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ABSTRACT

The Marie Curie Mathematics and Science Center at St. Thomas Aquinas College (New York), in a comprehensive effort to improve mathematics and science education, offers the Saturday Morning Search for Solutions enrichment program for area students in grades 7-12. The program is interdisciplinary, connecting technology and the study of societal problems with mathematics and science. This paper describes the processes and effects of team teaching and constructivist approaches to learning documented in 3 successive years of the program. The approaches were presented to students by teams of scientists and professional teachers in a community of discourse or apprenticeship model in nontraditional field sites that included real science laboratories. The purposes of the model were to improve students' attitudes and interests in their own involvement in mathematics and science; and increase students' knowledge of the practice of real mathematics and science and the working environment of scientists. Results confirm the feasibility of the model, and offer positive qualitative evidence of program effects. Sample activities and materials, and an outline of program evaluation design and outcomes are included. (Contains 14 references.) (Author/LL)

TEAM TEACHING

IN THE SATURDAY MORNING SEARCH FOR SOLUTIONS

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TEAM TEACHING IN THE SATURDAY MORNING SEARCH FOR SOLUTIONS

Abstract

The processes and effects of team teaching and constructivist approaches to learning were documented in three successive years of program. The approaches were presented to secondary students by teams of scientists and professional teachers in a community of discourse or apprenticeship model in non-traditional field sites that included real science labs. The purposes of the model were to demonstrate the model; improve students' attitudes and interests in their own involvement in mathematics and science; and increase students' knowledge of the practice of real mathematics and science and the working environment of scientists. Results confirm the feasibility and nature of the model, and offer positive qualitative but non-generalizable (at this time) evidences of program effects.

Conceptual/Theoretical Framework

Constructivism posits that each of us constructs his or her own schemata: bits of knowledge, explanations, or pictures of reality stored in the brain--based on their fit with our individual goals, previously existing concepts and new perceptions (von Glasersfeld, 1990). These pictures of reality may or may not be correct as judged by comparison with what most other human beings see as reality. Cobb (1986, 1990) ascribes the commonly held or shared realities to the "consensual domain." The instructional process then becomes a matter of helping the individual develop, confirm or correct his own reality pictures so that they approach the realities of the consensual domain.

Constructivists believe that learning does not take place until that newly formed construction of reality is put in place by the learner, and that learning does not occur when information is fed into a passive learner. **The learner must take ownership before true understanding is in place.**

This understanding of the dynamic and personal nature of how learning takes place propels the preferred method of instruction in the content areas toward "doing" endeavors that provide new sensory experiences and allow for the self-constructions which are also designed to increase the students' problem solving and reasoning power. Other research (Vygotsky, 1978) expands this philosophy with the evidence that although students must construct their own concepts, new constructions based on previously acquired informal knowledge are influenced by formal (e.g., top-down schooling) experiences.

The teacher's role would then be to lead a team that learns together: an apprenticeship model (Lave, 1977; Lampert, 1991) with the student conducting investigatory and constructive projects and the classroom serving as the journeymen's and expert's community of discourse.

This is not too different from the environment of cooperative learning (Johnson and Johnson, 1987; 1989) which we believe provides the opportunity for the interactive discourse that may stimulate new connections to previously informally developed constructions of knowledge. It is an extension as well of Vygotsky's description of learning as taking place when there are top-down (scientific) connections made to bottom-up (spontaneous) constructions. Vygotsky assumed adult top-down mediators--why not peers as mediators? **The extension in our case is that the teaching team models the community of discourse. They learn from the process and their students join in.** Together they learn to become good problem solvers.

The Marie Curie Mathematics and Science Center accepts these premises as its basic philosophy. Unfortunately, current high school curriculum is content based. Instructional methods often see the learner as passive--an empty vessel to be filled with information. The content, itself, does not reflect the dynamic nature of scientific knowledge. The breadth of this knowledge has increased so exponentially that it is impossible to give students a realistic picture of its scope.

Our alternative to the passive transfer of information and unrealistic surveys of content is an in-depth exploration of focused problems that offer interesting examples of society-relevant content and employ current technology and scientific methods in a real science environment. We believe that a complete restructuring of the existing mathematics and science curriculum toward this direction is needed; and that the potential for success of this undertaking by the educational establishment will be enhanced by attention to the models of practicing mathematicians and scientists. Active participation by members of the scientific private sector were critical in our program's success.

Program Context

The Marie Curie Mathematics and Science Center at St. Thomas Aquinas College is a comprehensive effort to improve mathematics and science education in the region. St. Thomas Aquinas College is located in Rockland County, New York. The community is quite diverse. Although essentially middle class, there are poverty pockets and at least two of our consortium districts have large Hispanic or African-American minority enrollments. The public schools within the Center's consortium reflect the diversity of the community. The parochial schools in our group (there are now seven of these) vary from mostly white to 100% African-American. All also have growing Asian-American populations and representations of the variety of new immigrants.

The Center represents a successful model of collaboration between businesses, professional science, local schools and a teacher education institution. There are several components to the Center activities. There are other programs which address the in-service needs of teachers directly, but this paper concerns one of the components, **The Saturday Morning Search for Solutions Program (SMSS).**

In 1991-1992 with the help of Dwight D. Eisenhower funds, the Center launched an enrichment program in mathematics and science for the students in the school districts that surrounded the college. In order to avoid conflict with other school activities, the program was designed to run on Saturday mornings. The initial group consisted of 109 students in grades 7-12 from three school districts as well as the parochial schools in each of these districts. The program was constructed to provide four grade level based curriculum units of fifteen-weeks duration. The positive response to the program was such, that during the 1992-1993 and 1993-1994 school years the program was expanded to provide 146 and then 170 student placements. The number of curriculum units offered was increased to eight and then ten separate units, each of ten weeks duration. Also, in an effort to have the student population become more culturally and racially diverse, the original consortium of school districts was expanded.

To help to achieve the goals as stated below, the American Cyanimid Company and its Lederle Laboratories Research Division and Columbia University's Lamont Doherty Geological Observatory have been members of the consortium since the program's conception. The 1993-1994 program saw the additional inclusion of I.B.M. and the environmental engineering firm of Lawler, Matusky, and Skelly.

Program Purpose

The purpose of SMSS is **to provide a "doing-rich" extra-curricula opportunity for secondary (7-12) students** from contiguous school districts. Students are actively involved in doing "real" science and mathematics in an environment that is different from their formal school experience. They are engaged in activities that have been designed to show the interdisciplinary nature of mathematics and science.

Although the program reaches out to students directly, it simultaneously addresses the needs of pre-service and in-service teachers, who become involved with scientists and their current technology on our teaching teams. Our own research as well as that conducted by others indicates that teachers can learn to provide a program based on constructivism (e.g., Resnick, 1983, 1989); and that students' problem solving and reasoning power will be increased as a result of this type of instructional approach.

Special emphasis is placed on the encouragement of female students to participate in the program and in further participation in mathematics and science. Approximately 60% of our students are females. Specifically, our goal for females is to provide a structured formal experience that will help to compensate for the missing informal experiences which are a normal part of the male experience in the American culture (Alper, 1993). However, because it is our belief that the restructured teaching approaches we use for these subjects would benefit all students the program has been expanded with an outreach to other minorities as well.

The most **unique** aspect of our program is the liaison that exists among the consortium members. A close working relationship between the college and consortium members is at the heart of our Center's efforts. The schools and the scientific agencies come together as the Marie Curie Mathematics and Science Center Advisory Board. The components are united on the Board as well as in the teaching staff of the Saturday Morning program. The Advisory Board's purpose is to define policy and conduct planning. They are involved in such decisions as whether or not to increase of the membership of schools and agencies in the consortium or to include a representative from the local town government.

Goals

The **Saturday Morning Search for Solutions** provides a program of enrichment for 7-12 graders which is interdisciplinary, connecting technology and the study of societal problems with mathematics and science. As described above it is based on a grounding philosophy of constructivism. The intended more specific goals of this program include all of the following, but this report will focus especially on the first two goals mentioned:

-To demonstrate a model of co-teaching with a team of scientists, pre-service and in-service teachers in non-traditional settings; and measure its impact on student attitudes and learning.

-To demonstrate the nature of a constructivist approach to teaching mathematics and science

-To demonstrate examples of interdisciplinization of the curriculum

-To demonstrate how to change prevalent perceptions of both students and teachers that mathematics and science are content areas to be learned passively, to a view that they are really doing endeavors.

-To help female and other students gain interest in mathematics and science

Target Group and Recruitment Process

Recent reports have indicated the urgent need to include more females and minority students in the mathematics and science courses that are being taught in our nation's high schools. It is hoped that participation in our program will encourage these groups to pursue careers in the mathematical and scientific fields; helping their own futures as well as national needs to meet the anticipated scientific and technical challenges that we will face as we rapidly approach the turn of the century. Many students in these groups shy away from enrolling in Math and Science courses because of negative school experiences or lack of informal or extra-curricula activities that might excite their interest.

To help to counteract this, SMSS presents mathematics and science in an unthreatening, interactive, and interesting form. The literature that is used in recruitment is written to encourage a diverse cross section of the population in the schools to participate in our program. Our students have therefore not just come from advanced science and mathematics classes. When selections were necessary we also looked for a broad range of students including some who were interested but may have lacked confidence in their own capabilities. Fortunately, we have not had to turn many students away, and therefore we have also included many students who already have interests and talent in these subjects.

Teachers were encouraged to suggest that all students should consider signing up [illegible] program. To counteract over-selective in-school decisions, we asked the schools to mail [illegible] brochures directly home to parents. Students must obtain brief recommendations from teachers and parents; and write one themselves. They may request either th[illegible] spring or fall ten week sequence or both.

Staff Recruitment

The Marie Curie Mathematics and Science Center Advisory Board has also been instrumen[illegible] in recruiting teachers and scientists, as well as in performing selection of both students and staff[illegible]e staff recruitment process requires scientists and teachers to propose a problem for study and [illegible] describe how quantitative components will be introduced. The Board and management th[illegible] to make a team match that is appropriate for a particular grade level.

Operation

Each curriculum unit is then taught by the team of scientist (or team of alternating scientists), a professional teacher (7-12 or college), and a pre-service teacher. This arrangement allows scientists to learn from the teachers, teachers to learn from the scientists, and pre-service teachers to learn from both the scientists and the teachers. Students learn from their peers and the teaching team, which in turn learns from the students.

Classes and laboratories are held at Lamont Doherty, Lederle Laboratories, at various field sites and at participating high schools and at the College. Some of the most current technology housed at the scientific institutions (Lamont Doherty and Lederle Laboratories) are used in the search for answers to the questions that have been proposed. Computers and other technologies are a vital component in the quest for these answers. The open interaction between the members of the teaching team encourages and sets examples not only for the secondary students but also for the pre-service teachers. We will describe the ethnographic detail of these in our section on results below. The exposure to the role models from scientific and industrial community is with the intent to improve the general attitude of the students toward both mathematics and science as a subject, as well as a career.

The weekend feature also helps to make the facilities at Lederle Laboratories, the boats of Lawler, Matusky and Skelly and at Lamont Doherty Geological Observatory more readily accessible for use, either on a regular basis or as locations for field trips as the curriculum warrants.

Indirect Effects

Several points of integration between the Saturday Program and the rest of the College and secondary school programs have significant indirect effects on participants.

A. In reference to the College program:

‡ Student teachers are involved with experienced teachers and scientists as team staff members.

‡ College faculty are involved with potential students and with scientists in the field.

‡ All math and science faculty are exposed to new technology, especially in the scientific

workplace. Even those who are not on the staff have become involved in exploring these. For example, new IBM software, and analytical methods and devices used at Lederle, or Lamont.

B. In reference to the consortium schools:

‡ Program teaching staff are involved as above for college faculty. A brochure inviting their participation is disseminated through the districts.

‡ There has been a cross-over with our in-service teacher leadership program. Teachers involved as Saturday Morning staff becoming involved in the inservice program as mentors for others and vice-versa.

‡ In-district math and science teachers are asked to recommend students and are then asked to evaluate the program's impact on the student. **There is anecdotal evidence that the program has had noticeable impact on school performance in a number of cases.** Students share their activities with classmates.

Curricular/Instructional Approach

Our curriculum is based on the philosophy outlined above. To help change not only the students' but also the teacher's perception that mathematics and science are content areas that are learned in a passive manner, we use activities that are exploratory, investigatory, conceptual, and proactive rather than reactive. By presenting them in a "doing" format, we hope to instill a sense of excitement that is infectious for both the students and the teachers that are involved.

Each one of ten curriculum units is built around finding the solution to a problem which demonstrates the relationship between science, technology, society and mathematics. Examples are: What is the possibility of an earthquake in Rockland County? How can we use mathematical models and the computer to help us make important world decisions? How do we develop natural products into disease fighting drugs? What is the quality of the water of the Hudson river? What is the relationship between science and fitness, beauty, and health? Our program has as one of its many aims to show the interdisciplinization of curriculum.

By teaming both in-service and pre-service teachers with professional scientists we have broken the isolation that teachers usually encounter in their classrooms and the image that the teacher is the sole and inviolate source of information. The students invariably report that they are inspired by the discourse that takes place--they have learned that there is not always a single right answer in a scientific endeavor and that different points of view and different collections of data have value in the final consensus. This atmosphere encourages them to take intellectual risks as well, and to use information obtained from interaction with their peers as well as from their teachers.

Learner Activities and Materials

The table below outlines some of the more specific activities and materials used in our program. Examples of our evaluation instruments, curriculum outlines and other documents are available from the Center.

SAMPLE ACTIVITIES AND MATERIALS

ACTIVITY	MATERIALS
Completion of application including recommendations from parent, teacher and self.	Brochure expalining program which is also an application form and is mailed directly by student to college.
Attendance with parents at opening breakfast session which provides orientation and complete perspective of program including introductions to staff and their personal scientific projects.	Letter of invitation to parents, who usually show in larger numbers than attendant students; sometimes to take the place of a student who can not come on this day.
Participation in ten or twenty sessions of one or more of our ten programs (some students come for both the fall and spring sessions), which may be at College labs or at Lederle labs, or at Lamont Doherty labs or at labs at local high schools. Most of this time is spent in the lab or in the field, but there always additional classroom discussion.	Too vast to completely describe here but included are such things as: computers, core samples and water sampling probes, seismograph data, internet computer programs, computer managed scientific probes, robotics, a variety of biological and chemical analytical instrumentations, microscopes (including electron), culture and fermentation devices and their living contents, a greenhouse, a marine science classroom with thirty aquariums
Participation in a variety of supplemental field trips	These included trips on marine exploratory vessels on the Hudson River, an overnight at an environmental study center, the Botanical Gardens, science museum and a variety of waterfront locales.
Participation in career day at which they had an opportunity to meet with a broad array of scientists and talk specifically about the nature of careers in science.	See career day bulletins.
Participation in program evaluation	See instruments

Research Design

We did not implement this program for the distinct purpose of conducting research, but from the beginning incorporated a number of program evaluation elements. Our program evaluation hypothesis is that the experiential activities described above will accomplish our program goals as stated above. However, as in true science, one can learn as much from the process and from the product. For the purposes of this paper, therefore, we will provide descriptions of the nature of the processes whose demonstration is our goal--team teaching and the constructivist approaches--as well as report the effect of these approaches as measured by the consequent change in student's knowledge of the methods of science and their attitudes toward it.

Quantitative and quaiitiative data were collected over two years (we will soon have the third year) via multiple means including the following:

- A two part questionnaire completed by students; one part open ended questions, and one a five point scale checklist. These were administered ex-post facto as a reflection of pre and post program understandings in the first year and as ten week interval pre and post administrations the second year (we have lengthened the effect interval to the double participation period of twenty weeks over a twenty four week time span) for the large number of students who came for double sessions this third year.)
- A reflective ex-post survey of student behavioral changes was asked of parents each year. A checklist was supplemented by open ended questions and a place for comments.
- A check list with place for comments was also sent to home teachers. Response on this was very disappointing--and the reasons worth exploring in detail beyond this paper.
- Interview feedback from staff was obtained at planning meetings and a post session debriefing.
- Ongoing field observations of program were recorded and documented on film.

The reliability of the instruments over time was tested in two ways: A coefficient of correlation between two non-involved student administrations in the home schools of our staff, r= .87; a test-retest measure of consistency over time from the first pre-post interval of ten weeks, r=.84. The content validity of the instruments was determined by an analysis of match to objectives by the staff. We also believe that the relative agreement between the student responses of the first year and their parents' notations of observed behavior offers construct validity.

We had no controls to separate the variables of team teaching and constructivism, and therefore can not make valid inferential claims in reference to either as a unique affecting variable. Interactive effects between the variables is assumed. Of course, as in most educational cultures, there are additional interacting variables such as the student self-selection process which must be considered; and so inferential generalizations to a larger population would be spurious.

Analysis of effect over the limited treatment period of ten Saturdays for some students (which we implemented in the second year for a variety of reasons) is also not likely to generate significant results on a pre-post administration of the same instrument. Instead significant correlations are more likely an indication of instrument reliabilty. The fifteen week period of the first year gave us higher percents of change, and so in this third year we have collected our data to be able to consider differently those students who were engaged for ten weeks and those who were engaged for twenty weeks. Although we have collected quite a bit of empirical quantitative data and done some descriptive analyses of our results, our emphasis is on the ethnographic qualitative pieces. We begin with the outline below.

OUTLINE OF PROGRAM EVALUATION DESIGN AND OUTCOMES

Goal and Claim	Methodology	Results	Supporting Evidence
To demonstrate the nature of a constructivist approach to teaching mathematics and science: *This has been demonstrated by the nature of the experiences.*	Participant observer field research. Observations of and by students and teachers in action. Documentation via video-tape, interview, (some by public media), student reflections and open ended written answers to questions. Cognitive changes measured below. Every program observed and recorded on tape. Every teacher interviewed. Sample size of students appearing in tapes approximately 30%.	Students and teachers observed participating in construct-building activities, using the most current technology. Student reflections and responses to questions indicate doing nature of experience.	Video tape,stills and written student and parent responses; reflections on activities. Comment summaries attached.
To demonstrate a model of co-teaching by scientists and professional pre and inservice teachers.	As above with additional interviews and reflections by staff.	Students reported that the teaming made the experience both different and better. They liked the repartee and discourse over results. It made them feel safe to venture their own points of view and discrepant data. Staff reported positively on mutual gain from the experience (see attached lists of comments).	As above
To demonstrate examples of interdisciplinization of the curriculum: *Curriculum outlines show inter-disciplinization.*	As above plus examination of curriculum outlines.	Curriculum applies quantitative methods and consider societal implications.	Above and curriculum outlines

Goal and Claim	Methodology	Results	Supporting Evidence
To demonstrate how to change prevalent perceptions of students that mathematics and science are content areas to be learned passively, to a view that they are really doing endeavors: *Perceptions were changed as student experienced doing science.*	Pre-post experimental design for analyses of program effect. Subjects for analyses included all involved students, parents and home teachers. Instrument item reliability determined by separate test\retest correlations (the ten week interval) and two control administrations with non-involved students: r= .84, r=.87 Content validity determined by staff analysis of agreement with program goals (see discussion on this below).	Gains* noted in pre\post frequency analysis comparisons of following cognitions. Knowledge of: Absence of need for memorization in science. Relevance of advanced math. Integration of laboratory and field work in science. Importance of data gathering. Importance of data recording. Understanding of divergent results. Importance of precision. Potential for new discovery. Usefulness of science to nation. Work environment of the scientist. * See separate table for percent gain in each administration; also see separate listing of ethnographic comments.	As above Instrumentation data and sample size table attached.

Goal and Claim	Methodology	Results	Supporting Evidence
To help female and other students gain interest and confidence in mathematics and science: *Interest and confidence were increased.*	As above for student data. All quantitative parent data was collected ex-post facto with parents and home teachers asked to reflect on changes in student behavior. Parent and teacher comments were also collected after the program completion.	Quantitative frequency analysis showed pre/post gains in following attitudes and behaviors as: A. Assessed by student Comfort with science. Hard work in math/science pays off. Desire for a career in science Chance for success in career Usefulness of science to student. B. Assessed by parents Looks forward to math and science courses. Talks with me about Science/Math Talks about a career involving math or science. Has more confidence in himself/herself. Is interested in science math programs on TV Is observant of things in the environment. Asks questions about science/math. Discusses specific items learned in class. Additional qualitative comments from parents and home teachers.	As Above

Process Descriptions

Janet is an assistant professor of chemistry, who has been with the program since its inception. She has worked mostly with Bernie Johnson, who is a research chemist at Lederle, but she also works with a team of microbiologists led by Debbie Steinberg. Janet and Bernie have really become very comfortable with each other even though there is a discrepancy in their ages and backgrounds. They plan together and often finish each others sentences in the lab. Debbie is a highly organized and take charge kind of person who has engaged a team of her colleagues in the natural products program. All of this component takes place in the Lederle Labs. Janet takes more of a back seat in this program, but is always there to interpret the scientist's language when necessary. She offered the following description of what happened in her program.

> *One of the experiments that we did involved a chemical synthesis called a Friedel Crafts Acylation reaction. In order to fully explain the mechanism of this reaction, our teaching team had to first explain the concept of polarity, and in order to explain that, we decided to explain the concept of effective nuclear charge. At one point, I was trying to explain that the more protons in the nucleus, the more the electrons in a particular shell are attracted to the nucleus. One of the students asked if the number of electrons in the same shell affected how much they felt the effective nuclear charge and my teaching partner, Bernie Johnson, answered with a delightful analogy. He said that if one person is listening to a radio or if eight people are all listening to the same radio at the same distance, are they all going to hear the radio whether the other people are there or not? The answer is that it doesn't matter how many people are listening to the radio as long as they are all the same distance from it; just like the electrons feel the same effective nuclear charge as long as they are in the same shell. The students immediately understood the concept and I was delighted by my colleague's contribution. I believe that this interaction demonstrates just one example*

of the positive effect that team teaching has on both the teachers and the students. I have since used the same analogy and others like it that I learned from my partner with other students--even in my own college classes. In addition, Bernie has remarked that he has found some of the comments I have made helpful to him in his interactions with the students and even his own children who are of college age.

In the program that I have done in the spring semesters for the last two years, my students and I have worked with a different scientist or group of scientists from the microbiology department at Lederle each week. What the students and I have learned from this experience is that scientists rarely work in isolation from each other. At one particular session, the students learn how one group of researchers grows groups of microorganisms that might produce certain natural products that could possibly be used as drugs, and at the next session how another group of scientists scale up the process to produce large quantities of the potential drugs. Then at another session they discover how yet another group develops robots to screen for thousands of natural products as potential drugs. In other words, the students see how their teachers cooperate and work together to help them construct new knowledge; and then they see how scientists work together to construct their own new knowledge.

Before I worked on this program, I would have underestimated the intelligence and ability of High School students to learn the critical thinking skills and complex concepts that are traditionally taught in College. Since that time, however, I have explained the concept of mechanistic organic chemistry as well as nuclear magnetic resonance spectroscopy to groups that included ninth graders. I also believe that the ninth graders in question are not particularly gifted, but instead are of average intelligence. Yet, they are more than capable of grasping these complicated concepts if they are presented in the context of doing science rather than just reading science content. They can learn complex concepts because they not *only are exposed to descriptions of how nuclear magnetic resonance works, but at the same time they experience why it is important and how it can be used in the overall context of solving a problem (i.e. determining the chemical structure of a drug that they have synthesized.)*

Another benefit to my interaction with research scientists and their work has been my exposure to the very latest technology in spectroscopy, chromatography, and computer innovations. By visiting the laboratories at Lederle on a regular basis, I have been kept informed of the newest advances in my field in a way that I would never be able to do on the outside. It is a privilege to be allowed access to the labs at Lederle for me and the students because the general public is not invited to tour the facilities at most of these chemical companies due to industrial security constraints. In addition, as a result of my contact with the scientists from Lederle, our science department at the college has received the gift of all sorts of the latest in supplies and equipment which is a great benefit for my college students. This promotes a good image for the company in the eyes of my students and it promotes a good image of the college in the eyes of my student's parents.

Jim Elardi is a very successful high school teacher at one of our consortium schools. He teaches a marine science course and has a classroom filled with marine aquariums and living sea and fresh water creatures. I was delighted when Jim volunteered to work with us and we used his lab as a site for our program. Jim was teamed with Jordan Clark, an oceanographer at Lamont Doherty. Their program problem was to explore the quality of the nearby Hudson River. The addition of the environmental engineering firm to our consortium was most propitious because they owned several research vessels and invited the group for a trip on the Hudson, where they had a first hand experience with trawling and gathering important water quality data. They also went on other trips (even an overnight) to supplement their lab experiences. Jim, who has been in the classroom for most of his working life, was very impressed with the different approach that the scientists had. *"They know so much but don't get hung up on the facts and on specific answers--they consider every answer a possibility"* he commented.

Russel Such is a Geologist at Lamont, who has been with the program since its beginning. Russ is a natural teacher. He has gotten one group of students so involved that they keep coming back just to learn from him, and three of this group are now involved in independent study projects. His patience is typical of the requirements of scientific reseaearch and wonderful. There are long time lapses after he asks a question and you can see the minds at work. His amazingly trained dog Jake is part of the group and Russ says that Jake is important in establishing the atmosphere he feels is critical. In a setting of seismographs and complex computers and scientists in jeans at work on Saturdays, the ever present donuts also seem to proclaim that the pursuit of science is a labor of love. What really convinced us at first was Russ's attitude toward one of our students, John. John was an eighth grader from one of our parochial schools. He was not on the list of unsolicited recommendations that his principal gave us, because essentially he had a reputation as a loser. John's parents wanted him to come and he said he wanted to as well. We had some words with his principal who was disappointed that more deserving students weren't selected, but explained that our purpose was to see if we could interest even those who were not yet successful. On one occasion we observed John seemingly distracted and asked Russ how he was doing. He was most enthusiastic about his progress and refused to even consider not reinviting him. His home teacher and parent later said that there was a noticeable improvement in John's attitude.

In an open ended question we ask students to describe the advantages or disadvantages of team teaching. Only 1% of the students saw a disadvantage. The advantage most frequently described was that *"There was always someone there to answer your question."* Examples of other comments include the following:

I learned more and got different opinions; more fun; each one knows different things or could explain better; different point of view and different career; they were professionals and knew what they were talking about; you get more experience out of them; you get more information; more conversation helps; it was better because every one gave different opinions; more ideas were expressed and if one didn't know the answer than the others might know; I only saw advantages. If one forgets to say or do something someone else will do it; the teachers worked together, reinforcing what each was saying; the kids were able to get info from a varied person, not just a singular human; I could understand some better than others;I liked hearing different voices and ideas; hearing them discuss things made me want to join in; more people got involved

Outcomes

In the first year all quantitative analyses as described in the outline above were single administration ex-post facto with students asked to reflect on their knowledge and parents on the students' observed behavior before and after participation. All data was based on a fifteen week experience. See table below for percent gains and final sample sizes. The second year's analysis was based on separately administered pre and post questionnaires for students. It was based on each ten week participation unit. Program effects, as evaluated by this method and with a shortened treatment period were much less than in the previous year and showed little gain. In this, the third year, we are collecting data separately for students who participated for 10 or twenty weeks. We are not at this point sure whether it was the ex-post-facto administration in the first year or the longer treatment period that made the difference. The data from parents was similar for both years and both were ex-post-facto reflections on changes in student behavior as a result of program participation.

As revealed in the student survey students showed increased cognition in their recognition of the concepts about science in general as listed below. We did not assess their specific gain in the content of the courses. Behavioral changes were assessed by the parents and home teachers and we show these changes as increases in observed specific behaviors (by parents) or as comments from parents and teachers. Additional items assessed will appear in the attached sample questionnaires.

Cognitive Changes

Cognitive Area	% of students who gained after 15 weeks of treatment	% gain after 10 weeks of treatment
Absence of need for memorization	18	14
Relevance of advanced math	37	7
Integration of laboratory and field work	34	no appreciable gain
Importance of data gathering	33	15
Importance of data recording	33	no appreciable gain
Understanding of divergent results	51	no appreciable gain
Importance of precision	31	no appreciable gain
Importance of new discovery	33	no appreciable gain
Usefulness of science to nation	34	no appreciable gain
Work environment of scientist	51	7%

Behavioral Changes
Percent of Parents Who Observed a Positive Change in Attitude and Behavior

Behavior	After 10 wks	After 15 wks
Looks forward to math and science courses.	71	71
Talks with me about science/math.	64	60
Talks about a career involving math or science.	58	58
Has more confidence in himself/herself.	51	51
Is observant of things in the environment.	81	73
Is interested in science/math programs on TV		47
Asks questions about science/math.	53	60
Discusses specific items learned in class.	73	80
Has less difficulty relating to new peers.	60	44
Talks with peers about math or science.	67	47

Sample Sizes of Returns

Year	**Parent Number**	**Student Number**
1991-1992	46	73
1992-1993	49	106

We also add the following examples of descriptive outcomes from the comments on parent and home teacher questionnaires.

A. Parents

Learning about science in a relaxed atmosphere(no tests); trips to industry, challenging problem. I think that the SMSS program has stimulated her interest in science given her new confidence and since the problem was difficult it created a challenge for her. She never complained about getting up on Saturday mornings; considerably increased my son's interest in science; my child was able to deal with topics not covered in the school curriculum, staff was very interesting; changed *child's attitude toward science and math; discussions about science occupations was a good idea; the field trips; and Nick liked the style of teaching; thanks for giving Gavin this opportunity; I think* (otherwise) *he may have had a problem not being prepared in his school work for that particular subject; my son said he enjoyed these classes and learned more than in his regular classes, I felt it was a great experience for my son; different perspective of the scientist; the students were able to learn from hands on experience rather than from books; not only did he learn a great deal but he was treated like a mature young man; the chance to work with scientists; The best thing about the program was for my child to experience the actual working environment of the professional scientist; Sarah's science teacher has commented to me that there was a noticeable change in Sarah's attitude toward her science class during the third quarter and her test grades improved to A+. I believe that your program was a significant factor in this increased interest.*

B. Home teachers

this exposure has helped him to understand how science is carried out rather than just knowing about the devices and information of science; increased confidence and experience; became more involved with her peer group because of common ground; more confident and outgoing; Edsel was a solid B student, but as the program progressed his critical thinking skills improved and he bridged the gap, earning an A for the year. It was an obvious and marked change in thinking processes; more open; more communicative; more relaxed; more enjoyment; more organized.

Research Limitations and Rival Hypotheses

As described above, the short term of the ten week treatment, and the probable diminished reliability of the student instrument because of the minimal interval of pre\post repetition, may have precluded the acquisition of statistically significant results on the student questionnaire. The fifteen week results of the first year are more hopeful, and with our current sorting procedure which separates out the twenty week treatment data we will very soon be able to get some clarity on whether it was the length of treatment or the instrumentation that made the difference.

Our descriptive data for both years is consistent, as is the quantitative data from parents.

We do not wish to get caught in the midst of current discussion of the value of positivistic and qualitative research and its corollary discussion of the validity and reliability the instruments used in educational research. We make no inferential population claims. Instead we offer our findings as we pursued our goals. These were to provide demonstrations of the process of constructivist learning and examples of scientist\teacher teaching teams.

Educational Significance

There is already evidence that peer interactions promote learning. Our addition to this is that these interactions might be extended to the teachers. They, too, need to learn from the experience of on-going peer interactions; and they need to provide a model for their students, a real world model. In the real world of today little of great scientific significance happens in isolation. The demands and benefits of modern technology and communications diminish the impact of the kind of relatively isolated and long term efforts that an Edison or a Marie Curie contributed--although their work as well was built on that of others. The schooling model of the past millennium has been that of the single teacher, possessing the only right knowledge that must be transferred--perhaps for the new millennium this may need to be changed.

The one thing all of our students and staff agreed upon was the advantage of the team teaching approach. Unfortunately, we are unable at this time to separate this variable from other interacting variables in our program. We suggest this as a further line of research. We do feel, in spite of the paucity of statistically significant quantitative data, that our experience tells us something of value. It may not be possible to duplicate this kind of teaming in schools as they are presently structured, but some kind of apprenticeship with real scientists for upper level students, and a similar apprenticeship for all math and science teachers might work. Enrichment experiences such as ours are certainly feasible in most communities. In terms of application to the present structure of classrooms, Lampert's (1990) description of how she set up a community of discourse with her students in her fifth grade classroom is not too different from Janet's description and our observations of other components of our program. Teachers working on teams might also be able to set a similar stage.

The one complaint about our program, when we asked the students for the worst thing, was that it was on Saturday morning. Some parents told us, however, that strangely they had less difficulty getting their kids out of bed on Saturdays than they had the rest of the week. We were competing with other activities such as sports and part-time jobs as well. We are not sure what this means, but we do know that for the most part our students came without pressure and without the lure and structure of competitive grades; and they stayed with us for the full sessions and for additional ones.

References

Alper,J (1993). The pipeline is leaking women all the way along. Science, 260, 409-411

Anderson, J. R. (1990). The adaptive character of thought. Hillsdale, New Jersey: Erlbaum

Carnegie Co..mmission On Science Technology and Government, (1991). In the national interest:The federal government in the reform of k-12 math and science education. New York, N.Y.: The Commission

Cobb, P. (1986). Making mathematics: Children's learning and the constructivist tradition. Harvard Educational Review, 56, 301-306

Cobb, P. (1990). Multiple perspectives. In Transforming children's mathematics education: International perspectives. Hillsdale, New Jersey: Erlbaum.

Johnson, D. W. & Johnson R. T. (1989). Cooperation and competition: Theory and research. Edina, Minnesota: Interaction Book.

Johnson, D. W., Johnson R. T., & Holubec, E. J. (1987). Revised circles of learning: Cooperation in the classroom. Edina, Minnesota: Interaction Book

Lampert, M. (1990). When the problem is not the question and the solution is not the answer: Mathematical knowing and teaching. American Educational Research Journal, 27, 29-63.

Lave, J. (1977). Cognitive consequences of traditional apprenticeship training in West Africa. Anthropology and Education Quarterly, 8, 177-180.

Resnick, L. B. (1983). A developmental theory of number understanding. In H. Ginsburg (Ed.), The development of mathematical thinking, (pp. 110-149). New York: Academic Press.

Resnick, L. B. (1989). Education and Learning. Pittsburgh, Pa.: University of Pittsburgh

Learning, Research and Development Center.

von Glasersfeld, E. (1990). Environment and communication. In Transforming children's mathematics education: International perspectives. Hillsdale, New Jersey: Erlbaum.

Vygotsky, L. S. (1978). Mind in Society: The development of higher psychological processes. M. Cole et ai. (Eds.). Cambridge, Mass.: Harvard University Press.