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ABSTRACT

This report describes a 9-month, nationwide project which investigated the teaching strategies and teacher attitudes which successfully encouraged girls in science. Subjects included 205 females and 147 males from seven high schools. In addition to analyzing instructional techniques, classroom climates, and teacher-student interactions, a selected sample of former and current students received a variety of instruments which assessed attitudinal, cognitive, and socio-cultural variables. Results obtained from the case studies and survey instruments indicate that teachers who successfully encourage girls in science maintain well-equipped, organized, and perceptually stimulating classrooms, are supported in their teaching activities by parents of their students, are respected by current and former students, use non-sexist language and examples, include information on women scientists, use a variety of instructional strategies, stress creativity and basic skills, and provide career information. Factors which discourage girls in science include high school counselors who do not insist on further courses in science and mathematics; lack of information about science-related career opportunities and the prerequisites for them; sex-stereotyped views of science and scientists fostered by textbooks, media, and many adults; lack of development of spatial ability skills; and fewer experiences with science activities and equipment that are stereotyped as masculine. (JN)

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Factors Affecting the Retention of Girls in Science Courses & Careers: Case Studies of Selected Secondary Schools

A Study Conducted for the
NSB Commission on Pre-College Education
in Mathematics, Science & Technology

by

The National Association of Biology Teachers
11250 Roger Bacon Drive #19
Reston, Virginia 22090

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EXECUTIVE SUMMARY

In the United States women comprise approximately 50% of the work force, yet only 6% are employed as scientists and engineers. Factors contributing to this situation have been analyzed in research studies, and explanations have ranged from differences in spatial ability linked to a sex-linked gene to differences in early childhood toys and games. One analysis has shown a dramatic decline in positive attitudes toward science as girls mature; the authors attribute this decline to startling inequities in the number of science activities experienced by males and females in elementary and secondary classrooms. In addition, the analysis of the results from the 1981 National Assessment of Educational Progress indicate that girls continue to score below the national mean on all cognitive science items and to express negative attitudes toward science. Although societal, educational, and personal factors are all involved, differences within the science classroom may be the basic reason why fewer women study science or pursue scientific careers.

Some girls, however, like science and some continue to study science. In order to determine what motivates these girls to pursue science courses and careers, a group of researchers conducted nationwide studies of teachers who have successfully motivated high school girls to continue in science. In addition to analyzing instructional techniques, classroom climates, and teacher-student interactions, a selected sample of former as well as all current students received a variety of instruments which assessed attitudinal, cognitive, and socio-cultural variables.

Two types of research, observational and survey, provide the descriptions and data for this project. The case studies, which were part of this project, include evidence of student-teacher and student-student interactions as well as descriptive materials which assist in their interpretation. Since case studies are limited in the extent to which they may produce generalizations applicable to other situations, they have been supplemented with objective data, describing the abilities, activities, and aspirations of both the involved students and teachers.

Both types of information have led to the following conclusions.

Teachers who successfully encourage girls in science:

* Maintain well-equipped, organized, and perceptually stimulating classrooms.
* Are supported in their teaching activities by the parents of their students and are respected by current and former students.
* Use non-sexist language and examples and include information on women scientists.
* Use laboratories, discussions, and weekly quizzes as their primary modes of instruction and supplement those activities with field trips and guest speakers.
* Stress creativity and basic skills and provide career information.

Factors which discourage girls in science:

* High school counselors who do not insist on further courses in science and mathematics.
* Lack of information about science-related career opportunities and the prerequisites for them.
* Sex-stereotyped views of science and scientists which are fostered by texts, media, and many adults.
* Lack of development of spatial ability skills, which might be fostered in shop and mechanical drawing classes.
* Fewer experiences with science activities and equipment which are stereotyped as masculine (mechanics, electricity, astronomy).

Factors Affecting the Retention of Girls in Science Courses & Careers: Case Studies of Selected Secondary Schools

INTRODUCTION

This report describes a 9-month project, conducted from Maine to California, of the National Association of Biology Teachers Committee on the Role & Status of Women in Biology Education. Members, supplemented by other concerned researchers, sought to observe, describe, and analyze teaching strategies and teacher attitudes which successfully encouraged girls in science. Biology, taken by over 80% of high school students, was the course selected for observation; for if girls are turned off to science in biology, they effectively close the doors to scientific or technological careers. Two types of information were gathered: first, qualitative assessments, which formed the basis of individual, observational case studies; and, second, quantitative assessments, which provided the data for an overall summary. In this report, data collected at all the case study schools are analyzed, case study sites and teachers are compared and contrasted, and general conclusions are drawn. It is anticipated that readers will gain insights, interpret vignettes, and draw conclusions that will improve biology and science education for all secondary students - but especially for girls.*

PROCEDURES

Two types of people have contributed greatly to the information included in this report: Case Study Researchers, the people who conducted the studies and described their observations; and Case Study Teachers, the classroom instructors who were observed and who assisted by distributing and collecting surveys, by being interviewed, and by arranging for the researcher to interact with administrators, parents, and students. Researchers were sought who could

*The entire report has been submitted to the National Science Foundation and to the National Association of Biology Teachers. It is available from them as well as from the author.

provide geographic, racial, and socio-economic representation in the various case studies. Each researcher was free to select a case study teacher for his/her report. The basic criterion was that the teacher selected had to have a "track record" of success with young women in science. The distribution of the case study researchers resulted in the following types of sites for the eight case studies. Although it was hoped that certain standardized data could

Table 1

Number of Schools in Basic Groups

Geographic Area	Community Type	Racial/Ethnic Group
1 East	3 Urban	4 White, Non-Hispanic
3 Midwest	2 Suburban	2 Black
2 South	3 Small town/ rural	2 Hispanic
1 Rocky Mountain		
1 Far West		

be collected, the primary aim of the study was the thoughtful observation and analysis of teacher behavior and student/teacher interactions. The intent of the overall project was to identify instructional strategies or teaching behaviors among the teachers, from rural Texas to urban Chicago, which could be adopted by other teachers to improve the retention and achievement of girls in science classes and the entrance and success of women in science careers.

OBSERVATIONS & RESULTS

Throughout this study we have asked, individually and collectively, what makes these teachers exceptional? How do they succeed, not only in encouraging girls, but in inspiring both boys and girls in science? What commonalities are found in these classrooms from Maine to California, from center city to rural community, from modern edifice to deteriorating facade? What theme unites their work and our study? The answers have been obtained from hours of transcribed interviews, from dozens of former student notes and messages, from carefully articulated reports of trained observers, from responses to thousands of survey items, and from a critical review of the literature. Although commonalities will be discussed among teachers and across student samples, the purpose of our study was to observe in diverse communities. Therefore, there are few similarities among schools or communities. The hope was that eight diverse situations would provide a composite picture as well as a collective pool of data, in which commonalities could be found and from which generalizations could be made. This report is both a qualitative and quantitative assessment of teachers who make a difference.

Demographics

All socio-economic levels were represented in the overall sample of students and in the sample of schools. Inner-city schools in two diverse metropolitan areas as well as rural schools in Colorado and Maine described at least part of their student population as disadvantaged. In contrast, another school was in an affluent white suburb, and one enrolled middle-class and upper-middle-class blacks. In some cases, the general socio-economic level of students within a school was atypical of the community in general; the central city high school in Colorado, the laboratory school in Louisiana, and the inner city school in Chicago were examples of this situation. In other instances, the school population reflected the general socio-economic level of the community; for example, in Indiana, Maine, and Missouri, the schools were microcosms of their communities. Although political and religious information was reported sporadically, there was every reason to believe that all views were expressed approximately proportionally to their national representation. Together the communities and schools formed a composite picture of public high schools in the United States.

Classrooms

Although the physical condition of the eight high schools varied greatly, all the biology rooms observed were filled with posters, pictures, models, live specimens, equipment, and projects. They were visually stimulating. One commonality among these eight teachers, who had been successful in encouraging girls in science, was an attractive, well-equipped and maintained classroom. Each case study researcher attributed these pleasant learning places to the energy, creativity, and initiative of the individual teacher. In diverse schools and communities, these teachers had been successful in creating optimal learning environments. The extent of their success may be found by comparing their responses to items on a survey concerning facilities to those of a national sample (Weiss, 1978).* Although teachers in both the case study and the national samples responded that improvement was needed in building/classroom facilities (28.6% and 34%, respectively), space for classroom preparation (28.6% and 28%, respectively), space for small group work (42.9% and 44%, respectively), and availability of laboratory assistants or paraprofessionals (71.4% and 62%, respectively), the case study teachers compared to the national survey teachers did not report a need for more equipment (14.3% vs 35%, respectively), supplies (0% vs 21%), money for daily supplies (14.3% vs 47%), or storage space (14.3% vs 39%). The ambience of their classrooms, pleasant, cheerful, and well-stocked, was the first commonality identified among the teachers in these divergent schools.

*Although these results are not directly comparable due to the difference in sample size between the national and case study samples (586 teachers vs 7 teachers, respectively), rough comparisons can be drawn. It should be noted, however, that 14.3% of case study teachers represents one teacher; and 28.6% represents two teachers. Tabular data, therefore, should be interpreted with this in mind.

Many of the observed teachers bemoaned the quality of the curricular materials, particularly the textbooks, available. One suggested that she had gone along with the other teachers in selecting a traditional text, while another one defended her style of "teaching from the text." All of them responded that they used more than one published text (compared to 52% of the national sample who used multiple texts) and six of the seven biology teachers reported that they frequently used text replacements or supplements.* The most frequently adopted biology text was Otto, J. H., A. Towle, and M. E. Madnick, Modern Biology, New York: Holt, Rinehart, & Winston, 1977. All texts in use were analyzed for sexism in language, illustrations, citations, and references. Those analyses suggested that although progress had been made, it was limited. Women, for example, were pictured in non-traditional careers and were represented in approximately 50% of the illustrations. However, their meaningful contributions to science were seldom cited or referenced.

In addition, teacher-developed instructional materials were examined for any sexist characteristics. Almost all used both pronouns or the plural pronoun; approximately equal numbers of scientists, researchers, etc. were referred to as men or as women. In one lesson concerning superstitions about reproduction and birth, items showing both male and female bias were included. In answers to surveys taken prior to the study, all case study teachers stated an awareness of sexism in science. For example, 71% of these teachers stated that they included information about the important contributions of women

*The eighth teacher taught high school algebra, therefore her responses are not included in the analyses concerning science teaching and science classrooms.

scientists in their class discussions and that they tried to correct the conception that science is an exclusively male domain. Seventy-one percent of them had invited female scientists to their classes to discuss science careers with their students. Generally, another commonality among these teachers was the complete absence of sexist language, materials, or humor in their instructional materials.

As a group, the case study teachers taught in a particular way. When compared with the national sample, described by Weiss (1978), they reported using laboratory and discussion activities much more frequently. Over 80% of the case study teachers used laboratory materials in their classes at least once a week; less than half of the national survey teachers used hands-on materials that often. Dramatic differences are shown in Table 2 in the use of science materials by these two groups of science instructors. All of the case study teachers indicated that microscopes, models, balances, living plants, and living animals were essential for teaching their science classes and a large majority of these teachers used these materials 10 or more days. One-third or more of the national survey teachers responded that microscopes, living plants, and living animals were unnecessary for instructing their classes. Furthermore, all of the case study teachers used microscopes 10 or more days each year, while only one-half of the national survey teachers used microscopes that often.

In addition, a majority of the case study teachers used filmstrips, film loops, and slides at least once a month; less than one-half of the national survey teachers used those media that often. Over one-half of the national sample indicated that videotapes were not needed for their teaching; although most case study teachers did not use videotapes often (85.7% responded they used this item "less than once a month"), all of these teachers indicated that videotapes were necessary for their instruction.

in addition, all of them responded that they used weekly quizzes or tests. In comparison, only 37% of the national sample responded that they evaluated students at least once a week. The case study teachers invited in guest speakers and took their students on field trips more often than the national sample. Furthermore, students of the case study teachers were more frequently assigned independent projects, library research, and televised instruction. In contrast to the national sample, these teachers less often lectured or performed teacher demonstrations.

Table 2

Use of Audio-Visual Equipment and Science Materials by Frequency and Availability

	Percentage of Teachers					
	Used Once Per Month or More		Needed but Not Available		Not Needed	
Audio-Visual Equipment	NABT Sample	Natl. Sample	NABT Sample	Natl. Sample	NABT Sample	Natl. Sample
Films	71.4%	55%	0%	9%	0%	5%
Filmstrips	100	48	0	8	0	8
Film loops	57.1	8	14.3	22	0	38
Slides	71.4	10	14.3	20	0	32
Overheads	71.4	38	0	4	28.6	19
Videotape	0	10	14.3	16	0	54
Science Materials	**Used More Than 10 Days**		**Needed but Not Available**		**Not Needed**	
Calculators	28.6%	26%	14.3%	14%	14.3%	47%
Microscopes	100	50	0	1	0	33
Models	85.7	44	0	12	0	15
Balance	71.4	57	14.3	1	0	9
Living Plants	71.4	38	0	4	0	39
Living Animals	71.4	28	0	7	0	43

All of these responses suggest good science teaching as another commonality among these teachers. In fact, the researchers began to wonder if there were any unique teaching behaviors contributing to their success with girls. We found unique behaviors as we observed their interactions with students, which will be described later. However, it is important to note that laboratory-based science teaching has been found to be an especially effective strategy for interesting girls in science (Harding, 1983). Over and over, girls responded "The labs," to the question, "What do you like best about your high school biology class?" Perhaps it was expressed best by a 15-year-old, black girl in the deep south, who said,

> I enjoyed working with microscopes. We had a cow heart and we opened it up. [We] looked in the microscope at the different parts of the inside of the heart and I enjoyed that.

Instructional techniques that involve students also may encourage and excite young women to study science. As a minority girl on the South Side of Chicago stated,

> [Our teacher] always has discussions. We always ask questions, and we learn the most from discussions.

Classroom Teachers

The case study teachers taught an average of 18.4 years and all of them held college degrees beyond the bachelor degree level. Five of the seven held at least one biology degree. Science teachers in the national survey, on the other hand, had taught an average of 11.8 years and only 54% held advanced degrees. Eighty-six percent of the case study teachers were women; nationally, women compose 24% of all science teachers. Both groups of teachers had approximately the same number of students per class; the averages were 25.2 students/class for case study teachers and 22.8 for national survey teachers. While the majority of teachers in both groups reported their classes were composed mainly of students with average abilities or with a wide range of ability levels, more case study teachers than national survey teachers taught high ability students. However, none of the case study teachers were teaching classes composed primarily of low ability students.

These instructors taught between two and six hours of biology classes a day and spent four or more hours a week preparing biology lessons. Four of the teachers sponsored a science club at their high school. In general, the teachers thought their science programs were well supported by their school communities. Responses to items querying sources of support rated parental support the highest. It was followed by support from other teachers, principals, superintendents, and school boards, in that order. Six of the teachers reported that they were more enthusiastic about teaching now than when they began their careers. In addition, their answers to items in a science attitude inventory indicated that they held very positive attitudes toward science as a discipline ($\bar{X}$ score = 199 out of a maximum of 240).

The case study teachers were active professionals. All but one had attended at least one science-related professional meeting within the last ten years. Eighty-six percent had made presentations at local science teacher meetings or at inservice teacher education functions. Most of them had been involved in science-related activities outside of their school. For example, several had coordinated science workshops and science fairs, one was on the local park board, and one had been on the staff of a college marine biology institute. Their hobbies ranged from soapbox racing and hot air ballooning to reading and gardening. Several indicated that they enjoyed photography and had science-related hobbies such as bird-watching and wildlife exploring.

The case study teachers were special in two other aspects of teaching. They provided career information and related biology to everyday life. Although all students liked those aspects of their biology classes, girls, especially, mentioned them. For example, girls attending an affluent, suburban school commented,

> She gives us up-to-date information and relates it to how we are living today. She does not give us old stuff from the text book.
>
> If we want to go into a science career, she tells you what classes you should take for a particular career.

When survey responses were tabulated for all case study students, both boys and girls were positive about the instructional techniques of their teachers. As Table 3 shows, these teachers were uniformly fair in their treatment and expectations of both boys and girls. In fact, this unisex treatment was another commonality found. Unfortunately, most teachers still hold, consciously or unconsciously, sex-stereotypes which affect their classroom behaviors. The importance of teacher behavior and instructional style cannot be underestimated. Jan Harding (1983) suggests that they may be more influential in encouraging girls in science than the presence of a same-sex role model as a science teacher.

Table 3

Male & Female Students' Perceptions of Their Case Study Teacher

	Students Who Agree		df = 1
Does your biology teacher...	% of Males	% of Females	Sig.
encourage you to be creative, original?	58.2%	66.8%	ns
differentiate between jobs for males and for females?	27.0	23.3	ns
frequently talk with you individually?	57.4	54.5	ns
encourage education and/or training beyond high school?	67.1	76.5	.1201
describe science courses work as difficult?	28.9	21.5	ns
give advice on future plans?	38.7	37.9	ns
encourage mathematics courses?	50.3	44.0	ns
encourage optional choices for post-high school?	47.5	42.2	ns
differentiate between courses in which males and females can be successful?	27.1	14.0	.0094
encourage basic skills?	70.5	72.4	ns
treat you childishly?	20.1	12.5	.1008
seldom take your opinions seriously?	18.0	18.5	ns

Descriptions of Current Students

Students who were currently enrolled in biology courses taught by the case study teachers were asked to complete several demographic surveys, attitude scales, and cognitive ability tests during the period of observation. In addition to questions concerned with demographics (grade, gender, race, etc.), previous academic experiences, and extracurricular activities, students responded to items about their future career plans, including any probability of science careers, as well as their opinions concerning women's roles and scientific abilities. Furthermore, each student received a spatial visualization test, a cognitive style test, a locus of control test, a science attribution scale, a science attitudes scale, and a science anxiety scale. These tests were selected and used because scores on each of them have revealed gender differences in previous research. It was hypothesized that there would be no differences between the scores of male and female students for the variables of science attitudes, science anxiety, and participation in extracurricular science activities. In other words, the case study teachers would have had a positive influence on the science attitudes, the levels of science anxiety, and the number of science extracurricular activities of girls enrolled in their classes.

Sample

The sample included 205 females (58.2%) and 147 male (41.8%) students from seven high schools. All teachers and researchers had the option of omitting any or all surveys and instruments; the California school chose to do so. The students were primarily 9th and 10th graders (87%), and the sample was predominantly white (73.9%) with some black (18.9%), Hispanic (3.7%), and Asian/Pacific Islanders (1.4%) represented. There were no gender differences in racial distribution but, as indicated in Table 4, the schools varied considerably in their racial composition.

Table 4

Distribution of Students by Race and School

School	American Black	Hispanic	White, Not Hispanic	Asian/ Pacific	Other
Suburban Missouri	1.0%	- %	95.0%	3.0%	1.0%
Rural Indiana	-	1.5	95.5	0	3.0
Urban Colorado	2.3	2.3	90.9	2.3	2.3
Urban Texas	13.6	40.9	45.5	-	-
Urban Illinois	87.0	4.3	4.3	-	4.3
Suburban Louisiana	95.3	2.3	-	-	2.3
Rural Maine	-	-	96.1	2.0	2.0

Note. School vs Race: X = 395.55, df = 24, p = .0000

Academic Abilities

Students in the sample identified their academic abilities in a fairly typical fashion, and self estimates of grades did not differ between the boys and girls in the sample. Students also were asked to estimate their abilities in relation to those of an average person of their own age. Boys estimated their abilities considerably higher than girls did in athletics, math, mechanics, science, problem-solving, and ambition. Girls, on the other hand, ranked themselves approximately as high as boys only in academic, speaking, and social abilities; girls did not rank themselves higher than boys in any given category. The student sample, therefore, had very traditional and sex-stereotyped views of individual abilities.

However, when actual enrollments were assessed, few differences were found in the percentages of boys and girls taking advanced or honors courses in math, English, foreign languages, or social studies. Perhaps more important than the lack of gender enrollment differences in honors/advanced courses was the lack of differences between boys and girls in the number of courses taken in algebra, plane geometry, trigonometry, college algebra, senior math, calculus, biology, chemistry, and physics.

When surveyed about future educational plans, a large percentage of both boys (85.7%) and girls (76.6%) planned to attend college after high school. Their educational aspirations probably reflected the educational levels of the students' parents. For example, 32.2% of their fathers and 35.8% of their mothers had attended 1-3 years of college or had a bachelor's degree. Over 22% of fathers and 11.6% of mothers held advanced or professional degrees. Overall, 74.9% of fathers and 66.4% of mothers had had some kind of post-high school training or education.

Science Careers

Some items assessed student interests in and aptitudes for a scientific career; others probed for the factors behind student career choices. Although large percentages of both male and female students in this study (79.7% and 55.1%, respectively) had considered science careers, students - especially female students - still viewed science and engineering as difficult areas and as predominantly masculine endeavors. When students were asked whether they could become scientists, only 5% of females and 12.3% of males indicated that they wanted to become scientists and that there were no major obstacles in their paths. However, 40% of males and 48% of females stated that they did not wish to pursue scientific careers due to inadequate grades, excessive educational requirements, or lack of required courses.

The case study students were asked to indicate with whom they had talked about jobs, work, or careers. Proportionately more females than males had talked with family members (97% versus 91%, respectively). Over 90% of both boys and girls had discussed careers with friends and nearly 60% had discussed careers with teachers. Furthermore, students indicated that the case study teacher, in particular, had encouraged students to consider education and/or training beyond high school (76.5% of females, 67.1% of males), had given students advice on what to do after high school (37.9% of females, 38.7% of males), and had encouraged students to explore many choices for post-high school plans (42.2% of females, 47.5% of males). There were no gender differences in students' perceptions of career counseling from their case study teachers.

What about the high school counselor? Most students were surveyed during the late spring of the 10th grade; therefore, most would have decided on either an academic, vocational, or general course of study. Probably, most of them were actively involved in choosing courses for the following year. Yet, over 35% of girls and 40% of boys had not discussed post-high school training or education with a counselor within the last year. Furthermore, over 40% of girls and 55% of boys had not discussed jobs or occupations with a counselor within the last year. There was one gender difference; girls had discussed jobs/occupations with counselors somewhat more frequently than boys had. In summary, these students had found family members, teachers, and friends more important sources of career information and advice than were high school counselors.

Student Experiences & Attitudes

As noted, all students in the observed classes were actively involved in learning. However, each case study teacher practiced what Shirley Malcolm (1983) calls "directed intervention." That is, girls as well as boys could not sit passively in the back of these rooms. Girls were called upon to recite, were requested to assist in demonstrations, were selected to be group leaders, and were expected to perform experiments. They could simply not get by taking notes as boys dissected, titrated, measured, etc. The effect of this instructional strategy showed when the responses of these students were compared with those from the 1976-77 National Assessment of Educational Progress' survey of science. Table 5 illustrates percentages responding to items which showed active participation in science classes. Overwhelmingly, young women in the case study classrooms have had more opportunities to use scientific apparatus, to conduct science experiments, and to participate in scientific field trips.

However, gender differences were found in the NABT sample for those activities which dealt with traditionally masculine areas such as electricity, mechanics, and astronomy. In addition, male students of the case study teachers reported more science hobbies, watched more science TV shows, and read more science books than did their female peers. These findings agreed with those of the 1976-77 NAEP survey. One important gender difference was not found in the current study; that is, girls and boys did not significantly differ in number of science projects completed. Furthermore, there were no differences between boys' and girls' participation in science clubs, science fairs, and math/computer clubs. However, significant gender differences were found in participation in chess club, chorus/choir, thespians/drama club, varsity/intramural sports. In all of those activities, participation was based on traditional sex-role stereotypes. It is, therefore, even more important that differences were not found between percentages of boys and girls participating in science clubs, science fairs, or math/computer clubs.

Table 5

Percentages of NAEP and NABT Students Responding Positively and Presence of Sex Differences in Extracurricular Science Activities

QUESTION Have you ever...	% Responding Positively NAEP** Sample	NABT*** Sample	Significant Sex Difference* NAEP** Sample	NABT*** Sample
experimented with erosion?	42.9%	38.7%	Yes	No
used a meter stick?	78.8	93.8	Yes	No
used a barometer?	48.5	57.1	Yes	No
used a computer?	36.2	83.1	Yes	No
used a graduated cylinder?	63.6	79.4	Yes	No
visited a sewage plant?	25.8	19.8	Yes	No
visited a weather station?	24.3	33.9	Yes	No
visited a research laboratory?	31.9	33.2	Yes	No
made a piece of science equipment?	53.1	51.1	Yes	No
made something from junk?	81.4	70.8	Yes	No
collected leaves/flowers?	83.3	95.1	Yes	No
found a fossil?	60.0	64.0	Yes	No
seen an animal skeleton?	87.7	86.7	Yes	No
seen an eclipse of the moon or sun?	78.7	79.7	Yes	No
seen the moon thru a telescope?	56.8	52.9	Yes	No
seen a solar heat collector?	19.9	43.9	Yes	No

*Significance levels are not included because the data treatment in each case was not identical. The comparisons, therefore, are only estimates. Percentages of males were higher than females in each case where a significant sex difference was found.
**17-year-olds
***Present students of case study teachers, predominantly 15-year-olds.

Perhaps, as the result of more experiences, more career information, and more extracurricular science activities, girls demonstrated more positive attitudes toward science classes and science careers than they did in the 1977 assessment. As shown in Table 6, proportionately more students in the NABT sample felt "curious," "confident," and "successful" in their science classes than did students in the NAEP sample. According to other responses, the case study students also enjoyed their science classes more than did students in the NAEP sample. None of the gender differences in attitudes, typically found among children 13 and older, were found. Girls, enrolled in classes taught by the case study teachers, held science attitudes equally as positive as those of their male peers.

Table 6

Student Attitudes Concerning Science Classes, by Sex and Sample Population

Question	NAEP Sample % Responding			NABT Sample % Responding		
How often have science classes made you feel:	Total	Male	Female	Total	Male	Female
curious?*	50.7%	53.4%	48.1%	85.3%	84.2%	86.1%
stupid?**	60.8	69.5	52.3	45.8	40.4	49.7
confident?*	21.5	26.8	16.4	59.9	59.6	60.2
successful?*	28.2	32.4	24.1	67.9	73.7	63.5
How often do you like to go to science classes?*	37.3%	42.8%	31.9%	70.2%	74.5%	67.2%

*Response = "Often" or "Sometimes"
**Response = "Seldom" or "Never"

Note. In all cases, a significant sex difference was present in the NAEP sample but was not present in the NABT case study sample.

Generally, students, girls as well as boys, of the case study teachers were actively involved in science. They performed experiments in their classes; they investigated opportunities in the field; they participated in science and math clubs, and they conducted special projects. The attitudes of girls toward science were positively affected by these myriad opportunities. In contrast with both the results reported in the 1976-77 and 1981-82 National Assessments of Science, these young women were confident, curious, and successful in their science classes.

Personality Dimensions

The effect of these teachers also was noted in the responses of students to instruments assessing science anxiety and attribution, cognitive style, spatial ability, and locus of control. Responses to a scale concerning science anxiety (Alvaro, 1978) were particularly interesting. Math anxiety and, to a lesser extent, science anxiety have been suggested as major detriments to girls achieving well in science (Smail, 1983). Others have maintained that experience ameliorates anxiety and that girls particularly must work with scientific materials (Malcolm, 1983; Kahle, 1983). Whether male or female, responses showed that experience alleviated anxiety. Selected responses in Table 7 show that, in general, girls are more anxious about tests and new experiences such as visiting a museum. However, students of both sexes demonstrated less anxiety if they were familiar with the task such as focusing a microscope (girls) or planning an electrical circuit (boys).

Table 7

Percentages of Male and Female Students Indicating Anxiety About Science Related and Non-Science Related Activities

How much does it frighten you to:	Not At All M	Not At All F	A Little M	A Little F	A Fair Amount M	A Fair Amount F	Much M	Much F	Very Much M	Very Much F
...study for final exam in English or History?*	32.2%	23.8%	28.0%	27.1%	23.7%	16.0%	10.2%	18.2%	5.9%	14.9%
...study for final exam in chemistry or physics?**	31.3	22.7	31.3	23.2	14.8	23.8	13.9	16.0	8.7	14.4
...visit the museum of science and industry?**	40.5	26.0	24.1	32.6	23.3	26.0	8.6	8.3	3.4	7.2
...focus a microscope?*	73.3	85.1	11.2	9.9	7.8	2.2	4.3	2.2	3.4	0.6
...to plan an electrical circuit?**	55.9	30.8	26.3	33.5	15.3	19.8	1.7	11.0	0.8	4.9

Key: Significant differences between male and female responses
* χ test, df = 4, p < .05
** χ test, df = 4, p < .10

The Science Attribution Scale used was a modified version of Fennema, Wolleat, and Pedro's Mathematics Attribution Scale (1979). The scale presented students with nine biology course situations in which the student was told that he/she had succeeded or failed. After each situation, the student was asked to agree or disagree with four different reasons for success or failure: ability, effort, task difficulty, or other environmental conditions (teacher, friends, luck, etc.). Scores were tallied by the number of "agree" or "strongly agree" responses given.

Previous research with non-scientific tasks had found that males attributed success/failure significantly more to ability and effort than females did (Pasquella, Mednick, & Murray, 1981). In the present study, however, no gender differences were found in attribution of success/failure in science to ability, effort, or environmental factors. A significant gender difference did occur, however, in attribution of success/failure in science to task difficulty/ease. Significantly more girls than boys ($p = .0227$) attributed success/failure to the difficulty of the scientific task. Girls, enrolled in case study teachers' biology classes, held equally high opinions of their abilities, efforts, and the influence of environmental conditions in achieving scientific success. However, typically, girls more than boys attributed their degree of success in science to the difficulty of the task. Students also completed a modified version of the Hidden Figures Test (HFT) to determine their mode of cognitive style (ETS, 1971). The HFT differentiates between persons with a field-independent and a field-dependent mode. Usually, field-independent persons are better at cognitive restructuring tasks, tend to think analytically, and are more autonomous in personal rela- tions and work behaviors. Field-dependent persons, on the other hand, display social behaviors useful for interpersonal relationships, tend to have extended experience in working with others and gathering information from them, and are less autonomous (Witkin & Goodenough, 1981). Although gender differences have been reported with more males than females scoring on the field-independent side of the scale (Witkin & Goodenough, 1981), results from the present study do not concur with those findings. In this case, there were no differences related to subject's gender across schools or in any individual school.

Students of the case study teachers also were asked to complete a modified version of the Flags Test (Thurstone & Jeffrey, 1956) in order to measure spatial ability, the ability to visualize and rotate three-dimensional figures. Many researchers had suggested that gender differences in spatial ability contributed to math and science achievement differences in boys and girls. For example, Maccoby & Jacklin's (1974) review concluded that spatial ability was one of the few attributes for which gender differences were consistently found. However, Linn & Petersen's (1983) meta-analysis indicated that studies since 1974 did not show that males possessed superior spatial abilities. Although boys in the case study sample scored significantly higher than girls on the measure of spatial ability ($p = .0013$), further analyses showed that the gender difference was mainly due to a significant difference found in two of the seven samples. Male students in both the suburban Missouri and the urban Illinois schools scored significantly higher than did female students in those same schools.

Locus of control is an expression of the extent to which individuals believe that they, rather than outside factors, control their actions and behaviors. Externally oriented individuals tend to attribute control to outside forces, while internally oriented people believe in their own control. Traditionally, women have demonstrated more external beliefs than men have on locus of control measures (Phares, 1976; Kahle, 1982). Furthermore, students with positive science attitudes and with intentions to pursue science careers generally are found on the internal side of the locus of control continuum (Kahle, 1982). With this in mind, case study students were asked to complete the Adult Nowicki-Strickland Scale, a modified version of an earlier instrument developed by Phares (1957). There were no gender differences in any of the seven subsamples or in the total sample; and students generally scored at the internal end of the scale.

Students in case study classrooms responded to a battery of personality measures. Their responses were compared to those of other samples in order to see if teacher behaviors and instructional techniques had affected student level of anxiety, attribution of success, belief in self control, or mode of perception. Previous research had suggested that specific instructional strategies could influence mode of cognitive style and locus of control orientation (Kahle, 1983; Head, 1983). In addition, researchers had hypothesized that spatial abilities could be fostered by the use of specific curricular activities (Skolnick, Langbort, & Day, 1982). Futhermore, it had been suggested that science anxiety could be ameleriorated by certain teacher behaviors and student classroom experiences (Malcolm, 1983). Comparisons of the responses of students of case study teachers with those of comparable groups indicated that, although other factors might be partially responsible, those teachers had an effect. Girls in case study classes expressed the same personality modes as did boys. Since some of these traits (internal locus of control orientation, field-independent mode of cognitive style, high spatial ability, and low science anxiety) have been directly related to success in science courses and choice of science careers, the absence of gender differences was important.

Reflections of Former Students

Former students, who were science majors in college or who were pursuing science-related careers, were surveyed by mail. Although a bias was present in their selection (all were recommended by either a case study teacher or a counselor), their answers were completely confidential. Therefore, they could be as frank as they wished in responding to questions concerning their choice of science careers, their future plans, and their past incentives. They were asked to indicate how certain people, courses, and activities had influenced their decision to pursue and their persistence in pursuit of science careers. Among the types of people rated (parents, science teachers, math teachers, other teachers, counselors, etc.), high school biology teachers (in all cases the case study teacher) were ranked first.* In addition, unsolicited comments indicated the extent of the case study teacher's influence.

> My role model was my high school biology teacher. She helped me decide on a science career because she showed me the many different aspects of science and the many different opportunities science has to offer career-wise.

> He was (and is) an enthusiastic, challenging, and supportive teacher. He helped me see, in concrete terms (in concrete successes) that I could be successful in medical science. He is one of a handful of outstanding instructors I have had in college (Harvard) and high school.

> [My] biology teacher...taught me how exciting biology can be.

> I had a very good teacher who interested me in biology and made me want to show other children how interesting science can be.

> She gave me support and guidance in matters of everyday living as well as my career decision.

These students almost unanimously (94.7%) felt that their high school biology teacher offered frequent opportunities for individual discussions and encouraged his/her students to consider further education. Furthermore, most indicated that their biology teachers encouraged them to be creative and original (84.2%) and to explore many educational and career choices (73.7%). None of the former students surveyed felt that their biology teachers treated students childishly or distinguished between educational opportunities for boys and girls. Several students described the biology teacher as a role model.

*On a 1-5 scale (1 = very important to 5 = not applicable), the following pertinent average ratings were found: high school biology teacher (1.74), fathers (1.95), mothers (2.32), high school counselors (3.58).

When asked whether any science courses had influenced their career decisions, former students indicated that high school biology and college biology courses* were important. Their comments about high school biology course(s) were revealing.

> The first experience I had with science as an exciting subject came in high school biology. Advanced biology was a difficult course but was good preparation for college level work. It was in high school that genetics was first mentioned. I thought it was a good area for me because I have always done well in math.

> I think that high school biology courses and my training in college certainly prepared me for my career in the research area. In my high school biology class I remember going on many field trips. The questioning and searching for information was certainly helpful to what I cam doing today.

> High school biology helped me appreciate the richness and diversity of science.

> The [high school biology experiences] have taught me what hard work is necessary for obtaining goals.

Overall, the students indicated that they enjoyed their science courses. All respondents (100%) indicated that they had enjoyed their biology courses, 84.2% enjoyed chemistry courses, and 60%-90% liked various mathematics courses. Case study teachers had significantly influenced some former students' career choices.

The positive influence of the case study teachers on both their past and present students was another commonality found among them. Responses to innumerable survey items suggested that their common teaching behaviors and their use of similar instructional materials and techniques were instrumental in encouraging all students to continue their educations. Many more students than usual selected advanced courses in science, which opened doors to future scientific careers. Over and over again students praised these teachers - their contagious enthusiasm, their high academic requirements, their personal

*On a 1-5 scale (1 = very important), high school biology courses were rated 1.56, while college biology courses received a 2.00 rating.

concern. Since girls often do not receive such positive messages from science teachers (Smail, 1983), their influence on girls continuing in science was disproportionately effective.

Perspectives of Current & Former Students

Evidences of change have been described. Girls in these classrooms performed science experiments, enjoyed science activities, and demonstrated confidence in their scientific abilities. Consequently, many continued in science courses and selected scientific careers. But, did the positive role model of a biology teacher and a positive image of science change traditionally held sex-role stereotypes concerning women as scientists? Responses to items and written comments on both the past and present student surveys suggested some progress. Differences were seen between the responses of 15-year-olds (average age of current students) and 22 year-olds (average age of former students). For example, only 14% of the 15-year-olds responded that women should work full-time without interruption for marriage or children; in contrast, 26% of the older respondents considered full-time, uninterrupted work a viable option for women (themselves or their wives). Overwhelmingly, both groups of students planned to marry and thought that the most appropriate life-role for women was marriage and/or family combined with a career.

Table 8

Current Student Opinions Concerning Science Careers for Women

	% Responding		
Opinion	Total	Males	Females
Approve	77.2%	69.1%	82.9%
Probably Approve	6.5	9.4	4.5
No Opinion	13.9	18.0	11.1
Probably Disapprove	0.9	0	1.5
Disapprove	1.5	3.6	0

Note. X = 17.05, df = 4, p = .0019

Other questions were directed specifically toward the role of women in science careers. Current students were asked whether they approved of science careers for women. Although proportionately more girls than boys expressed approval, the percentages of both who approved of science careers for women was large, as shown in Table 8. However, the boys and girls differed considerably when questioned further on the issue of women in scientific careers. Table 9 presents student responses to a series of statements about women in scientific as well as other types of careers. In all but two cases, girls, compared with boys, expressed stronger beliefs in a woman's potential for success in a traditionally masculine career (astronautics, government, science).

Table 9

Current Student Agreement With Statements Concerning Women in Science

Statement	% Males Responding Strongly Agree	% Males Responding Agree	% Females Responding Strongly Agree	% Females Responding Agree	Significance Level*
Women are as interested in mathematics as are men.	37.6%	53.2%	48.0%	44.0%	ns
Men don't like to work for women supervisors.	23.6	42.9	21.0	51.5	ns
Women should stick to "women's jobs."	7.4	20.0	3.6	4.1	.0000
Women have as much science ability as men do.	38.8	49.6	63.2	33.3	.0001
Education is wasted on women since they usually get married & raise a family.	5.9	11.0	3.1	2.6	.0000
Women have the ability & endurance to make successful space flights.	19.3	56.4	44.2	49.7	.0000
According to the latest Census data, equal job opportunities have now been achieved.	10.8	46.8	6.5	50.2	.0485
I strongly approve the election of women as governors.	18.8	50.7	56.2	34.8	.0000
I approve of appointing a woman as chairperson of the Atomic Energy Commission.	19.0	51.8	46.5	47.0	.0000
I would choose for myself the best qualified dentist available regardless of sex.	53.2	36.2	71.4	20.6	.0058

*χ^2 test, df = 4

In summary, both present and past students theoretically supported not only a woman's pursuit of a career, but also a woman's right to pursue a particular scientific career. Both groups expressed naive opinions about the possibility of interrupting a successful career without affecting it. Generally, 15-year-old boys, compared to girls, held more negative and more stereotypic views about the role of women in science-related careers. However, some girls in the case study classes expressed stereotypic views of science and of scientists. A privileged girl in a suburban high school said,

> Men are scientists. It is a masculine job career. Women don't go into it because being a scientist will make them look bad.

Her opinion was reiterated by a black girl in an inner-city school, who stated,

> If I married a scientist he'd never have time to be home with his family. I think men scientists would have more time than women scientists. It depends on the woman. If she can do it, fine; but most women can't.

But, across the country, girls, at least those in the case study classrooms, were beginning to question the old, masculine views of science and scientists. Two interesting and revealing comments were:

> I don't know if it is women thinking scientists should be men, or men thinking scientists should be men.

> There are some women scientists; but men have been in it longer. Women can do the same job as men. They may have a different way of thinking and might improve science.

Former students, those who had passed through these classrooms, also held refreshing and less stereotypic views of scientists. They were asked to select from a variety of clustered characteristics the groups which best described a "typical scientist" and the ones which best described themselves. The results (Table 10) indicated that a student's self-image was very similar to his/her image of a scientist and that these students held broader, less-stereotypic views of scientists. For example, over a quarter responded that scientists were "social, helping, guiding, and group-oriented."

Table 10

Percentages of Students Selecting Groups Which Describe Themselves & Scientists

Characteristics	Groups which best describe...* Yourself	A Typical Scientist
Realistic, Technical, Mechanical, Outdoor	57.9%	63.2%
Investigative, Scientific, Inquiring, Analytical	78.9%	84.2%
Artistical, Musical, Self-Expressive, Independent	31.6%	5.3%
Social, Helping, Guiding, Group-Oriented	47.4%	26.3%
Enterprising, Profit-Oriented, Persuasive, Political	5.3%	15.8%
Conventional, Methodical, Organized, Detailed	57.9%	68.4%

*Students were asked to choose 3 groups which best described themselves and scientists.

CONCLUSIONS AND RECOMMENDATIONS

The number of commonalities found among the case study teachers was surprising, and a synthesis and analysis of their teaching behaviors, classroom climates, instructional materials, and academic preparations suggest ways to improve the retention rates and the achievement levels of girls in science. Before delineating factors, which young women found especially encouraging, some general characteristics should be mentioned. Although exemplary teaching was not a criterion for selection, all of the case study teachers were outstanding classroom instructors. For example, the case study researcher in Colorado concluded,

> I think that rather than identifying a teacher who consciously encourages females in science, we have simply identified a very good teacher, whose talent, commitment, and rapport with her students combine to make the study of science an interesting and enjoyable endeavor. I am hard put to suggest any more direct cause and effect relationships, because the data will not support them, any more than the data will support more than a broad philosophic argument for the generalizability of [her] teaching approach to other classrooms.

His conclusion was repeated in most of the observational reports. As the researcher in Chicago stated,

> The case study teacher's experience, attitudes, and goals give her tremendous strength in motivating students to achieve. She is an exemplary teacher. Observing and talking with her, her colleagues, and her students, leaves one with the strong sense that there are no simple explanations for her success as a teacher. A major factor in her desire to motivate young people developed because she, herself, was frustrated in her search for loftier goals. She also is able to recognize the special needs of black inner-city students and address them in a sometimes humorous, always supportive way. She has a keen understanding of biological principles and a love for the field that is an important key to success in any subject. She is given recognition not becasue she seeks it, but because it is so well deserved.

Since those observations could not be generalized, we compared and contrasted the answers of the case study teachers to survey questions with responses provided by a national sample. We found that the case study teachers were all experienced teachers and active professionals. Proportionately more case study teachers than national survey teachers cited professional organization meetings and professional journals as important sources of information for curricular materials and new educational developments. The case study teachers were confident in their teaching abilities; proportionately fewer of these teachers than national survey teachers indicated that they needed assistance in various aspects of teaching such as obtaining information about instructional materials, using manipulative materials, or maintaining plants and animals. Although these teachers used many kinds of laboratory materials, none of them indicated that inadequate facilities were a serious problem or that improvement was needed in obtaining equipment or supplies. The successful case study teachers showed greater willingness than the national survey teachers to use varied methods of instruction, and they emphasized hands-on science experience for their students in teaching their courses. One general conclusion from the classroom observations, the past and present student surveys, the teacher reports, and all the analyses is that good teachers make a difference. Each teacher successful in encouraging girls as well as boys to continue in science courses and careers was also a successful teacher. For example, they were active professionally, were involved in science activities in their communities, were skilled in a variety of instructional techniques, and were informed about science careers and their educational requirements. In their own words, they were proud professionals. From rural Indiana to urban Louisiana they stated,

> Teaching is a profession. I can walk down the street and feel proud that I am a teacher. I think anything we can do as educators to put a feather in our cap; to say, 'hey, this is a proud profession,' is important. Let's build it up and speak positively about it.

> In the years I have been teaching, I have become, what I call, dedicated. I try to be professional, and I have influenced the lives of many young people. I have taught required courses and had the opportunity to touch every student who has been through the laboratory school for the last 24 years. I enjoy teaching.

Although at some point during the observational period, all teachers expressed a concern about sexism in science, the initial interviews and observations were structured to prevent the researcher from introducing any bias. However, by the end of the observational period, all teachers were aware of this special interest, and they, too, attempted to ascertain what they had done "right." As one teacher explained,

> If I have any secret it is that I try to be fair to all students. I don't care who their parents are, what they did last year, or whether they are boys or girls. I just try to treat them all alike.

Although some case study teachers expressed a lack of any special treatment, others admitted that they worked at encouraging girls in science. One teacher explained why she took special steps.

> I think it is ingrained in females that they don't have to take any more science. I work really hard...getting girls into science. All the male [students] want to take AP chemistry. The teachers tell them that this is the really hard course; this is the course for the men. I think [the female students] get a little scared.

Case study teachers worked to correct any negative images of science as well as its masculine mystique. The extent of the problem is indicated in the following excerpt.

> The impressions students have of scientists are generally negative, although they recognize that scientists are probably doing what they want to do. They envisage scientists as men in long white coats looking through microscopes. They think more men than women are scientists, and two students would place more faith in the work of a male scientist than a female scientist. Two other students said they would trust the work of men and women equally, but then qualified that statement, 'I would trust [the work of men and women] the same if they have enough background to know what they are doing. I think women usually don't have enough time to work and to know as much as men.'

Although each teacher attempted to correct stereotyped views of science and scientists in his/her own way, some commonalities were found. For example, one observer wrote,

> All seating and lab work is completely irrespective of sex. The teacher attempts to be fair so that the first person who volunteers to be a lab captain is the person chosen. When the lab requires the use of heavy equipment the girls are not given special consideration. However, since the beginning of this study the teacher has been more alert to the possibility of any sex bias in her teaching.

Most case studies included comparable observations. Generally, these concerned active professionals were striving to encourage all students to reach their maximum potentials. As the observer in a magnet school in Chicago wrote,

> In addition to motivating students to strive for academic and professional excellence, [the case study teacher] seeks to change their attitudes toward biology. Words such as 'nasty,' 'ugly,' and other such terms are unacceptable. She wants to give students an appreciation of things that are not familiar to them. They must become thinkers and listeners. Career awareness is another goal; she has invited speakers from a variety of scientific disciplines to address her classes. She has taken students on field trips to museums, to Argonne National Laboratory, and to nature preserves and zoos. Students prepare 'career profiles,' - oral and written reports on various scientific professions.

In addition to their generally high professionalism and concern for all students, these teachers displayed other commonalities. Certain teaching behaviors and instructional techniques were observed in all eight classrooms. In addition, analyses of both current and former student responses to a variety of surveys and measures indicated factors which positively influenced the retention of girls in science courses.

What were these commonalities?

* 1. Whether the teacher taught behind locked doors in an out-of-date, traditional laboratory with bolted chairs and tables or in a modular, open-concept arrangement with flexible seating and stations, their classrooms were attractive, well-equipped and maintained. All noted that they did not need equipment and supplies or money for further purchases. In addition, all had adequate storage space.

* 2. All used non-sexist teacher-developed instructional materials to supplement the basic text. As one researcher noted,

> There is no overt discussion of sexism that might be inherent in any of the instructional materials used, as none of the materials seem to present that problem. Five tests were provided for analysis. There appeared to be no problem with sexist language; scientific contributions were treated as neutral relative to gender.

Interestingly, no observer reported a single use of sexist humor by the case study teachers.

* 3. All the observed teachers were aware of sexism in science. Although they maintained that they did not treat boys and girls differently, they brought women scientists into their classes and they included a range of non-sexist career information. As one observer suggested,

> Perhaps the equitable treatment of male and female students is itself special, given what has been learned about the generally inequitable treatment of female students in the science classroom. Perhaps the simple lack of preferential treatment for males has resulted in a situation where the female students feel comfortable and are confident in their ability to contribute at an equal level with their male colleagues. Certainly, there is not enough data to support that hypothesis, attractive as it might be.

* 4. The teachers, perhaps unknowingly, presented what Harding (1983) and Smail (1983) call "girl friendly science. One observer wrote about this phenomenom in the following way.

Although she argues that one does not need special activities to interest girls in science, it is possible that for the less-motivated girl certain labs and/or research projects are more appealing. For non-science-oriented girls, experiments such as audio-tutorial units on bacteriology have considerable appeal. Nutrition and diets appeal to many girls. A unit on 'Complementary Proteins: A simulation' has appealed to many girls. Similarly, 'Dissection of an Orange, is very popular with many students. The teacher feels that the girls' interests are as varied as those of the boys. Last year a girl designed and built a windmill for a local garage and another girl spent hours assisting a vocational teacher who is building an airplane.

As noted, teachers used more laboratories, discussions and tests than is commonly found.

* 5. The case study teachers all had solid, academic preparations for teaching. It should be noted that most had degrees in their subject areas and that all had continued their formal educations. All were more enthusiastic about teaching now than when they began to teach.

* 6. These teachers were respected, generally recognized, and supported within their communities. In addition, all but one, mentioned that they received strong support from the parents of their students.

* 7. These teachers participate in and encourage their students to enjoy science beyond the schoolhouse door. As a result, one finds equal numbers of girls and boys preparing science projects and joining science, math, and computer clubs.

* 8. The case study teachers, individually and collectively, were unique in their emphasis on careers and further education. Although all students benefited from that interest, girls seemed to notice it and respond to it more than boys did.

* 9. According to their students, the instructional techniques of the case study teachers encouraged creativity, further education, and basic skill development. Again, girls noted these characteristics more often than boys did.

* 10. Both current and former students noted the positive attitudes as well as encouragement as unique personal characteristics and teaching behaviors of the case study teachers.

These ten special teaching behaviors and instructional strategies resulted in proportionately more girls in their classes continuing in math and science courses in both high school and college. Generally, the following behaviors characterize teachers who are successful in encouraging girls to pursue science.

Do	Don't
use laboratory & discussion activities	use sexist humor
provide career information	use sex-stereotyped examples
directly involve girls in science activities	distribute sexist classroom materials
provide informal academic counseling	allow boys to dominate discussions or activities
demonstrate unisex treatment in science classrooms	allow girls to passively resist

Once identified, these commonalities form the basis of recommendations of ways to encourage young women to pursue science courses and careers.

1. Science textbooks must go beyond the token inclusion of women. For example, McClintock's work should be included in every chapter concerning genetics.

2. Special workshops, projects, and activities are still needed to eliminate sex-bias in and sex-role stereotypes of science. These activities also need to include boys, who demonstrate more stereotypic views than girls do.

3. The professionalism and education of the case study teachers suggests the need for continual, supported educational opportunities for secondary teachers. Whatever the format, the courses, workshops, seminars must present solid science, include career information, and emphasize activities and topics which appeal to girls.

4. When teachers no longer have to expend inordinate amounts of time and energy on securing supplies and equipment as well as space to store them, they can direct their efforts to improving classroom instruction, to encouraging students in science, and to developing basic skills.

In conclusion, Cecily Cannan Selby, who encouraged this project and who was instrumental in funding it, has suggested that excellent science teaching must be innovative and exciting. She says,

> Science must be presented as not only basic but beautiful, as those of use whose lives and professions have been touched by this beauty are so proud and privileged to know (Selby, 1982).

The case study teachers demonstrate those feelings about science. Perhaps, because science is presented as beautiful, they are able to capture and intrigue the girls in their classrooms.

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