learned how to formulate their own questions, which could be addressed experimentally or through observation. Students designed experiments and practiced laboratory and field techniques that could be used to answer their questions. They also analyzed data through examining their own experiments and those of others. In addition, the college science labs provided students with the opportunity to engage in study that went beyond what the students experienced in their middle school science classes.

Selected middle-school teachers worked together with Hampshire faculty and students to teach in the program. The college faculty brought access to the latest equipment and technology and extensive knowledge and experience in research. The middle-school teachers brought highly skilled teaching capabilities and experience dealing with young teenagers. Together they were able to create an air of excitement and a sense of security. The program was designed to excite students' natural curiosity, to provide hands-on laboratory and field experiences, and to give students confidence that "they could do science."

The SSEP Program and curriculum is extensively described in the recently published book, *School/College Partnerships; Inquiry-Based Science and Technology for All Students And Teachers* (Bruno & Chase, 1998). A sample problem that students investigated at Hampshire (p. 19)

> Students worked with skeletal specimens and microscopes to identify indicators of disease and nutritional deficiencies and to understand how muscles and bones worked together . . . Throughout the program, students asked questions, collected data, and came up with theories based on their observations. Class discussions to compare data and different conclusions provided opportunities for students to practice scientific inquiry skills. Students always learned to complete their reports and discussions by making new lists of questions that would be interesting to answer next.

In the context of this study, inquiry-based SSEP activities involved students being engaged in answering scientifically orientated question, gathering data (evidence) which

allowed them to develop explanations, evaluating their explanations in light of alternative explanations, and communicating and justifying their proposed explanations. These are the essential features of classroom inquiry mentioned in *Inquiry in the National Science Education Standards* (NRC, 2000).

METHODOLOGY

Subjects

Three different subject groups were used in this study: SSEP students, SSEP control group, and the non-SSEP school cohorts (see Table 1). The sample of SSEP students who were followed longitudinally consisted of 79 out of the 158 students who originally participated in the summer program. From the pool of 79 SSEP students, 22 students were randomly selected for interviews after they were sorted by ethnicity and gender. Interviews were conducted with a total of 6 White females, 5 White males, 4 African American females, 2 African American males, 3 Hispanic females, 1 Hispanic male, and 1 Asian American male. The number of students chosen in each category reflected the ethnic and gender balance of the students who participated in the program. Of the 22 students selected for interviews, 6 attended camp in 1992, 7 attended in 1993, and 9 attended in 1994.

The SSEP control group consisted of students who applied to the program but, by chance as described above, were not chosen to participate. Survey responses from the controls were incomplete over the 5-year study, making comparisons difficult to do. Out of the 35 controls, survey responses from only 8 children were obtained during 1992–1994 and again in 1996–1997. In addition, survey responses from another 22 controls were obtained in 1996–1997, but earlier data from these children was not available. A longitudinal control group of only 8 children is small and may not be representative of those who applied but were not accepted to SSEP. However, as described below (see Tables 2 and 3), this group's survey results during 1992–1994 were comparable and in fact higher than the SSEP group. Their 1996–1997 results also were comparable to the other 22 controls. Therefore, this group was included in the longitudinal analysis for comparison purposes because they were part of a true control group with the same initial interests in SSEP science programs as the "experimental" group who were selected.

The non-SSEP school cohort group consisted of classmates enrolled in the same public schools that SSEP students attended. This cohort group allowed us to determine how the

TABLE 1
Participants in This Study

Groups	No. of Students
SSEP Participants	
Students who attended summer camp	158
Students who were followed longitudinally	79
Students who were interviewed	22
Controls	
Students who applied to attend summer camp but were not selected	35
Students who were followed longitudinally	8
Students who only were surveyed in 1996–1997	22
Non-SSEP Cohorts (Peer Group)	
7th and 8th Graders (1992–1994)	638
9th–12th Graders (1996–1997)	333

TABLE 2
Students' Science Attitude Mean Scores

Group	No. of Students	1992–1994	1996–1997
SSEP	79	0.96	0.78
Control	8	1.38	0.49
	22		0.44
Non-SSEP	300–600	0.28	−0.06

attitude of students towards science who attended summer camp compared with their peers. A cohort of over 500 students in grades 7–12 completed the two surveys in both 1992–1994 and 1996–1997.

Surveys

Students' scores over time were compared on two surveys: the Science Opinion Survey and the Career Decision Making System–Revised (CDM-R). Student responses to each survey were highly correlated ($r = 0.64$).

The Science Opinion Survey produced by the National Association for Educational Progress is a 30-item questionnaire, first developed at Florida State University in the late 1980s. This questionnaire was later adapted for the science framework in the 1996 National Assessment of Educational Progress (NAEP). Complete details about the science framework and 1996 survey are described in NAEP reports on Student Work and Teacher Practices in Science (O'Sullivan & Weiss, 1999) and the NAEP 1996 Technical Report (Allen, Carlson, & Zelenak, 1999). The Science Opinion Survey assesses current interest and attitudes in science activities at school. The Science Opinion Survey uses a 5-point scale (*Strongly agree*, *Agree*, *Not Sure*, *Disagree*, *Strongly Disagree*) to rate statements about science activities. Sample items are "Science lessons are fun; I really enjoy going to science lessons; I would like to be a scientist when I leave school; Working in a science laboratory would be an interesting way to earn a living; I look forward to science lessons; Science is one of the most interesting school subjects." Responses were scored on a scale from -2 to $+2$ with statements coded so that positive scores indicated an interest in science.

Career Decision-Making System–Revised, Level 1 (CDM-R) was developed by Harrington and O'Shea (1992). The CDM-R is a comprehensive career interest survey. Students rate their likes and dislikes on 96 questionnaire items that describe career activities using a 3-point rating scale (*like*, *not sure*, *dislike*). Level 1 was specifically designed for younger students, written at a fourth grade reading level. Reliability alpha coefficients range from 0.88 to 0.93 with test–retest correlations from 0.74 to 0.87. A sample of these items include "Perform scientific studies; Do research work; Do scientific studies of the sun, moon, planets, and stars; Do research on using the sun's energy to heat homes; Do scientific

TABLE 3
Students' Interest in Science Careers Mean Scores

Group	No. of Students	1992–1994	1996–1997
SSEP	79	21.79	19.30
Control	8	21.63	8.93
	22		8.05
Non-SSEP	300–600	13.65	10.23

studies about nature; Take a biology course." The items were totaled for six different career interests, one of which was science. Students' interest in science careers mean score could range from 0 to 32. Scores in the range from 0 to 15 suggest a lower interest in a science career, whereas a score above 16 indicates a higher interest in a science career.

Survey Administration Procedure. The surveys were administered to SSEP students at the beginning of the first day of the program. The follow-up surveys were administered during the fall of 1996, several years after students participated in the program. The non-SSEP school cohort completed both surveys in their local schools. Surveys were administered by Hampshire College research staff.

Interview Procedure

Semi-structured interviews were used to allow the researcher to be flexible and adapt the questions to each particular interview session. Three areas of interest investigated during the interviews were (1) students' academic life, (2) students' science education, and (3) students' experiences while attending SSEP. With a list of topics to cover and suggested questions (e.g., How do you feel about science in general and explain why?, How did the summer program affect you attitude towards science?, How do you think science should be taught?) the researcher introduced the topics of conversation and through questions steered the course of the interview.

The interviews were conducted during fall 1996. The researcher called students who were chosen for the interviews and asked for permission from the student and the parents to come to their homes at times that were convenient for students. The interviews were either conducted right after school or in the early evening. Parents and students were required to sign a permission slip before the interviews were conducted. The interviews were audio recorded and later transcribed. (Each interview lasted about 1 h.)

The resulting data from the interviews were coded using HyperRESEARCH (ResearchWare, 1994), a content analysis tool designed for qualitative assessment. This computer software helped to identify commonalties and draw conclusions about typical themes that emerged from the interviews (Borg & Gall, 1989). HyperRESEARCH aides the qualitative researcher in coding large quantities of data involved in a research project, as well as analyzing the data and reaching reliable, verifiable conclusions. The following are some examples of the codes that were used to sort the interview data: positive atmosphere, interest in science, I like science when, schools influence, teachers influence, wants a science career, and family into science. These codes were used to identify common themes.

Quantitative Assessment Design

The survey results from the three subject groups (SSEP students, non-SSEP cohorts, and the SSEP control group) were compared longitudinally and cross sectionally to measure developmental changes in student attitudes toward science using a quasi-experimental design (Cook & Campbell, 1979). The cross sectional comparison examined two groups of students who differ in age on the assumption that differences found are primarily related to maturation. Potential sources of error in this design involve selection bias of subjects and mismatch between groups on other important demographic variables. Longitudinal comparisons avoid these errors by allowing a direct comparison of a student's attitude changes over time, but introduce other potential sources of error. Since time has passed between baseline and posttest measures, other events will influence a student's responses, and repeated evaluations also could bias their answers. The combination of both procedures gives added strength to the design. When two comparisons are made, one which is longitudinal and another which is cross sectional, each can confirm the results of the other, providing

converging evidence which is mutually supportive, since the potential errors from the two methods arise from different sources.

QUANTITATIVE RESULTS

Four different questions were assessed with the quantitative analysis. First, what differences in attitudes toward science and scientific careers existed between students who expressed an interest in attending SSEP and their peer group? Second, how did attitudes toward science change as students matured from middle school to high school? Third, did the SSEP have a long-term impact on increasing or sustaining student interest in science? And fourth, were there differences in the three SSEP program years that had a long-term impact on student attitudes toward science? Following the design principles described above, these questions were examined in both cross sectional and longitudinal analyses.

Cross Sectional Comparison. Survey responses were organized into six different groups and compared in an ANOVA factorial design. The groupings consisted of the SSEP, Control, and Non-SSEP participants and their two sets of responses from 1992 to 1994 and from 1996 to 1997. Results for the Science Attitude and CDM surveys are presented in Tables 2 and 3, respectively. Strong group differences were found for the Science Attitudes survey (F (5, 1102) = 31.10, $p < 0.0001$) and the CDM (F (5, 1161) = 30.59, $p < 0.0001$) with power of 1.00 for both. Student-Newman-Keuls posthoc analyses were performed for each survey with a significance level of 0.05 using the harmonic mean to estimate n because of unequal group size.

Looking only at differences that were consistent from both surveys, several patterns were found. First, prior to participating in the SSEP program, SSEP participants and controls both had a stronger interest in science than their peer group (non-SSEP cohort), but they were not different from each other. Second, interest in science decreased from middle school to high school for all three groups, but only the controls showed a statistically significant decrease on both surveys. Finally, by high school the controls had about the same degree of interest in science as the non-SSEP cohort, but the SSEP group's interest remained significantly higher than both the controls and their other peers.

Longitudinal Comparison. Longitudinal data was available from 79 SSEP participants and 8 controls. Both groups were compared in an ANOVA mixed-factorial design using the same data summarized in Tables 2 and 3. For the Science Attitude survey, there was no difference between groups, but there was a significant decrease in attitude from 1992–1994 to 1996–1997 (F (1, 85) = 10.37, $p = 0.002$, power = 0.91). A significant interaction between group and time (F (1, 85) = 4.53, $p = 0.04$, power = 0.55) showed that controls lost more interest in science between middle school and high school than the SSEP participants, although the power of the effect was weak due to the small size of the control group.

An ANOVA on the CDM survey produced a similar pattern of results with no group effect, a significant decrease of interest in science careers from middle school to high school (F(1, 85) = 9.82, $p = 0.002$, power = 0.89), and a weak interaction (F(1, 85) = 3.37, $p = 0.07$, power = 0.43). The pattern of the interaction was consistent with the Science Attitude data, suggesting that as they grew older, controls lost more interest in science careers than the SSEP participants.

Longitudinal Comparison of Three SSEP Years. An additional longitudinal analysis was made to compare effectiveness of the different programs offered in each of the 3 years the camp was held. Revisions to the camp program occurred each year (see Bruno

& Chase, 1998 for details); perhaps some of the changes were more beneficial than others. Survey data from the Science Attitude and CDM questionnaires were compared from each camp year using ANOVA in a mixed-factorial design. For the Science Attitudes survey, there were no main effects but there was a statistically significant interaction (F (2, 76) = 3.24, $p = 0.05$) between students' science attitude mean scores and the year students attended camp (see Table 4). For students who attended camp in 1993, the scores on the science attitude survey showed a decrease from 1993 to 1996. For those students who attended camp in 1992 and 1994, the scores on the science attitude survey showed no change over time.

An ANOVA of the CDM survey showed a similar pattern of results for students' interest in science careers (see Table 5). There was no significant effect for the SSEP year, a marginally significant drop in their scores over time (F (1, 76) = 3.63, $p = 0.06$), and a marginal interaction ($p = 0.10$). The interaction appeared to come from larger decease in science career interests among those who attended SSEP in 1993, whereas interests in science careers among students who attended camp in 1992 and 1994 remained relatively unchanged as they matured.

It is unlikely that these interactions were the result of variability between the time when SSEP student baseline measures were taken and outcome assessed in 1996. Ideally, the effects of variable time lapses (4 years for 1992 SSEP, 3 years for 1993 SSEP, and 2 years for 1994 SSEP) could be sorted out by additional surveys conducted during the intervening years. However, such measures were not made. Considering that the 1992 and 1994 SSEP groups that had the largest difference in the time lapsed between baseline and outcome measures showed similar results, the difference in time lapsed for the 1993 SSEP group was probably not a contributing factor.

Another possible explanation is related to the design of the 1993 camp program. At that time Hampshire College had, for several years, been running a summer workshop for the Coalition of Essential Schools. This summer workshop was designed to train teachers in how to use an inquiry-based approach to learning in science classrooms. In 1993, Hampshire combined parts of the two programs. During part of the SSEP program the Coalition of Essential Schools teachers conducted classes with SSEP students. The Coalition teachers were not experienced working with junior high students and were still learning about how to use an inquiry-based approach in their classrooms. Further evidence for the effectiveness of specific program activities 1992 and 1994 and detrimental comments about the 1993 program were found in the interviews with students. For these reasons, the 1993 SSEP program may not have been as successful as the other two summers.

Summary of Quantitative Results

A consistent pattern of results emerged from both the cross sectional and longitudinal analyses.

- Throughout middle school and high school, SSEP students and the students who applied to attend summer camp but were not selected to participate had a

TABLE 4
Students' Science Attitude Mean Scores

Year	No. of Students	1992–1994	1996–1997
1992	21	0.63	0.69
1993	31	1.11	0.64
1994	27	1.03	1.00

TABLE 5
Students' Interest in Science Careers Mean Scores

Year	No. of Students	1992–1994	1996–1997
1992	21	19.38	20.38
1993	31	22.36	17.42
1994	27	23.00	20.63

more positive attitude towards science and interest in science careers than their classmates.

- All students' attitude towards science and interest in science careers decreased as they went from middle to high school.
- Students who applied but were not accepted to SSEP started off with a high interest in science, like SSEP students. However, their interest in science decreased much more than SSEP students' interest in science over the time period studied, and dropped to the same level of interest expressed by the non-SSEP peer group.
- The quality of the camp experience appears to have made a difference to students—as suggested by the decrease in science interest among students who attended a weaker program during 1993.

QUALITATIVE RESULTS

Students who attended SSEP had the opportunity to explore science in a fashion that helped them understand that science could be fun and interesting to do. Seventy percent of the students interviewed mentioned that they really enjoyed the experience. Furthermore, 77% of the students said that the summer camp experience increased their interest in science. The following excerpts demonstrate what made science at camp enjoyable and interesting for students.

> Student 5: I remember it was fun. I remember going to a pond once and we got tadpoles and bugs and all that. I liked doing that. Dissecting was good. We dissected a sheep's brain, a sheep's eyeball, and a cow's heart. At first I thought it would be disgusting, but once you actually did it, it wasn't that bad.

> Student 10: We would like dissect frogs, we dissected a cow's brain and the heart from a sheep. The teacher was real nice. We watched a lot of videos. It was really fun. I really had fun with science. Teachers made it fun, so it made it enjoyable to learn science. You learned science and it was fun.

Many aspects of the program made it enjoyable. Students reported that they liked doing hands-on laboratory activities, the content covered at camp was interesting to them, and the teachers created an enjoyable atmosphere in which to learn. Thirty-two percent of the students interviewed talked about how SSEP staff created a positive atmosphere for learning. SSEP students said they felt safe to voice their opinions and share information with one another. The data collected clearly shows that SSEP staff created an environment that fostered and nurtured students' innate curiosity and questioning and the sharing of ideas.

> Student 2: When I went there it wasn't that stuff you get taught by a teacher like sit down and be quiet. You get to talk to people, discuss things, explain your ideas, you have an opinion, you speak about it, and you have freedom. Learning is fun if you're in the right environment.

> Student 4: I learned to open up more, to let others know what I think. I have always been afraid of participating because I was afraid of getting the wrong answer but I wasn't afraid at Hampshire College. I didn't have to be afraid.

In many classrooms students are afraid to speak up for fear that they may give the wrong answer or be criticized by their peers. In contrast, SSEP staff was able to create an environment where students felt safe to voice their opinions and share information with one another. Communicating and justifying explanations are some of the essential features of inquiry in the classroom. SSEP students had the opportunity to discuss issues with their peers while they were at summer camp. They enjoyed doing science at camp. Analysis of the interview transcripts, using HyperRESEARCH, revealed some of the factors that influence students' enjoyment of science at school. Here are a few examples of what they said:

> Student 2: I like science but I don't like the structured science they give you at school. When I went to the program it was a lot more hands-on touchy freely. I guess in school they just don't have that kind of time. There's a limit.

> Student 15: I like science. It's a pretty good subject but it all depends on how you learn it. If a teacher breaks it down for you, if she really goes in-depth in the subject instead of like my teacher now who just gives the notes and expects you to learn everything. At my age, you stop and look and say "Am I ever going to use this in life?" and I think that's a big problem because you gain a negative aspect of the subject.

The interviews indicated that students were able to identify some of the key components, advocated for in science education reform, that are needed to improve science teaching and learning. Students want less structured science classes with less time devoted to lectures and note taking. Instead, they want the opportunity to do hands-on science activities that are relevant to their lives, the chance to discuss issues, and the time to explore issues in-depth. *Inquiry in the National Science Standards* stresses the importance of science that is relevant to students lives in the following excerpt: "Fruitful inquiries evolve from questions that are meaningful and relevant to students" (NRC, 2000, p. 24). According to the students interviewed, the greatest influence on students' attitude and interest in science appears to be their science teachers. Over 60% of the students interviewed spoke about their science teachers' influence.

> Student 1: Last year my science teacher wasn't good. He just made us read and do questions. If it's just that all the time then it's not interesting. There's not much you can do with that and the teacher wouldn't give you a chance to talk. He would just make us do questions and read. That's it.

> Student 6: In chemistry this year we don't get to ask questions, we take notes, read the chapter, do vocab, than take a test. My biology teacher last year loved biology, it was great. I had so many questions, it was so interesting.

The above interviews with SSEP students suggested that teachers' instructional methods have an impact on students' attitudes towards science. In addition, Student 6 above identifies the importance of the learner having his or her own questions. Student generated questions play an important role in inquiry-based science classrooms. Good science teachers know how to use students' questions to guide instruction. The data collected from the interviews also helped us identify several other important factors that had positive influences on SSEP students' attitude and interest in science. These factors included parents, the schools students

attended, school officials, outreach programs, television, and science clubs. These factors were not related to participation in the SSEP program.

Summary of Qualitative Results

- Seventy percent of the students interviewed said they really enjoyed the summer science camp experience.
- Seventy-seven percent of the students interviewed said that the summer camp experience increased their interest in science.
- Thirty-two percent of the students interviewed talked about how SSEP staff created a positive atmosphere for learning.
- Many factors besides SSEP affected students interest in science, including teachers, parents, schools attended, school administrators, after-school programs, television, and science clubs.

CONCLUSION

The comparison of non-SSEP students' science attitude data from 1992 to 1994 with data from 1996 to 1997 indicated that at both times the high school students had a lower interest in science than the middle school students. This change may be due in part to differences in the way science courses are taught. Many science teachers in the middle schools of the students who participated in the study used a hands-on, inquiry-based approach in their classes. However, these students' high school science teachers used traditional teaching methods, which included lectures, note taking, and lab demonstrations rather than student-directed lab explorations.

The interviews conducted with SSEP students suggested that many of these students do not enjoy science when their only activities involve note taking, lectures, and demonstrations. Students said in the interviews that they preferred having the opportunity to be more directly involved in asking their own questions and to participate directly in the laboratory exercises. These findings suggest that when science is taught using an inquiry-based approach, students remain interested and become motivated to put more effort into their studies.

The Long-Term Impact of SSEP

The comparison between students who applied but were not accepted, and students who went to camp, indicated that over the years, SSEP students maintained a more positive attitude towards science and a higher interest in science careers. In contrast, students who applied and were not accepted showed a decrease in attitude towards science and interest in science careers over time. Attending SSEP helped students maintain a high interest in science, helping to sustain them through science courses in high school that they did not like.

Students who participated in SSEP were actively engaged in science using a hands-on inquiry-based approach. The interviews suggest that this pedagogical approach is what made science not only enjoyable but also interesting for students. Students stated they prefer hands-on, inquiry-based science, and this active approach is more engaging to them than sitting and listening to teachers.

A possible explanation for the observed decrease in non-SSEP students' interest in science from middle to high school may be the use of traditional methods of science teaching at the high school level. The interviews suggest that students lost interest in science because of the way their science classes were taught. Some students stated they were "turned off" by learning science through traditional methods that merely included lectures and note taking.

The Long-Term Goal of SSEP

The long-term goal of SSEP was to increase students' interest in science and science careers between middle and high school. The surveys and interviews found that increasing interest during this time period is very difficult to do and may be an unrealistic goal. At this age most students are losing interest in science. However, the data do show that SSEP was able to sustain students in middle school who have a high interest in science. These results suggest that attitudes toward science are developed early in a child's education and are difficult to change once they reach middle school. Summer science programs, such as SSEP, are probably best suited to help support and sustain interest in science.

Summary

This longitudinal study provides evidence that a 2-week summer science program which used an inquiry-based approach may have helped middle school students, who had a high level of interest in science, maintain their interest during their years in high school.

Poor science teaching may cause some students to leave science. In *Talking About Leaving: Why Undergraduates Leave the Sciences*, Seymour and Hewitt (1997) reported that poor science teaching was the most common complaint (83%) cited by all undergraduate students. They also found that the most effective way to retain students from underrepresented ethnic groups is to improve the quality of the learning experience. The approach that teachers use to help students learn is an important factor that affects students' interest level. It is apparent from the interviews that students are willing to exert more effort in science classes if they are encouraged to express their interests by asking questions about the material being covered. Traditional methods of instruction, which often include lectures, note taking and "cook-book" science, may not be as effective as hands-on, inquiry-based methods.

Recommendations for Future Studies

First, further research is needed to learn more about what causes students to lose interest in science as they go from middle to high school. Second, research that compares the program reported in this study to other inquiry-based programs would be enlightening. We need more data regarding factors, circumstances, and environments that help students maintain a high interest in science. Third, additional studies are needed that follow students for longer periods of time after they participate in inquiry-based science programs. We need to study the impact that inquiry-based programs designed for middle school students have on students' majors in college as well as on their career choices. Fourth, SSEP students felt that their teachers' practices greatly influenced their attitude towards science and interest in science careers. Further investigations should be conducted to study the impact of teachers' methodology on students' attitude towards science, to discover what specific characteristics are most important. And finally, while SSEP helped students maintain a high interest in science over time, further studies should examine the correlation between students' interest in science and their understanding of science.

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