University Science Students as Curriculum Planners, Teachers, and Role Models in Elementary School Classrooms

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Abstract

Project SEARCH (Science Education and Research for CHildren) is an outreach program designed to teach science and to foster positive attitudes toward science. Through the project, university science students bring activity-based learning, plus materials and content expertise, to local classrooms and after-school programs. Using observations, surveys, and interviews, we examined the experiences of these students as curriculum planners, teachers, and role models for the children. We found that teachers value the enthusiasm and the resources provided by the SEARCH students. Children were engaged in the activities and looked forward to the students' visits. They also see them as positive and diverse models for the role of scientist. But there were often problems in the areas of preparation, scheduling, and communication, and the classroom activities often replicated traditional didactic lessons. The SEARCH experience highlights both the value of providing diverse and challenging experiences for children, and the need for dialogue and reflection on those experiences. Despite several concerns, the SEARCH model is one that deserves expansion and further study as it is extended into new settings.

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Despite a general recognition that early experiences with science learning may be extremely important in forming positive attitudes toward science, familiar statistics reveal a lack of emphasis on science in elementary classrooms. The National Assessment of Educational Progress reported that 40% of third graders had conducted no science experiments in the previous month. Another 19% reported never performing experiments in science class (Mullis & Jenkins, 1988). According to Goodlad (1984), science is the most neglected of all academic subjects in elementary schools in the United States, occupying an average of only 10% of total instructional time. Although there are many promising counterexamples to these overall trends,

most classrooms still need better science materials and equipment, as well as support for teachers in content instruction and use of new technologies.

Project SEARCH (Science Education and Research for CHildren) is a program designed to address these problems through a collaborative model for science teaching and learning (Barlow, 1993; Wurth, 1993). Its overall goal is to enhance children's understanding of the meaning and excitement of science. Project developers hoped that children would then experience science as a way to ask questions, not just as a collection of answers to be memorized (Lauterbur, Dawson, & Bruce, 1993).

SEARCH works by connecting schools and community programs with science departments at the university. Through the project, which is now in its fourth year, university science students bring activity-based learning, plus appropriate materials and content expertise, to local classrooms and after-school programs. The students are viewed as both teachers and learners, and receive college course credit for their work. All the parties involved appear to desire continuation and expansion of SEARCH. The enrollment of students is increasing semester by semester. More teachers are asking to be included. At one school, the success of an after-hours program convinced teachers to extend the program to the regular classroom. At another school, SEARCH was extended from the elementary level to the middle-school level. A boys and girls club incorporated space needs of the project into its own expansion plans. These events suggest a project that is meeting diverse needs in a substantive way. However, anecdotal evidence of excitement about the project among teachers, students, and children needs to be critically examined.

We observed students playing three major roles in the project. They collaborated with teachers in developing and implementing curricula, they served as teachers themselves, and they were scientist role models for the children. We focus here on three questions corresponding to these roles. [Our analysis draws from a large evaluation study of Project SEARCH (Bruce, Bruce, Conrad, & Huang, 1994).]

1. What forms of collaboration occurred between classroom teachers and university students in curriculum planning?

2. What opportunities did SEARCH students as teachers provide for children to ask questions, explore phenomena, construct their own theories, and express their developing understandings?

3. What images of science and science learning did children create based on their interaction with the university students?

Background

Project SEARCH was developed out of the desires to provide a meaningful service learning opportunity for university science students and to help the community improve science education for children. There were three underlying assumptions: (a) To bring about positive change in classrooms, there must be collaboration—between scientists and educators, between schools and universities, among university students and faculty, between classroom teachers and

university students, and among children in the classroom; (b) children learn science best when given the opportunity to ask questions, explore phenomena, construct their own theories, and express their developing understandings in language that is meaningful to them; and (c) the development of positive attitudes toward science and science learning is a critical element in bringing about engagement of students in learning. This is especially so for children, including many girls and minority students, who have traditionally been excluded from full participation in scientific and technical arenas. These themes can be seen in a number of related projects. In the sections to follow, we elaborate upon them and the way they are implemented in the project.

Collaborative Models for Improving Science Teaching and Learning

The school reform movement of the 1960s called for a general upgrading of science education (Dow, 1991, p. 250). A well-known example is Man: A Course of Study (MACOS), which was based on Bruner's idea that children "need reassurance that it is all right to entertain and express highly subjective ideas and to treat a task as a problem for which one invents an answer, rather than finds one in the book or on the blackboard" (Education Development Center, 1970, p. 3). Children were introduced to a variety of course materials, including booklets, films, games, records, maps, photos, and charts (Dow, 1991). Learning was organized around broad questions such as: "What is human about human beings? How did they get that way? How can they be made more so?" The goals included that children should learn how to pose questions, adopt a research approach to learning, use primary sources to make hypotheses and draw conclusions, learn to listen to others as well as express their own views, and reflect on experiences. As a consequence, there was a new role for the teacher as a resource, rather than an authority dispensing information.

Like MACOS, the Elementary Science Study (ESS) emphasized "developing science learning materials which would engage the mind and the hand" (Education Development Center, 1973, p. 1). Stressing problem solving, process skills, creativity, and positive attitudes, ESS enjoyed support of both the science and science education communities. Shymansky's (1989) review of ESS, the Science Curriculum Improvement Study, and Science—a Process Approach shows that these innovative, hands-on programs had several positive effects. Among others, "students . . . outperformed their traditional counterparts by 9 percentile points" (p. 33).

In recent years, there has been a renewed awareness of the need for improving science curricula and enhancing interest in science and understanding of science among elementary children. This awareness is evidenced by a wide variety of outreach programs aimed at improving precollege science education (Russel, 1992). These programs vary in terms of their audience, ranging from pre-K through high school. They occur in various settings, including both schools and community sites. Some, such as Grow in Science (Brown & Sinclair, 1993), emphasize an inquiry learning approach for both teachers and children. Outreach programs may involve scientists from industry or universities, other spheres of the community, museums, or university science students. Some of the programs involve demonstrations; others emphasize hands-on activities.

A common theme in both the 1960s reform efforts and those of today is the call for collaboration among scientists and educators. One recent example is the Bouchet Outreach and Achievement in Science and Technology (BOAST) program. Named for the first African-American to receive a doctorate from a US University, the program brings engineering graduate students together with children from a low-income housing site for Saturday science demonstrations and recreational activities. Another current outreach program is Science Experiences and Resources for Informal Education Settings, which links university resources and 4-H programs through regional leadership centers at several sites around the country. An outreach program run by the Physics Department at the University of Illinois includes a Physics Van that presents demonstrations in schools and a Saturday program that offers high school and college students and teachers the opportunity to interact with world-class researchers. It also works with Operation Physics (originated by the American Institute of Physics), a national program of teacher workshops intended to enhance teachers' understanding and comfort with physics. Each of these and numerous similar programs throughout the country operates on the premise, established in the 1960s science education projects, that collaboration among scientists and educators is needed to address the educational needs.

Opportunities to Learn Science

Children naturally attempt to make sense of the world in which they live through their previous experiences, their current knowledge, and their use of language. Their conceptions influence the way they observe events, the interpretations they offer for observations, and the strategies they use to acquire new information, including reading from texts and experimenting (Driver, Guesne, & Tiberghien, 1985; Osborne & Wittrock, 1983). Thus, learning cannot be repeating the knowledge supplied by others, but rather, constructing meaning based on interaction with the world (Glaserfeld, 1989; Saunders, 1992). Children need multiple opportunities to engage in direct encounters with diverse and interesting phenomena. Dewey (1956) argued that children's interests in communication, inquiry, construction, and artistic expression are the "natural resources" on which their active growth depends. These interests are the basis of the curriculum, not because they lead to more effective learning, but because we have no choice; all learning begins with the child's interests and experiences rather than abstract formulations.

SEARCH students provided opportunities for children to learn through a variety of science topics, as shown in Table 1. Activities such as building an electrical circuit or dissecting a frog offered children an opportunity to manipulate materials and equipment. They also engaged children in learning science process skills such as observation, measurement, prediction, testing, and experimenting.

Direct experiences are a prerequisite for meaningful learning, but they are far from sufficient. As Dewey and others have also argued, the inquiry process requires processes of dialogue and reflection to become more than the accumulation of experiential memories. Duckworth (1987) articulated this idea in her discussion of the role for teachers. One aspect is to provide the opportunities for students to interact with phenomena in the area being studied— exploring real stuff, not just reading books or listening to lectures. The teacher can help students

notice what is interesting and engage them so that they continue to think and wonder about they have experienced. A second aspect is to have students explain the sense they are making and to reflect upon their growing understandings. This concept of direct experience coupled with opportunities for reflection and elaboration is central to successful science teaching. It also provided a lens for us to use in studying the activities and discourse patterns in SEARCH classrooms.

Table 1

Incomplete list of science topics presented by SEARCH students

Topic	Example activities
Zoology	Frog hatchery kits
Invertebrate anatomy	Dissecting a frog
Bacteriology	Growing colonies of bacteria
Physics	Making gas to inflate balloons; friction experiments
Paleontology	Studying reproductions of fossils; making dinosaur models
Electromagnetism	Constructing a simple circuit; working with magnets
Ecology	Field trip to a natural history museum
Physiology	Anatomy apron; cow's heart
Microscopes	Studying prepared slides
Astronomy	Theories of the origin of the solar system
Weather	Measuring temperature
Nutrition	Measuring fat and sugar content of foods
Chemistry	Measuring pH; making oobleck; working with mystery powders
Computer simulations	SimAnt; Body Works; GeoSafari; Carmen Sandiego

Development of Positive Attitudes toward Science

The development of positive attitudes toward any school subject is fundamental for several reasons (Mager, 1968). One is that attitude is related to achievement and may enhance cognitive development directly. Another is that a positive attitude toward a subject makes students more likely to engage in lifelong learning, both formally and informally. More specifically, in the area of science learning, positive attitudes affect both course and career choices. Student self-perception of ability in mathematics and science, perception of the curriculum, identification of a high school mathematics or science teacher as influential, and the academic atmosphere of the high school are predictors of taking advanced mathematics and science courses in high school. Furthermore, enrollment in advanced mathematics courses in high school is a major significant predictor of choosing a career in mathematics or science (Griffin, 1990).

Choice of a career in mathematics or science usually occurs relatively early in students' school experience. An early study (Snelling & Boruch, 1972) found that 40 to 50% of science and mathematics college graduates had decided that science was a field of interest for them before the ninth grade, and most of the remaining graduates chose science as a field of interest

during Grades 9 to 11. There are no indications that this picture has changed in recent years (Hall & Post-Kammer, 1987).

Thus, positive early experiences in science are likely to promote achievement, cognitive development, additional learning in science, enrollment in advanced science courses, and choice of a career in science. Yet we still know little about the determinants of attitudes toward science as a school subject or how to promote the development of positive attitudes toward science (Myers & Fouts, 1992). It is clear that development of these attitudes begins early. A recent study found that as early as kindergarten, children's attitudes toward science and their participation in it were strongly defined and highly gendered (Lin, 1994).

Moreover, whatever positive experiences children have seem to decline consistently. Yager and Yager (1985) found that students' perceptions of science, science classes, and science teachers were more positive in Grade 3 than in Grade 11. Piburn and Baker (1993) pointed to a growing abstraction and complexity of science classes as a factor creating an increasingly negative outlook on science, especially in high school. Students in their study reported that they were no longer able to understand science, no longer enjoyed it, and would not pursue it any longer or consider it as a career.

It is apparent that students' perceptions of the nature of science affect their attitudes toward science and science learning. Moreover, these perceptions are influenced by teaching (Kyle, Bonnstetter, & Gadsden, 1988). If teachers are able to convey a positive and exciting image of science and scientists, students' attitudes toward science will be positively enhanced. If students view science as consisting only of proven facts and absolute truths, their learning strategies will focus on memorizing these facts and truths. Thus, investigating students' perceptions of science can help teachers develop science instruction that allows students to experience science as a continuous process of developing concepts, making sense of data, and negotiating meanings with others (Roth & Roychoudhury, 1994).

Project SEARCH

Project SEARCH offers an apparently unique combination of the features found in current school–university collaborative programs. It supports the introduction of hands-on activities to children in public and private elementary schools, as well as to those in community-based settings. It also provides the opportunity to integrate these activities into the curriculum, material, and resource support for elementary teachers. Moreover, it adds another dimension, in that the science resources, expertise, and activities are offered by undergraduate science majors. The undergraduates are viewed as learners, not simply as experts. This approach broadens the potential impact in terms of the kinds of people who might benefit from the project, but also may constrain its effectiveness as an outreach program per se.
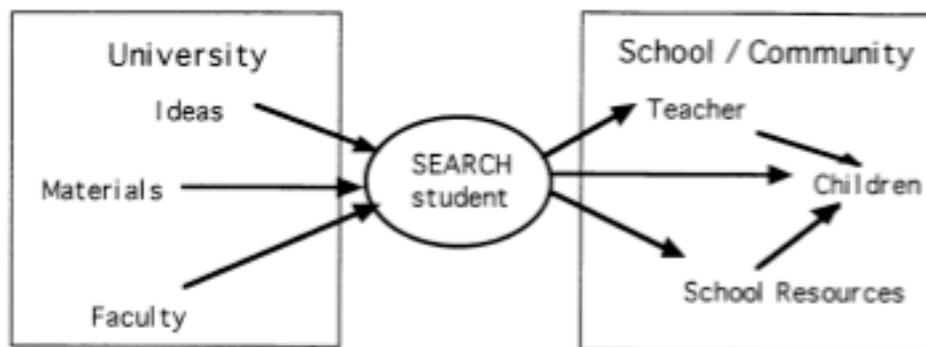
Figure 1.   Initial model for outreach flow in the SEARCH project.

Organization. In the SEARCH project, pairs of undergraduate science majors develop and present hands-on science projects for children at local schools and community centers. The students are supported by the participation of university science and education professors, postdoctoral and graduate students, and the teachers or other professionals in the settings. (In this report, "teacher" indicates an elementary school teacher or other professional, "student" indicates a university undergraduate, and "child" indicates an elementary school student.) The pairs meet once or twice a week with participating classroom teachers, both developing activities and presenting them to children. The timing, format, and degree of integration of the projects with other classroom subjects is largely determined by the teachers. At the end of each semester, the students develop original science lessons, which then become materials for use by themselves or other project participants.

The students in the project are seen as providing a link between the university and the community. As Figure 1 shows, the project originally conceived of students drawing from the resources of the university for the benefit of teachers and children in school and community settings. One aspect of our evaluation was to assess the extent to which this linear model accounts for the diversity of relations established by the SEARCH students' activities.

Participation. Participation in Project SEARCH has grown steadily since its inception, from 18 participating university students in the fall of 1992 to about 50 in the fall of 1995. The number of participating teachers increased from 11 to 20 during that time period, and the number of children reached grew from approximately 200 to 500. Combining student data across 3 years, we found that there had been 53% female students. According to student self-identifications, there have been 5% African-American, 4% Latino, 36% Asian or Pacific, and 56% white students. As we discuss later, we saw several ways in which the representation of women and international students provided diverse role models of scientist for the children.

Each semester, students rated the course on various dimensions. Their ratings have indicated a consistently high level of satisfaction. They also rated high on the critical dimension of recommending the course to other students. These positive responses to the project coupled with the increased interest in joining the project demonstrated their high degree of satisfaction, but need to be investigated in more depth.

Student Roles. Students played three important roles in the project. They worked with teachers to plan curriculum topics and activities. This included developing materials as well as locating them in the SEARCH office, school, or various resource centers. They were also teachers themselves, for at least 2 direct contact hours per week. Finally, they effectively served as role models of science learning and scientist for the children. In many cases, these undergraduate science majors were the only scientists the children had ever had an opportunity to interact with directly. They represented both gender and ethnic diversity. Their very presence in the classroom directly countered the stereotype of the scientist as the older white male with a mad gleam in the eye.

Through our observations we formed our first important impression of the project: There was great diversity in the settings, in the way students carried out their roles and in the science content. We quickly began to realize how varied the students' experiences might be. Even among the eight classrooms within one school, students showed widely differing patterns. As curriculum planners, a number of students developed and implemented activities without any teacher interaction. In contrast, others had lengthy meetings with their cooperating teachers to plan. As teachers, some taught entire class lessons; some assisted the teacher with a unit she had developed, using materials available in the classroom; some worked with small groups of children as they rotated through activity centers; some divided the class and each team member taught one group; some worked with individual students on computer programs. Some students told us they had found themselves working in settings very different from what they expected and were adjusting to new demands: for example, learning to communicate effectively with very young children.

Methods of Evaluation

Project SEARCH poses interesting challenges for evaluation. The settings vary widely, including public and private school classrooms, preschools, after-school programs, and a boys and girls club. The fact that the project has been found useful in these diverse settings is one of its strengths, but the diversity makes it difficult to specify precisely the boundaries of the SEARCH approach. Second, the settings often had minimal science programs prior to SEARCH, making it difficult to find appropriate comparison groups. Third, although the project seeks to promote children's science learning, it also attempts to improve learning for undergraduates as well as classroom teachers, and to create new partnerships among university faculty, school faculty, community organizations and people, and students from preschool to college. These diverse goals are an exciting aspect of the project but one that requires a creative and comprehensive approach to evaluation. Finally, the project is a new approach that is still developing. Accordingly, we incorporated both formative and summative evaluation perspectives.

Because of the diversity of settings and goals for Project SEARCH, we decided to adopt a situated evaluation approach (Bruce & Peyton, 1990; Bruce, Peyton, & Batson, 1993; Bruce & Rubin, 1993; Rubin & Bruce, 1990). A situated evaluation examines the realization of the project in each of its diverse settings. It does not begin with the assumption that the implementation in each of these settings is identical, nor even that it ought to be, but rather identifies both

similarities and differences across settings as a step toward understanding the meaning and value of the project for those who participate in it. The situated evaluation can be used formatively to help guide the development of the project, and summatively, to provide an overall account of its effects.

Situated evaluations typically employ a variety of methods. For Project SEARCH we decided to collect multiple sorts of data as shown in Table 2.

Table 2

Data sources for evaluation

Data source	Amount
Field notes based on observations of the science learning activities in each of the settings	approx. 100 hours
Interviews with children, focusing on their experiences with SEARCH and their attitudes toward science and scientists	48 children, ages 5–12
Problem-solving protocols to assess children's learning and understandings of science concepts	48 children, ages 5–12
Children's work, including writing and drawing products, and other artifacts of the science activities	
Children's drawings of scientists and their accounts of scientists' work	48 children, ages 5–12
Interviews with university students	10 students
Questionnaire surveys of university students	24 students
Student course ratings	30 students
Observations of SEARCH project meetings	7 student meetings; 2 teacher meetings
Analysis of E-mail communication	Approx. 50 messages/semester
Examination of student projects	30 students
Interviews with teachers	7 teachers

A key aspect of this study was to solicit the perspectives of different participants, including the coordinators of the project, SEARCH students, teachers, and children. We met initially with the project coordinators to consider their questions and perceptions in our analysis. To get a general sense of how the project was structured, we scheduled a series of initial observations at schools, in which we watched the students working in the classrooms and had informal conversations with teachers. As our strategy for evaluating the project solidified, we began formulating questions about what we were seeing and how all of the participants perceived their roles. We visited the SEARCH office and surveyed the materials available to the students. We also attended the monthly meetings with the university students to see how the students were prepared and what kinds of issues they were sharing with their classmates and supervisors.

Over time, we observed, and often videotaped, all of the settings where SEARCH students were placed. Typical sessions involved two SEARCH students working with children for 2 hours. We produced copious field notes and analyzed our observations throughout. The

settings included 8 public school classrooms, 3 preschool classrooms, 2 private school classrooms, an after-school program in a public school, and a boys and girls club.

We also sent a questionnaire to all SEARCH students designed to explore their background, beliefs about teaching children science, and current classroom experiences in Project SEARCH. Ten students were selected to participate in semistructured half-hour interviews. These included both returning and novice students, males and females, students working with primary or lower-elementary grade level children (K–2) as well as upper-elementary–grade-level children (Grades 3 through 5), and students working in after-school programs. Students were asked to provide examples to describe how they conducted science activities in classrooms. Other interview questions focused on students' beliefs about the goal of teaching science; their approaches used to achieve that goal; and what they believed were the benefits of the project for elementary schools, teachers, children, and themselves. All interviews were audiotaped and transcribed. The data from the questionnaire and the interviews were analyzed to examine how students' backgrounds and beliefs were reflected in their classroom experiences.

We also interviewed teachers, all of whose collaborating students had also been interviewed. We observed in each of their classrooms and talked informally with each of them prior to the interviews. Interviews lasted approximately 30 minutes and were audiotaped. Our questions focused on how the teachers learned about Project SEARCH, their expectations of the project, the role of the university students in their classrooms, the planning of activities with the students, and the learning that occurred for teachers and children.

The initial observations were very useful in giving us an overall picture of the project. However, they told us little about the semesterlong process of having a SEARCH student in the classroom. They also told us little about the impact of the SEARCH activities on children. We also conducted three in-depth case studies of classrooms in which we observed nearly every meeting of the SEARCH students with the children. These were a K-1 combination room, a Grade 3 room, and a Grade 5 room. In each class we administered open-ended interviews to elicit children's perceptions of the project. The interviews included a problem to solve, to observe their approach to scientific reasoning; and a draw-a-scientist activity, to examine their attitudes toward science and scientists. We also observed SEARCH students working at a boys and girls club site and in a science camp program. These observations gave us an extended and detailed picture of how the project operates.

Results

Our results provide a picture of Project SEARCH in terms of the students' roles as curriculum planners, teachers, and model scientists.

Students as Collaborators in Curriculum Planning

The students perceived that teachers were very excited when they arrived in the classroom with opportunities for creative discovery. One student said, "I think this is the most helpful to teachers. We kind of facilitate their knowledge, their ability to bring science to kids."

Teachers did see a strong need for the project in their schools. They reported that it brought expertise, materials, and equipment to make science learning richer for children. They said that it prompted them to reflect on their own knowledge and to learn more in new areas. It also provided a source of teaching ideas, and, as several said, a reaffirmation of the need for hands-on, mindson activities. They also said that it provided an enjoyable opportunity to supervise students. It was interesting for them to observe how the science majors differed from education students they had been used to seeing in the classroom.

Students Providing Expertise in Science. A majority of the teachers reported that the students played a positive role in the classrooms. In part, they were impressed by the creativity and enthusiasm the students brought to the classroom. However, they often emphasized students' science expertise. They said that the students could provide in-depth explanations and resources, set up experiments, model processes of research, clear up incomplete information, question analytically, and cover a variety of topics the teachers might know little about.

One commented that when children "begin to probe and ask more questions, to have those students there to really break it down and give [children] some in-depth knowledge I have found invaluable." Another said,

> [Students also] attacked areas that I have not done very much with, so it had been wonderful to give me ideas. And I think there are times when they have helped us clear up things that I have been giving probably incomplete information about.

A fifth-grade teacher said,

> I have always found that they have an analytical questioning that is somewhat different from the way education approaches it, but very good for fifth grade.

Students also saw themselves as science experts, in part because one underlying premise of the project was that university could offer science expertise that the schools might not have. In answer to a question about the role students played in teaching, one student said:

> It depends on the teacher they have. My cooperating teacher is very excited about teaching science. Therefore, the best thing I can do is to complement her. But I cannot really pass her up, you know, be more than she is. In another classroom though, if the teacher isn't comfortable with science materials, then I think the Project SEARCH student is going to have more impact on what they [the children] are learning, and how they respond to it [science] than teachers themselves might have.

Thus, when the teacher is uncomfortable with science, the SEARCH student will have "more impact," but even when the teacher likes science, the student complements her efforts by bringing more science. The view of students as experts had important consequences for the content of activities. Although teachers and students adopted a variety of approaches to planning, ranging from simply working on activities the teacher had scheduled to basing them on the student's presumed areas of interest, we found very few examples in which the topics grew out of children's expressed questions or interests.

Students Bringing Resources to the Classroom. Students brought materials including petri dishes, birds, mealworms, snakes, clay, sound and light materials, anatomy kits, wooden dinosaur skeletons, a model of the ear, posters, frogs to dissect, pigs' hearts to dissect, batteries, bulbs, wires, rock tumblers, fossils, and equipment from a local nature center. They drew upon a variety of sources, including materials they created themselves, activity kits they found within the school, resources from the local nature center, and kits created by former SEARCH students. Sometimes they brought these to enrich a particular unit of study that the teacher had already planned. At other times they used materials that reflected their own interests not directly related to the classroom curriculum. One teacher commented,

> It has all helped broaden my ideas on what's available in science. . . . It's exciting to see them bring in these different things that we aren't able just to run and get. I think it's a learning process both ways. They learn what it's like to be in the classroom and then they really help us out by giving us some more science experiences for the kids. So it's real joint collaboration between both the university and the classroom.

Another teacher described Project SEARCH as "a reaffirmation of lots and lots of good things about science and the real value of having it in the grade schools."

Teachers reported that without involvement in Project SEARCH they would be providing related science activities but with less depth and with a more restricted range of topics. One said that without SEARCH he would select more topics from the basic curriculum units and spend more time covering the textbook, because of limits on time and funds. A teacher at one site did not know how science would be taught at all without Project SEARCH. Five others reported that their science activities would not be as rich and full.
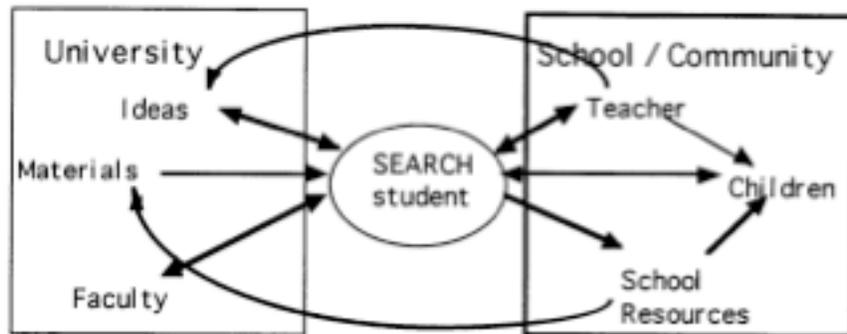

Figure 2. Network flow of benefits and information realized through SEARCH activities.

The Collaborative Model. The descriptions of the SEARCH project emphasize the ways in which the university, acting through the students, could provide materials, ideas, and expertise that were ordinarily unavailable to the schools (as shown in Figure 1). We found that in many cases this linear model operated, but that often, collaborative relations developed in which the school or community provided as much or more than the university. SEARCH students learned from teachers, not just about working with children, but also about materials and interesting science experiments. The flow of information and resources was thus more, as shown in Figure

2. For example, the university often functioned less to provide unique technical resources than to coordinate among the schools, selecting and maintaining worthwhile curricula and materials developed within the school context. The university materials were thus often developed by teachers or by teachers collaborating with SEARCH students.

Summary. The forms of collaboration around curriculum planning were simultaneously leaner and richer than the original SEARCH design implied. Students and classroom teachers often worked in isolation, severely limiting the kinds of collaboration and the mutual teaching that might have occurred. On the other hand, the one-way model of outreach has given way to a network of relationships in which materials, activities, and ideas about teaching and learning flow in many directions among all the participants. Thus, despite many difficulties in scheduling and collaboration, the SEARCH model is actually fulfilling much of its promise in terms of university–school collaboration.

Students as Teachers

One of our first questions for SEARCH students concerned the extent to which they had experienced the kinds of learning they were trying to foster for the children. Only half indicated positive experiences with science before age 12. They had participated in science fairs and special science programs, or they remembered positive classroom experiences with science activities. When asked to describe a significant science learning experience, one student answered, ". . .the science fair. This helped me research a scientific topic and create my own experiment to test something about my research." Another said, "During the summer after fourth and fifth grades, I participated in a program called College for Kids at [a college] in my hometown. This experience first exposed me to science as something more than just a topic in school."

One-fourth of the students reported significant family influence on their attitudes toward science. As one said, "My parents were the greatest influence; they really pushed me toward science. I got a microscope kit when I was young and my sisters and I would have a lot of fun looking at things with it." Another reported, "I learned more about science from my family, television, and Girl Scouts than I did in a classroom." Another one-fourth reported no specific experiences with science during their elementary school years: "I really can't think of any. In my elementary school we never had science fairs or did science projects. Back then science was just another subject along with reading, writing, and arithmetic."

Hands-on Activities. It is noteworthy that few of the science students reported positive experiences with science in their own schooling, even though they had such experiences outside of school. This provided a strong motivation for them to help children experience science as they had experienced it, through informal and fun learning activities.

Many students said that the children should learn through hands-on activities or experiments. They wanted them to learn scientific methods and to see science as a search for answers, a way of thinking, a process of learning. They wanted them to develop an appreciation for science, work with interesting phenomena, experience the creative side of science, and expand their curiosity.

Although they had university science training, few verbalized current views of science teaching and learning except in the most general way. In many cases, their own university-level science courses provided had few opportunities for the scientific research they were supposed to model. Students often expressed the goals of giving children a basic understanding of science concepts and of helping them relate science to everyday life. One student indicated somewhat a constructivist perspective on science and science learning:

> The big thing about science learning is how to study science. I know a lot of things I learn are not truth. I learn them as truth, but I am sure 20 years from now they may be replaced; but that's fine, as long as I know how to find out, how to think that way, a logical way, that's more than knowing facts. Learning facts is important, too, but there are a lot more things; thinking is more important.

Doing hands-on activities and experiments to let children experience by themselves was the most frequently reported approach to teaching science. Rather than using only lectures and worksheets, students thought that science teaching should use discussions, questioning, and relating the activity to something children know or can picture. One pointed out,

> It's important not just to read them books and tell them the information. It's important to base it on what they know; it doesn't matter if it's right or wrong; make a prediction and do it, and then find out if the results match your prediction. If they don't, figure out why.

Often, however, the exploratory aspects of the activities gave way to an emphasis on vocabulary learning and to extrinsic rewards to keep children interested. As one said in her monthly progress report,

> Then the next week we dissected frogs to show the kids some anatomy and today we learned about human anatomy. They liked the anatomy game, Some Body. We gave prizes for correct answers. Maybe that's why it went over so well! Everything is going great.

The Student as Expert. Nine of 24 students said that the most important thing for children to learn about science is general science principles. Several students indicated that specific topics should be taught to children, such as the study of the human body or weather. This content emphasis sometimes overcame their expressed interest in hands-on learning and children's construction of knowledge.

Observations of one fifth-grade class provided an example by exception of the importance of hands-on activities for children. In the course of the semester, topics covered included gravity, space travel, interplanetary distances, the electromagnetic spectrum, radio telescopes, astrolabes, the moon, and meteors.

The SEARCH student presented science content in a formal lecture format. He wrote definitions and other information on an overhead projector and children were expected to take notes of these facts. At other times, children were asked questions as an introduction to a lecture or to provide definitions of words. For example: "What do you think a hypothesis is?" "How was the moon created?" or "Does anyone know what trigonometry is?" Little discussion was

promoted by the children's responses. A more formal answer was always provided. Children were never encouraged to discuss answers with each other or collaborate.

Science subject matter was sometimes presented at a level beyond the children's level of knowledge and understanding. One teacher applauded the student's analytical method of breaking down information for the children with an attitude of expertise and what she described as a lack of flippancy toward science. Initially the children assimilated some new words. However, as the semester continued and the children grew bored with note taking, they also grew impatient with his big words and seemed to feel alienated by their use.

One child in this class said that graphs are fun, "but you have to be right." Another said the SEARCH students always know the right answer: "They know about every answer that we ask and they know about everything." Suggestions children made to improve the science activities included having more field trips and allowing the fifth graders to find their own topics. One student said, "If we could ask the students what kind of experiments they wanted to do and what they wanted to study, then you could break up into certain groups that want to do a certain thing." This idea corresponds to the way science had been handled in an earlier grade for this child and is more consistent with the general ideals espoused by Project SEARCH than some of the realized activities in this class.

We observed that it was not always the case that the students were more expert in science than the teachers were. The teachers often had a greater breadth of knowledge, and especially a breadth with regards to science activities for children. Thus, they knew more about classic elementary school science activities, such as mystery powders and oobleck, than did the students.

Discourse Patterns. In presenting science content, the SEARCH students tended to follow the structure typical in most educational settings: teacher initiation, student response, and teacher evaluation (IRE) (Cazden, 1988). Usually, the initiation was in the form of a factual question asking children to recall or recognize specific information, such as "Can you name the organs inside our body?" or "Do you know what kind of cells we have?" Except when questions might have been too abstract for the children ("Does anyone know what human anatomy is?"), many hands went up to offer answers. When questions were directly related to children's experiences ("Does anyone wear glasses?" "How many people like frogs?"), children were particularly motivated to provide answers. Occasionally they could not figure out how to respond to questions about information which was new to them. However, children continued to pay attention and would respond either by relating to whatever they were familiar with or by guessing.

Often, project students provided opportunities to help children construct the meaning of a science lesson in a group. For example, 2 to 6 children would be assigned to work as a small group. In these small-group activities, children had many more chances to manipulate materials and equipment than during whole-class instruction. In addition, they could do experiments on their own rather than just watch experiments demonstrated by the students. They also talked to each other about the topic of the science lesson and had discussions during the small-group activities. They interspersed comments and questions about the activity.

Summary. SEARCH students felt that their own school experiences had fallen short of their outside-of-school opportunities for learning science. This motivated them to want to provide to children rich opportunities for engaged, hands-on investigations of interesting phenomena. In many SEARCH classrooms this happened, supported by the ample supply of university-based materials and curricula. All too often, however, the students assumed a simplistic version of their role as expert, seeing that in terms of content delivery. They then failed to listen to children and resorted to familiar patterns of teacher-directed learning in which the children had few chances to examine their own theories or articulate their ideas. These patterns were reinforced by the teachers' perceptions of the university students as content experts who would remedy the teachers' perceived lack of science knowledge—to clear up things and deliver the complete information.

Students as Role Models for Scientists

Many project students saw themselves serving as role models for the children, presenting them with the opportunity to interact with someone who had chosen science as a career. One student described this experience:

> One day, three little girls talked about what they were going to do when they grew up. They said, 'We want to be scientists or we want to be painters.' . . . I mean, that just made my day . . . they are thinking about being scientists later and working in a lab. I think they never thought about being scientists before I came in. Scientist may be a too large a concept. You know, you go to a doctor you see what he does, they give you an idea what you can do. Who works in research lab? That's not something you are exposed to as a little kid, unless your parents do it.

On the whole, SEARCH students reported that children were excited by their presence in the classroom and that children treated them both as a teacher and a friend. One student related,

> They seem to grow attached to me quickly and from the sounds of the general rumbling when I arrive they're happy to have me there to teach them science. I think it's partly because, while I am there to teach them, I'm also a student just like them—maybe it makes science something that I'm doing with them, not just teaching them.

This view was echoed by the teachers. Many felt that the SEARCH students were good role models, and more accessible to the children than practicing scientists would be, because they were younger and in classrooms themselves. This, of course, had its downside as well. Because the students were not in fact working scientists, they often found themselves in the position of trying to portray a role that they were only beginning to understand themselves.

Images of Science and Scientists. Most of the children called the SEARCH students scientists, although most also said they did not know what a scientist was. Many seemingly had difficulty with a definition or even a reference to a media scientist. One first-grade girl, however, said that "Scientists make things and do stuff that is real neat. Do stuff with different kinds of things. At the university." She then referred to the example of the students who did a liquid nitrogen demonstration at the science fair.

When asked to draw a picture of a scientist, one girl in kindergarten asked, "Can a kid be a scientist? I'm a scientist; I try to figure things out." She then drew a picture of herself walking her dog. The children most often drew one or both of the SEARCH students. One first-grade girl asked, "Does it have to be a girl?" She said she asked this because one of the SEARCH students was "a girl." In all three classes we saw many similar examples of the ways in which the presence of the SEARCH students had substantially affected children's images of scientists.

However, very few children seemed to know that both of the visitors to their classroom were university students, and many said they had never been to the university. During the semester, the SEARCH project held a science fair there. This was the first visit to any university for many of the children, although many did not know afterward that the building housing the science fair was actually part of the university.

Andrew is a first-grade boy whose responses during the interviews were typical of many of the children:

I: What else do you remember? A: [I] remember that pop can? It shrank, crinkled up.

I: Why did that happen?

A: It's part of the science. And [I remember] Jake the snake and lizards. Wherever they go they turn the same color.

Later,

A: Remember that frog? His heart was still beating but he couldn't think. The heart gots a mind of its own when he's dead. We saw eyes; it was scary, the chin inside, the mouth and tongue.

I: What is a scientist? A: Scientist is like an artist [points to picture of whales]. They cut them open and cut skin off and use it for clothes. I: Do scientists study whales?

A: *We* study whales. [A whale exhibit was an important learning center in this class] A: Last year [the student] cut open a squid.

During this interview, Andrew referred to two activities that the SEARCH student had led a year earlier, a long time for a first-grade child. As did many of the children, he found these activities very memorable.

In answers to a survey questionnaire across three classrooms, children offered many answers about what scientists do. These included general processes such as observe, do research, work in a lab, make things, invent, experiment, and explore. Some answers described scientists doing something related to the topics children had studied: for example, learning about an animal, dissecting, studying planets, learning how plants grow, looking for fossils.

On the whole, children adopted the popular stereotype of scientists as people who "mix chemicals, mix things." This was evident in their drawings: 12 of 21 third-grade children drew a scientist doing a chemistry experiment. Two children drew a picture of scientist standing beside a table with some equipment. One drew a scientist dissecting a frog, and 5 showed people just standing. Some said they showed the scientist wearing a lab coat because it would protect against

chemical spills or harm by poisons. The coat usually contained several pockets in which the scientist could put pencils or test tubes. In the fifth-grade class, 4 showed a scientist with a lab coat; 2 showed glasses; and 4 included a lab setting with beakers, test tubes, and clipboards. Only one drawing showed a scientist doing field work— digging dinosaur bones at an archeological site.

Figure 3. Fifth-grader's drawing of a scientist.

Beyond the obvious influence of television and movies, however, the children were also affected by the presence of the Project SEARCH students. When we asked whether they had seen any scientists, many referred to both project students as scientists. A girl explicitly indicated that she drew a woman scientist who was the project student. When they were asked to name the scientist, however, 9 of 12 children thought of a male name.

Two of the scientist drawings in the fifth grade were clearly women scientists. Three of the 17 children did not draw a scientist. Each of these and one other student wrote that a scientist could look like anybody. Figure 3 represents one child's drawing of a woman scientist. This child also wrote that a scientist can be a man or woman. During the interview, one child simply said, "Anybody can be a scientist; even if it is not what they do for a living, they can make things and investigate." Finally, one drawing included a caption with the scientist saying, "I am smart."

Children's responses showed that they were beginning to see themselves as scientists, as can be seen in this interview with a third-grade student:

I: Do you have a name for the scientist [in the child's drawing]? C: Bob.

I: Oh! Bob, why is it Bob? C: Because this is like my name.

I: You kind of think you are a scientist like him? C: Yeah! Sometimes I try to mix, mix up juice.

I: You think scientists do the same thing as you did? C: They do things to make us healthier. Because too much juice has a lot of sugar, so they put water in and mix it.

Children's Interest in Learning Science. Near the end of the semester, we interviewed all 18 children in a K–1 class. We asked what they liked and what they remembered about the science activities. Among the most popular and memorable activities were making oobleck, dissecting a frog, mixing colors, and using a prism. Children often spoke with great animation about these, although they sometimes lacked the formal vocabulary to describe what they had done. A word such as *prism,* for example, was remembered by only a few of the children, but many described the process of making rainbows.

Children seemed to particularly enjoy the messy activities (7 of the 18 mentioned oobleck first, even though it was one of the early activities in the semester). They also most frequently mentioned the activities in which they could directly interact with materials. Frog dissection was the only exception. Many remembered the frog dissection first, although on that occasion children were limited in their ability to handle tools or touch the frog.

In a third-grade class, children gave other examples: "I like to put things together. Like we did on Wednesday, light, battery, and wire," or "Before this week, like how we looked at different kinds of things in the microscopes, and dissecting the frog." One child said he did an experiment mixing detergents at home, because they mixed colors in the classroom and "they gave me the idea to do it." In addition, children tended to describe as their favorite science class one in which they could observe and experiment by themselves: "I like all of it, because it is fun, and you get to do experiments," or "I like doing dissecting, so I can see it with my own eyes."

In the third-grade classroom survey, 81% said they liked science "very much" and 67% said it was "very important" to learn science. In the fifth-grade classroom, only 53% said they liked science "very much" and 41% said they liked it "a little." However, 82% said it was "very important" to learn science.

When children were asked what they liked most about science, most of the answers related to the topic they had recently studied with the SEARCH student. Five students indicated dissecting frogs, 1 mentioned the human body, and 1 the solar system. Four students liked chemistry, 1 liked learning about animals, and 1 liked lasers. Five students replied they like all aspects of science. Other answers included testing things and doing experiments. However, they could not articulate very well why they liked a particular topic or what aspects of the topic they liked most. The common answers were, "I liked to dissect a frog because it was interesting," "I like learning about animals because I really like animals," "All of it [science lessons], because it is fun," and "You get to do experiments," "Laser, I don't know why," and "I like to learn more in science because I like to learn stuff."

The interviews showed that children liked the SEARCH classes because they could directly observe phenomena such as the inside of a frog's body or an electrical circuit. For example:

In the book, if I haven't dissected the frog, I don't know about it. Then I wouldn't know if it is true or not. I probably won't believe the book, so I try to do a lot of things in science. I really like science a lot. I don't believe it until I try it.

[I: What do you like in science?] Dissecting, see what's inside the body, see what color it is, and see differences about boys and girls. Because the girl has eggs, purple things, but the boy didn't, and making machines and stuff like that . . . so I can see it with my own eyes.

Summary. Children in SEARCH classrooms were generally excited about the science learning opportunities afforded by the project. They saw science as fun and a chance to mess about with interesting materials. That is hardly sufficient for lasting learning, but it is an improvement over what many of them had had before the project. Unfortunately many did not experience the questioning, dialogue, articulation of theories, reflection, and other aspects of science that might have altered their conceptions of science as mixing things. Nevertheless, their views of what science can be and what scientists are like expanded through their interactions with the SEARCH students. Most notably, many had reinforced the idea that they could be scientists, too.

Conclusion

Project SEARCH is a simple concept: Enlist the energy and expertise of university science students to improve science learning opportunities for children. Despite its simplicity and face validity, approaches such as SEARCH are not widely adopted. Those who are so inclined quickly encounter institutional and logistical constraints that dampen initial enthusiasm. However, Project SEARCH is now in its fourth year, reaching dozens of university students and teachers and hundreds of children.

All of the students interviewed indicated that they had learned from the project. They stated that they learned how to present things to young children; they gained teaching experience, communication skills, and organization skills in designing activities and became more creative in developing activities. They also believed it strengthened their knowledge of science. One related that actually setting up experiments was something new for him:

I actually learned something about science. This was because I had to teach kids. Things like bacteria. I know the stuff about bacteria, but I never set up experiments, I never made agar, you know, little things like that. Now I know how it's done.

Another said that the experience helped her "see if I can actually use what I have learned." Yet another talked about how this experience might affect his future career as a teacher:

[I am considering] possibly teaching; I am not sure. I enjoy students. I have a lot more responsibility; it helps me grow and learn a lot more. I've always been a student all my life, and now I feel like I crossed the line. If I didn't do this before, and I went on with my life . . . I don't know if I want to be a teacher, [but] this is very positive experience. It encourages me.

The project is not without its problems. The collaborative aspects of SEARCH could certainly be strengthened. In terms of curriculum planning, there could be better communication between teachers and SEARCH students, perhaps through small-group meetings, or schoolbased teams. This might facilitate a stronger integration of SEARCH activities into the life of the

classrooms. Electronic communication might be used in more substantive ways among SEARCH students, teachers, and children.

In terms of teaching, many of the students are ill prepared to work with children. Some replicate the textbook or lecture approach to science teaching that they have experienced, despite the fact that these are the methods SEARCH was designed to counter. Most do engage children in hands-on activities, but only a few find ways to build activities out of children's own interests and questions or to provide opportunities for children to articulate their ideas in their own words, reflect on what they're learning, or participate in constructive dialogue.

This relates to another missing element. The SEARCH students themselves are learners in this project, and it is unrealistic to hold them to a standard of master teaching. However, especially because they are learners, it is crucial for them to have analogous opportunities to articulate their ideas about teaching and learning, to reflect on what they are learning, and to participate in constructive dialogue. Unfortunately, institutional, logistical, and financial constraints make it difficult to provide these opportunities.

Despite these concerns, we see a project that is already affecting teachers and students in positive ways, some of which were unanticipated. Students report learning about and enjoying working with children. In a number of cases they describe learning new science content or having greater hands-on science learning opportunities for themselves. Several said that their experiences have led them to consider education as a career. Similarly, teachers report learning about new activities and new ways of working with children.

There is evidence that children's attitudes about science, science learning, scientists, and their own roles are changing in positive ways. We saw this in the interviews, the scientist drawings, and the way children were engaged in learning with the SEARCH students. It has been difficult to assess the amount of learning brought about in the project, but children do find the activities to be engaging and memorable. The hands-on experiences the project provides for children are often their first opportunity to investigate phenomena in depth and to construct their own understandings. Our observations are consistent with the impressions of teachers and students that Project SEARCH is an outreach model worth replicating and studying further.

Acknowledgements

References

Barlow, J. (1993, December). *Undergraduates help kindle young pupils' scientific curiosity.* [Press release]. U of Ideas in Science. Champaign, IL: University of Illinois at Urbana-Champaign.

Brown, D. E., & Sinclair, M.R. (1993). Grow in science: Explorations in science, learning, and teaching. In P. A. Rubba, L. M. Campbell, & T. M. Dana (Eds.), *Excellence in science teacher education* (pp. 191–202). Yearbook of the Association for the Education of Teachers of Science. Columbus, OH: ERIC Clearinghouse for Science, Mathematics, and Environmental Education.

Bruce, B., & Peyton, J.K. (1990). A new writing environment and an old culture: A situated evaluation of computer networking to teach writing. *Interactive Learning Environments, 1,* 171–191.

Bruce, B., Peyton, J.K., & Batson, T.W. (Eds.). (1993). *Network-based classrooms: Promises and realities.* New York: Cambridge University Press. Bruce, B.C., Bruce, S., Conrad, R., & Huang, H. (1994, December). *Evaluation of Project*

SEARCH (Science Education and Research for CHildren): 1993–94. Urbana, IL: University of Illinois, College of Education.

Bruce, B.C., & Rubin, A.D. (1993). Electronic quills: A situated evaluation of using computers for writing in classrooms. Hillsdale, NJ: Erlbaum.

Cazden, C.B. (1988). *Classroom discourse: The language of teaching and learning.* Portsmouth, NH: Heinemann.

Dewey, J. (1956). *The child and the curriculum and the school and society.* Chicago: University of Chicago Press. (Original works published 1902 and 1915)

Dow, P. B. (1991). *Schoolhouse politics: Lessons from the Sputnik era.* Cambridge, MA: Harvard University Press.

Driver, R., Guesne, E., & Tiberghien, A. (1985). *Children's ideas in science.* Milton Keynes: Open University Press.

Duckworth, E. (1987). *"The having of wonderful ideas" and other essays on teaching and learning.* New York: Teachers College Press.

Education Development Center. (1970). Man: A course of study: An evaluation. Cambridge, MA: Author.

Glaserfeld, E.V. (1989). Cognition, construction of knowledge, and teaching. *Synthese, 80,* 121–140.

Goodlad, J.L. (1984). *A place called school: Prospects for the future.* New York: McGrawHill.

Griffin, J.B. (1990). Developing more minority mathematicians and scientists: A new approach. *Journal of Negro Education, 59,* 424–438.

Hall, E.R., & Post-Kammer, P. (1987). Black mathematics and science majors: Why so few? *Career Development Quarterly, 35,* 206–219.

Kyle, W.C., Bonnstetter, R.J. Jr., & Gadsden, T. Jr. (1988). An implementation study: An analysis of elementary students' and teachers' attitudes toward science in process-approach vs. traditional science classes. *Journal of Research in Science Teaching, 25,* 103–120.

Lauterbur, P.C., Dawson, M.J., & Bruce, B.C. (1993). *Project SEARCH (Science Education and Research for CHildren): Science education outreach for K–6* (Proposal submitted to the National Science Foundation). Urbana, IL: University of Illinois at Urbana-Champaign.

Lin, H.-F. (1994). *Science discourse in one American kindergarten classroom.* Unpublished doctoral dissertation, University of Illinois, Urbana-Champaign.

Mullis, I.V.S., & Jenkins, L.B. (1988). *The science report card: Elements of risk and recovery. Trends and achievement based on the 1986 National Assessment.* Princeton, NJ: Educational Testing Service.

Myers, R.E. III, & Fouts, J.T. (1992). A cluster analysis of high school science classroom environments and attitude toward science. *Journal of Research in Science Teaching, 29,* 929–937.

Osborne, R., & Wittrock, M. (1983). Learning science: A generative process. *Science Education, 67,* 489–508.

Piburn, M.D., & Baker, D.R. (1993). If I were the teacher . . . Qualitative study of attitudes toward science. *Science Education, 77,* 393–406.

Roth, W., & Roychoudhury, A. (1994). Physics students' epistemologies and views about knowing and learning. *Journal of Research in Science Teaching, 31,* 5–30.

Rubin, A., & Bruce, B. (1990). Alternate realizations of purpose in computer-supported writing. *Theory into Practice, 29,* 256–263.

Russel, A.A. (Ed.). (1992). *Changing the image of chemistry: Biennial Conference on Chemical Education* [Abstract]. Washington, DC: American Chemical Society, Division of Chemical Education.

Saunders, M.L. (1992). The constructivist perspective: Implications and teaching strategies for science. *School Science and Mathematics, 92,* 136–140.

Shymansky, J.A. (1989, April). What research says . . . about ESS, SCIS and SAPA. *Science and Children, 26,* 33–35.

Snelling, W.R., & Boruch, R.F. (1972). *Science in liberal arts colleges: A longitudinal study of 49 selective colleges.* New York: Columbia University Press.

Wurth, J. (1993, January 27). UI Beckman science fair features joint projects by kids, undergrads. *Champaign News-Gazette,* p. 3.

Yager, R.E., & Yager, S.O. (1985). Changes in perceptions of science for third, seventh, and eleventh grade students. *Journal of Research in Science Teaching, 22,* 347–358.