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SuperQuest 1989-1995: Research and Evaluation

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Introduction

Rapid advances in computational science have presented challenges to science and mathematics education at the secondary level. SuperQuest, a National Science Foundation funded program, was designed to bring computational tools and techniques to high school students and their teachers, with an ultimate goal of integrating computational science into the high school curriculum. For six years, SuperQuest conducted a national competition. Teams of students and their teacher-coaches proposed significant research problems that required computational science for their solution. The winning teams were selected by a national review committee. Winners attended three-week summer institutes at the participating SuperQuest Centers[1], where they learned how to use high-performance computing and visualization tools to solve their scientific and mathematical problems. The winners' high schools received workstations and communication links to the Internet.

This report presents the findings of an external research project that evaluated the program. Participating schools, teachers, and students from each of the six years of the program (1989-95) were included in the study. We sought to understand the qualities of the program as it was experienced by various stakeholders and school sites, its degree of success, and factors that may have mediated impacts.

Research Method

How was the program implemented in different sites? What factors are linked to successful and sustained effects? What program refinements might contribute to greater impact? We made a vigorous effort to reach all SQ schools, teachers, and students from the program's six years. We collected a variety of data from many of these participants. We also collected in-depth data from a sample of schools through site visits. These data were used to develop systematic profiles of the program at these schools. We also collected information from SQ project personnel who participated in the summer institutes.

SuperQuest attracted applications from across the nation, with 66 teams winning slots at the summer institutes over the life of the program, and equipment for their schools. This evaluation consisted of two levels of data collection:

1. At the first level, data were collected for *all schools* who have participated in the program since its beginning. Information about each participating school (teachers, students, outreach efforts) was collected for all sites using written instruments, analyses of program documentation and products, telephones interviews, and electronic-network supported inquires.

2. A second, more intensive, level of data was collected from a *sample of schools* selected to represent a range of experience with SuperQuest. This sample consisted of 14 schools[2] and included sites that varied in type and level of activity related to SuperQuest (e.g. schools that have been more and less successful over time; schools that have participated in the program more than once), and that represent the range of school

characteristics (e.g. location, size, relative affluence). The sample selection was drawn from existing information at Theory Center Theory Center and in consultation with all SuperQuest project directors. Each school was visited by two researchers for an intensive site visit. Interviews were conducted with teachers, students, administrators, and technical support staff at each school. Structured observations were done in science/computer classes when feasible. We also assessed the computational resource distribution and use throughout the school.

Teachers

A comprehensive questionnaire was distributed to all SuperQuest *teachers*. The teacher questionnaire was developed from information obtained from focus interviews with teachers who attended the *SuperComputer '94* conference in Washington, DC and initial site visits to schools in the DC vicinity. It was designed to capture SuperQuest teacher's experiences of the project, their prior and subsequent professional development activities, effectiveness of the summer institutes, perceived impact on curriculum and teaching practices, and factors and problems in implementing and sustaining program impacts. In addition, questions covered demographic variables, teachers' backgrounds, school variables, and perceived impact on students and on the broader community.

In addition to the questionnaires, for schools in the intensive sample, individual in-depth interviews were conducted with SuperQuest teachers, non-SuperQuest teachers, and key administrators. Characteristics and development of the SuperQuest program was probed to understand the professional development experiences that were most effective both in the summer institutes and the local level. Structured observations were conducted in the SuperQuest teachers' classrooms, when feasible, with particular attention paid to classes and other events where the SuperQuest resources were used. These observations were focused on whether and how SuperQuest resources and techniques were integrated into the curriculum and teaching practices.

Students

A student questionnaire was developed and distributed to all SuperQuest students. As with the teachers questionnaire, the student questionnaire was developed from information obtained from focus interviews of SuperQuest students at the *SuperComputing '94* conference and within two schools in Washington, DC. We probed students' SuperQuest experiences: how they developed the proposal; what they did and with whom at the institute; did they work on their project after the institute; did they complete a final report and submit it to the best paper competition; and, the students' perceived effects of their SuperQuest experiences. General demographic information was also collected, including their current academic and/or work activities, and anticipated career choices.

For the schools in the in-depth group, a sample of students was selected for in-depth individual interviews. When possible (given many SuperQuest students had graduated from high school), we interviewed students who participated in the summer institute, and others who did not participate but who have had access to SuperQuest resources.

Curriculum and Learning Environments

We reviewed SuperQuest documentation that was available at the Theory Center. This review included: (1) each school's original SuperQuest application materials, as well as the school's curriculum plan; (2) curriculum materials that were developed for SuperQuest; (3) curriculum plans and course descriptions, prior and subsequent to SuperQuest; and (4) any planning documents concerning the use of computational technologies.

During the site visits, interviews with teachers and administrators included queries about curriculum and resource changes that may be related to SuperQuest. We observed the physical distribution of computational resources and determined how often they were used, by whom, and for what purposes. We were particularly interested in reflections about the appropriate uses of high-performance computing resources, where they proved essential, and where not.

SuperQuest Centers

We visited four of the five participating SuperQuest Centers: Cornell Theory Center (Theory Center), National Center for Supercomputing Applications (NCSA), University of Alabama in Huntsville/Alabama Supercomputer Network (UAH), Reed College (we did not visit Sandia National Laboratories since it only participated for one year). During these visits we interviewed project directors and staff members responsible for the organization, curriculum development and support of the SuperQuest program. We also interviewed scientists and graduate students who served as mentors to the winning SuperQuest teams. The purpose of these visits was not to evaluate each Center's particular SuperQuest program, but rather to understand the experiences offered by these institutions, and the support each Center provided to the schools and winning team members during *and* after the summer institute.

Design of SuperQuest Program: *Application Process*

The application process is a rigorous and significant part of the SQ experience, since students and teachers were required to do a substantial amount of work in order to complete it. SQ had a two-step application process. In the fall semester, teams were required to submit a document of intent, indicating that they planned to apply to the program. Teams then were to develop a project idea(s), carry out initial research and write a proposal that was submitted to SQ in the spring. The process of developing the proposal thus is segmented into 4 phases, and constitutes a considerable commitment on the part of the teachers and students:

1. Selecting a research question, and deciding whether the application was going to focus on individual projects or a group project;

2. Researching the topic/topics as background for the proposal;

3. Designing plan to solve the identified problem, including computational resources;

4. Writing the SQ proposal.

In the late spring, an independent, national team of judges reviewed applications and evaluated them according to criteria listed in the application book and generally selected four school teams for each participating institution. The SQ director at the Theory Center, then contacted each of the other SQ centers for their input regarding which winning teams went to each center, in an attempt to achieve a balance of school type, geographic mix, and appropriate projects.

The application process itself was a series of learning experiences for any high school student and teacher. In many instances, this was the first exposure to the scientific research process for the teachers as well as the students. Teachers approached the task in a variety of ways. For the teachers who decided to organize a group project, this was often their first experience building a team and managing team dynamics for such a long term project. The group project was a favored option for "ordinary" schools (compared to magnet schools) since they might not have a large enough pool of highly motivated science students to field four quality projects. Teachers also adopted various strategies to structure the proposal stage: some teachers had SQ clubs that would consider and research multiple topics before a final selection. Others incorporated SQ proposals into their classes as a required assignment, and thus submitted five or more separate proposals. At a few schools teachers took a secondary role while a few motivated students generated their own proposals.

During the research phase, students did library research, consulted with scientists and/or used the Internet (if available to them). Teams would have to coordinate their efforts, distributing the tasks efficiently among the members. In generating solutions to their questions, some students developed algorithms and began to write code. In the final proposal, students had to write in formal science text format. This task would often involve reading prior science proposals to learn the style and presentation.

Summer Institutes

Summer Institutes were the heart of the whole experience for the students and the teachers. The Institute represented the culmination of an entire year's effort, an unprecedented reward for intellectual endeavor for most of the student participants. The central *raison d'être* of the Institute was to pair the students with mentors, as well as with the advanced computational tools offered by a supercomputer, to enable them to organize and complete their research projects. The routine at most of the Institutes was intense. The workload was heavy, with teachers and students expected to work together on a given project. Although the specifics varied, all sites combined classes, guest lectures, lab time and mentor conferences during the day, with the computer labs opened in the evenings. Teachers had some separate activities and training sessions, but for the most part they worked and learned alongside their students. Teachers also chaperoned their student teams.

In interviews, many teachers thought that the stipend was an important part of SQ for both teachers and students. While three weeks was noted as a long stretch to be away from home, the stipend was an incentive and unusual according to most. They also noted that many students who were working to save money for college could not have afforded to go to the institute without the stipend.

For most winning students, we found that the Institutes were also a vastly rewarding personal experience: living and working on a college campus; deep involvement in an intellectual community for the first time for many; being respected as an intelligent person; and, for many, a first extended time away from home for intellectual pursuits.

***Technology Connection/ Hardware*[3]**

After the Institute, each SQ Center sent hardware to the winning schools and arranged for Internet connections through local service providers. The Internet connection turned out to be a crucial element in SQ and to the success of each school. The successful integration of the Internet was affected by two variables.

First, the actual equipment was different from year to year, depending on the corporate sponsors. The particular equipment supplied to schools would not necessarily be easily integrated with the technological infrastructure of the school, or could be new for the teachers. Second, the installation of the equipment could be delayed well into the school year. Especially in the early years, schools might not get connected until the Winter holidays. For high school students such a delay can break the momentum necessary to carry a project through to completion.

Most of the Institutes became aware, through experience, that the teachers needed more staff development, particularly the technical skills needed to set up and maintain the technology back at their school. The Theory Center and Reed developed a one-day set up procedure. Members of their staff would go to each high school and set up the equipment. NCSA was moving toward teacher-only institutes so that there would be greater outreach.

Post-Institute Activity

The post-Institute phase of SQ is bounded by distinct time frames depending upon the point of reference. When considering the individual students, the timeframe is most often nine months, since many are seniors during the SQ school-based project year. For the teachers, the timeframe can be more extended. Upon returning from the SQ Institute, they first work with the winning students. Subsequently, they can begin integrating the new techniques into their curriculum with other students. The timeframe for school or community changes can be even longer.

For students, the endpoint for SuperQuest experience was not the Institute, but their submission to the Best Paper Contest that came at the end of the school year following each Institute. Upon returning to their home high school, with the new machinery, the SQ participants were to complete their research and submit their research paper to the Best Paper Contest.

Most SQ Centers were disappointed by the paper completion rate; few expressed any knowledge of the high school students schedule (graduation, college applications, social life). Several SQ directors noted that while they understood that the students' work was generally not groundbreaking, the importance of the SQ experience for the students and teachers was the process of writing a proposal and completing a project.

An additional goal of the program was to encourage students to continue on in science in higher education. SQ also hoped to stimulate the teachers to integrate computational science and its tools into high school science and mathematics curricula. Longer term goals focused on the extension of SQ benefits to the rest of the school, and to other schools in the community.

Program History

SQ was initiated in 1986 by a corporate sponsor (ETS, a subsidiary of Control Data Corporation), a manufacturer of mini-computers. They were interested in the usefulness of these then-powerful computers at the high school level, at a time when microcomputers were still finding their way into K-12 schools.

The first SQ competition took place in the 1986-87 school year, and concluded with a summer institute in 1987. This initial institute is probably best considered a pilot phase of SQ; experience from this initial institute led to a refined design that was subsequently supported by a grant from the National Science Foundation to Cornell Theory Center (noted throughout paper as the Theory Center).

The first SQ summer program, sponsored by the computer manufacturer, was designed fundamentally as a competition. A selection process narrowed the field to four teams who were invited to a seven week SQ Institute in Minnesota. At the end of that time period, the four teams competed for an award of a small supercomputer: adult experts judged their projects. The winner of that first award was Thomas Jefferson High School for Science and Technology, from Alexandria, Virginia, who remained an active SQ participant in subsequent years.

After the first program, the computer manufacturer went out of business, therefore could no longer financially support the SQ program. They inquired whether the Theory Center would be willing to take over the program and seek additional funding. Although the Theory Center staff had some initial reservations regarding the program design, they assumed leadership of the project and obtained grant support from NSF.

Although this inherited structure was changed substantially, part of this legacy is of interest when thinking about the impact on curriculum and teacher practice. Some of the centers' SQ program put less emphasis on teacher support and training than it did on the student on-site training.

Modifications of Program Design. The Theory Center-led SQ program modified the initial design, based on the experience of the first institute. First, while the technology donation aspect of the program was considered important, the Theory Center staff did not believe that on-site supercomputers were the best choice for high schools. The machines had challenging maintenance requirements, and students could easily access the supercomputing resources they needed for their projects through telecommunications. The supercomputer award was modified to donations of workstations and access to a supercomputer at the Theory Center for winning schools.

The second change was reducing the duration of the summer institute from 7 weeks to 3 weeks (although the first the Theory Center-led SQ institute was only 2.5 weeks for logistical reasons). Third, the on-site competitive element of the institute was eliminated in favor of a Best Paper Contest submitted when students completed their research at their own schools. Students thus had a substantial part of the school year to complete their SQ projects and submit their final papers.

SQ program staff were also aware of the reservations among the university faculty concerning appropriate levels of research work for high school students. Some Theory Center staff were skeptical about the Theory Center’s involvement in SQ because they felt that high school students could not do research warranting use of a supercomputer. However, during the Theory Center’s first summer institute, faculty realized that these high school students did fairly sophisticated work given the resources and support. While Theory Center staff did not consider most of the students’ research ground breaking, they were persuaded by the evidence that students could benefit from the type of computing support provided by SQ.

The first Theory Center Institute had one unique feature when compared with subsequent ones. Five individual students came to the Institute without a team or teachers. This design feature was eliminated in later institutes because the solo students were never fully integrated into the social and academic environment. They did not have on-going adult support compared to the teams with accompanying teachers.

Individual students were admitted in the first round because SQ staff did not want to penalize students who excelled, but did not have classmates on their level. This concern was of course intensified if an excellent student application came from an ordinary high school.

The argument against individual student awards were centered on reservations around the social dynamics of high school. These individual students traveled alone and spent three weeks virtually on their own. The other students were in teams and chaperoned by familiar teachers, and essentially maintained their groups. The single students were not incorporated into any of the groups, nor did they have the support of a teacher. The Institute itself had not been designed to support the individual students in any way beyond strictly scientific areas.

An additional program modification was made in 1991 regarding teachers. Two teachers from each school were encouraged to participate in the program. This change was made so that teachers could support each other when they returned to their schools, increasing the possibility that the program would have sustained effects.

Many participants, both teachers and students, also noted that social aspects of the design of the program were very important. For example, this was the first time many students were away from home for an academic reason, working with other students and expert adults in a college setting. In addition, the social activities that some of the programs offered (field trips, athletics, picnics and other informal gatherings) were important for many students, including those less socially confident. The SQ staff was encouraged to participate in these offerings. Some noted that undergraduates from the participating institutions were especially successful with the high school students because they were closer in age and experience than were the faculty and graduate students.

The SQ program made considerable effort to recruit a variety of schools to participate. They especially wanted to encourage schools who did not have specialty programs, and schools with large concentrations of minority students. Schools who repeatedly applied tended to be magnet schools who sought, often successfully, science competitions for their students. In order that these accomplished schools not dominate the program each year, after their first win, they were placed in a separate applicant pool where they competed with each other.

Quantitative Analyses: Large Sample of SQ Schools

As noted above, we made a vigorous effort to collect quantitative data from all participating SQ schools for all years. Written survey instruments (attached) were designed and distributed to all participating teachers, and to all students for whom we could obtain current addresses.

The following section is divided into three sections, *Teacher Characteristics and Experiences*, *School Characteristics*, and *Student Characteristics and Experiences*. The first two sections are based on information gathered from the teacher surveys and the latter is based on student survey responses.

Teacher Characteristics and Experiences

During the six years of SuperQuest, 92 teachers representing 42 high schools from around the United States won the opportunity to assist their students in developing their projects at the SQ Summer Institutes. Survey instruments were sent to all of these teachers, and vigorous follow-up was done to encourage responses.

A total of 46 completed surveys (50%) were returned, another eight surveys (9%) were undeliverable and 40 were unreturned (41.3%). The respondents represent teachers from 30 of the 42 winning schools. We can identify no bias toward particular kinds of schools in the pool of respondents, e.g. magnet schools, geographic location, Institute attended, and the like. (Note: there are occasionally one or two missing responses for particular questions; for those questions where the missing data are greater than this, the numbers of respondents are noted in the text).

Twenty-eight (58.3%) of respondents were men, and twenty were women (41.7%). The respondents were overwhelmingly white (93.8%). One teacher each was Asian, Native American, and Hispanic.

Table
SQ Teachers Gender and Race

Gender	White	Native American	Asian	Hispanic Latino	Row Total (Percent)
Female	18	1	0	1	20 (41.7%)
Male	27	0	1	0	28 (58.3%)
Column Total (Percent)	45 (93.8%)	1 (2.1%)	1 (2.1%)	1 (2.1%)	48 (100%)

The mean age of the respondents was 44.3 years. This is slightly higher than the national average of 42 (NCES, 1993). None of the reporting teachers was younger than 30. Grouping teachers by age ranges places 16% from 30-34 years, 33% between 35 and 44 years old, 44% between 45 and 54, and 7% over 55 years.

The SQ teachers had a wide range of experience, from 3 years of teaching to a high of 37 years. The mean was 17.2 years of classroom experience. When compared to national statistics (NCES 1993), the SuperQuest respondents are somewhat more experienced: 39% of SQ teachers had over 20 years of experience compared with 29% of the national population; 41% of SQ teachers had between 10 and 20 years, compared to 39% nationally; 20% of SQ teachers had between 3 and 9 years of experiences compared to 24% nationally

Many of these teachers were very experienced users of computers in their teaching, with an average of 9 years. Nineteen teachers (41%), have been using computers in their classrooms for 10 to 14 years. About one quarter of the sample (26%) are relatively new to the technology, with less than six years experience. Seven teachers (15%) have had from 6 to 9 years experience and eight teachers (17%) have had over 15 years of prior experience.

Original Area of Certification. Only two teachers were originally certified in computer sciences at the beginning of their careers. Given the older mean age of these cohort of teachers, that is not necessarily surprising. The largest share of teachers (42.2%) were originally math teachers. Ten teachers were originally trained in biology or chemistry (22.2%), and eight (17.8%) in physics.

Current Primary Teaching Fields. The most common current teaching among these teachers is computer sciences (33% of responses). The next largest group are physics teachers (25% of respondents). Twenty percent of teachers taught either math, or other sciences (chemistry or biology). The overwhelming majority of teachers were licensed in their specialty. Of the five teachers who were not licensed in their current areas, four were in computer science. This is indicative of the way many schools filled the need for computer science by shifting interested teachers into this new and growing area. In this type of situation these teachers often train themselves and adapt or develop their own curriculum.

Other Teaching Fields. Many teachers teach a variety of classes. Of the nine math teachers, six also taught computer science. The physics teachers also taught math and sciences: three in math and four in chemistry or biology. Only one of the physics teachers taught computer science.

Of the 15 computer science teachers only 5 taught other subjects, 3 of them in math and none in the sciences. The limited crossover between the sciences and computer sciences might indicate a split between the teaching resources of these two areas which would slow the spread of an integrated approach of using computers to support science learning.

Involvement in School Reform. We were interested in whether SQ teachers were active participants in other innovations in their schools. Seventy-two percent indicated they were involved in some level of curriculum reform: 36% were involved at the school level; 24% in their state initiatives; and, 15% at the district level and 15% in curriculum projects. Two teachers were involved in national reform efforts. Overall this indicates an active and innovative group of teachers. When cross tabulated with by teaching fields, the numbers show that all nine math teachers are involved in reform efforts, as are 80% of the computer science teachers and 89% of the chemistry/biology teachers. Physics teachers seemed less likely as a group to be involved, with only 36% of the physics teachers reporting participation in school reform efforts at any level.

Table
SQ Teachers Involvement in Reform Efforts

	Math	Physics	Chemistry Biology	Computer Science	Row Total	Row Percent
Curriculum	3	0	0	2	8	24.2%
School	2	2	5	3	5	15.2%
District	3	0	1	1	12	36.4%
State	1	1	1	5	5	15.2
National	0	0	1	1	2	6.1%
Other	0	1	0	0	1	3%
Total (Percent)	9 (27.3%)	4 (12.1%)	8 (24.2%)	12 (36.4%)	33 (100%)	

School Characteristics

Communities. Over half of reporting schools (63%), based on teacher surveys, were located in a large city (population larger than 200,000) or its immediate suburbs. Twenty-seven percent of the schools were in small cities (population under 200,000, not a suburb). Only 13% of the schools were in rural environments: two in a rural, semi-farm area and two in small towns. Compared to national distribution of schools, SQ schools under represent rural and small town districts which comprise 49% of schools nationwide (NCES).

Mean per student expenditures for the schools that reported this information was $5,155 (number of respondents for this question was 19). This is equivalent to the national average of $4,822 (NCES).[4] The distribution of expenditures for SuperQuest schools ranged from $1,700 to $12,000. Ten of these schools were below $4,000. Three were above $9,800 per student (twice the national average).

Table
School Expenditure Per Student by Community

Expenditure Per Student	Rural	Small Town	Small City	Suburb	City	Row Total	Percent
$1,700-3,000	0	0	1	1	4	6	31.6%
$3,001-3,999	0	1	1	0	1	3	15.8%
$4,000-4,999	0	0	0	2	2	4	21.1%
$7,000-8,000	0	0	0	2	1	3	15.8%
$9,000-12,000	1	1	0	1	0	3	15.8%
Column Total	1	2	2	6	8	19	100%
Percent	(5.3%)	(10.5%)	(10.5%)	(31.6%)	(42.1%)		

Enrollment. The SuperQuest schools tended to average to large high schools. The mean enrollment was 1,565 compared to a national average of 678 students per high school. Only six schools (20%) were below 600 students; eleven schools were above 2,000 students.

Student/Teacher Ratio. The mean ratio of students to teachers reported in these schools was 22.6 students for one teacher. This is significantly higher than the national mean of 17.6 students per teacher. Eight schools have ratios of over 29 students per teacher.

Race and Ethnicity of School Community. When examined by race of the student population, 70% of the reporting schools in the sample had students populations that were more than 50% Caucasian. In four of the schools, over 90% of the students were Caucasian.

One school had a 95% African American student population. In four schools, between 30 to 50% of the students were African American.

Two schools had over 80% Hispanic students. In two schools between 30% and 65% of the students were Hispanic.

One school had 30% Asian student body. One school had a 15% Native American student body.

Graduation rates (n=25). The mean graduation rate for these schools was 86%. A total of ten schools (40%) reported 99 or 100% graduation rates. Eighty-four percent of these schools reported graduation rates of over 80%. Only two schools reported lower rates, one reporting 60% and one reporting 12%.

College Attendance Rates. Most of the SuperQuest schools have a high portion of students who move on to college. The overall mean of 73% of students attending college is well over the national mean of 60%[5](NCES). Half of these schools report college attendance rates over 80%, with four schools reporting 99-100%. Three schools reported college attendance rates of less than 35%.

Teaching Staff. The smallest school in the SQ sample had only 14 teachers; the largest had 225. The size of the math and science staff varies accordingly, ranging from 4 to 45.

Location of Computers Throughout the School. Teachers were also surveyed about the location of computers in their school as a measure of technological saturation. Nearly all schools (96%) had computer labs and computers for the school administration (86%). The next most common location for computers was in libraries (80%). Fewer schools (70%) had computers in classrooms, although this is more than is common in schools throughout the U.S. Fewer schools (53%) had computers in their science labs.

Type of Computational Platform. Teachers were also questioned about the diversity of platforms and systems available at their schools. Most of these schools had multiple systems and platforms available for their students. Apple was the most common system present at 90% of the schools. IBM (and compatible) computers were found in 87% of schools. Eighteen schools had DEC 5000's, most likely a result of SuperQuest since this was the equipment awarded in some years. Some type of networking was present in 73% of the schools. One school had four LAN's.

Teachers' Perspectives on SuperQuest

The Application Process. Teachers' evaluation of the application process identified *four key components*. Twenty-six percent of the teachers felt that the application *provided a good vehicle for team work*. Interestingly, 21% also stated that team dynamics had been the most difficult part of the process. Twenty-three percent of the teachers noted that the application package provided *clear instructions and useful project examples*. Seven teachers reported that the *application deadlines* were a beneficial part of the application process, seven teachers also reported that SQ provided an *incentive for student project work*.

The most common reason teachers reported applying to SuperQuest was the competitive element (81%). The second most frequently reported reason for applying was interest in subject material (53%).

Expectations. Essentially, the teachers' main expectations of the institute focused on their students' learning. For example, 75% of the teachers expected project support, 66% expected programming, and 51% expected some science content. Only 28% of the teachers expected some form of system operations training and only 26% of the teachers expected some curriculum development

The SQ Institute[6]. Forty-eight percent teachers felt that group work and learning with their students was an important aspect of the institute. (Seven of the eleven physics teachers noted this element.) Overall, 17% reported that the sense of accomplishment from completing a project was a positive factor for their students. Teachers also noted technical issues were important factors of the institute: technical access (26%) and technical support (21%). Only six teachers (14%) reported that the institute was an important professional development experience. This may reflect less the professional changes that followed the institute, and more teachers' perception that there were relatively few structured teacher development activities at the institute.

Sixty-one percent of teachers reported students' prior knowledge and experience was problematic at the institute. Twenty-one percent noted different academic levels between students teams was a negative aspect of the institute; 17% noted lack of background for themselves and their students; 13% thought material presented at the institute was "over their students' heads". Four teachers (17%) reported that there were no negative aspects of the institute.

As will be noted later, any concern about different academic levels seems largely limited to the teachers. Only three students reported any reservations in this regard.

Teachers' Evaluation of SQ

What Teachers Learned. *All* of the teachers reported that they learned about computational science, which was one of the primary goals of the SQ program. Obviously, the program was very successful in meeting this goal. Just under a half of the teachers (47%) reported learning programming. Seventy-one percent reported that they learned about visualization tools. Forty percent reported that they learned curriculum design.

What Students Learned. Likewise, all of the teachers reported that students learned about computational science. Eighty-seven percent reported that their students experienced team work through SuperQuest. Eighty-four percent felt that their students' experienced of "real-world of science research", and that this was a positive factor. Eighty-two percent noted that students developed interpersonal skills, emphasizing the importance of the social dimensions of the program. Seventy-three percent reported that their students expanded their knowledge of their project field.

Most Effective Aspects of the SQ Institute. (Multiple answers were acceptable.) Seventy-three percent of the teachers felt that learning programming was one most effective part of the experience. And it is interesting that an equal number of teachers reported that a social aspect of the program was one of the most effective aspects: 73% noted that living at a college campus was the most effective aspect of the institute. Seventy-one percent also thought that seeing real examples of supercomputing was effective for their students.

Who Was Most Important at the Institute. Eighty-two percent stated their students were the most important people at the institute. Seventy-three percent reported that the technical support staff were the most important people; our interview data suggest that teachers were most likely to stay in touch with the technical support staff on their return to their schools. Just over half of the teachers (51%) felt that the scientists were important at the institute. The last two categories, technical support and scientist, were reported equally by computer science teachers. But, biology and physics teachers were roughly three times more likely than computer science teachers to value the support of the faculty scientists.

Post-institute Activity. When questioned about what occurred after the institute, teachers reported most frequently was that worked continued on students' project (83%). Eighty-three percent taught other teachers how to use the Internet, and 78% reported a growing participation of students in the on-line communities. Seventy-six percent reported that students submitted a best paper to the SuperQuest committee. Seventy-two percent reported that they built some type of student computer club; this was most prevalent among the computer science teachers (14 out 15).

Curriculum. The most common technology that was integrated into the school following the institute was the Internet (88%). Eighty percent of teachers noted that programming was integrated into the school curriculum. However, when asked if they had developed new curriculum materials based on their SQ experience with technologies, these teachers most frequently reported that they designed curriculum around the graphing calculator (31%), and other visualization tools (31%). Twenty-eight percent reported developing Internet curriculum based on their SuperQuest experience. Only two teachers noted developing modeling curriculum (math and earth science teachers).

Teachers Suggestions for SQ (n=28). We asked teachers for their suggestions for changes in the SQ program in an open ended question. Ten of the teachers who answered this question (36%) thought that some form of pre-training for teachers would be useful, which may reflect their concerns noted above about their lack of background or preparation for the level of work expected at the Institute. In a similar vein, three teachers suggested dividing the Institute by academic levels. Eight teachers (29%) also suggested that the Institute staff adopt teaching styles more suited to high school students. Six teachers (21%) asked that the program be refunded and continued.

Student Characteristics and Experiences

According to the combined records of the different institutes there were 243 student winners of SuperQuest throughout the six years of the program. Survey instruments were sent out to all students, using addresses obtained from the Theory Center SQ database which were most often students' home addresses from high school. A total of 86 (35%) students responded, another 20 (8%) surveys were returned as undeliverable and 137 (56%) students did not respond. In light of the distance some students are from their SQ experience, and the fact that most have moved away from home, the student response rate is surprisingly good.

The Theory Center's records contain information on the gender of all participants. The split between boys and girls for the SQ population was 87% to

13%. (n=179). The survey sample is thus quite representative of the overall population: 86% boys to 14% girls.

There is no reliable information on race and ethnicity for the whole SQ population because the SQ program application specified only “optional, self-reported” data for these categories. However, this information was collected on the research survey. The survey sample is 74% white, 25% Asian and 1% African American (n=81).

Table
SQ Students’ Gender and Race

Student Gender	Asian	African-American	Caucasian	Row Total	Percent
Female	2	0	10	12	14.8
Male	18	1	50	69	85.2
Column Total	20	1	60	81	100
Percent	(24.7%)	(1.2%)	(74.1%)		

Students were also asked to report their parent’s occupation and highest educational attainment as indicators of their families’ socio-economic status. Most students come from highly educated professional families: Eighty-nine percent of students reported that their fathers were professionals (67%) or executives (19%). Fifty-seven percent reported that their mothers had similar occupations (46% professional and 11% executive/ official). Twenty-six percent of mothers were identified as “housewives”. The parents also tended to be highly educated. 81% of fathers have a college degree or higher (59.3% actually have post graduate degrees). As with occupations, the mothers parallel the fathers, 70% have a college degree or higher (42% have post graduate degrees).

High School Preferences. Students were asked to specify their favorite high school subject(s), permitting multi-responses. Mathematics/computer science and the sciences were overwhelmingly the preferred subjects of these students. Seventy-two percent of the student respondents reported liking science in high school and 62% liked math and computers. Below are the students’ favorite subjects based on SQ year (Percents and totals are based on 82 respondents).

Table
SQ Students’ Favorite High School Subjects

Favorite High School Subject	SQ‘89	SQ‘90	SQ‘91	SQ‘92	SQ‘93	SQ‘94	Row Total	Percent
Science	4	2	6	19	23	5	59	72.0%
Math/Computer	4	3	3	15	21	5	51	62.2%
Languages	0	2	0	3	3	0	8	9.8%
Humanities	0	0	1	8	8	0	17	20.7%
General	2	0	2	3	5	4	16	19.5%
After-school Activity	0	0	0	1	0	0	1	1.2%
Column Total	7	3	8	25	30	9	82	100%
Percent	(8.5%)	(3.7%)	(9.8%)	(30.5%)	(36.6%)	(11.0%)	(100%)	

Current Situation. Sixteen of these students (19%) are still in high school, 62 students (73%) are in college and 3 (4%) are in graduate school, and four students are currently working full-time. Eighteen percent of the students are also working part-time while in high school or college . Of the 27 students who reported their place of employment, 67% work either at a computer/ technical company or in scientific jobs at their universities.

The SQ students are still heavily involved in science, mathematics, and computational science. This data may be slightly skewed by the likelihood that science students would respond to a computational science research study. Sixty-two percent of the students reported they are in science or engineering fields and another 26% are in computer sciences. Forty percent plan to get a graduate degree in the sciences and move into academia or industry. Sixteen percent want to go on to Medical school. Another 5% want to pursue graduate work in Humanities. Twelve of the students still in high school only indicated going on to college but did not specify the field.

Age of SQ Participation. We calculated each winners' age the summer they participated in the SQ institute. More than half the students (56%) were 16 during the program, 22% were 17 years old and 15% were 15. Three students were 18, two were 14 and one was 13. We found the age of 16 to be significant at two moments in the SuperQuest programs. The first moment is in the proposal stage, where students 16 years and above appear more likely to contact science professionals as a research resource. The second moment, appears at the SQ summer institute when 16 years olds were more likely than any other age group to report effectively engaging with the scientists (indicated by 52% of sixteen year olds). Only 2 of 16 students (13%) below the age of 16 years, indicated that scientists had been important to their institute experience. Seventy-two percent of the students who reported SuperQuest impacted their career choice were 16 years old. Eighty-five percent of sixteen year-olds reported continuing their projects after the institute.

Individual or Group Project for SQ. SuperQuest allowed two types of projects, group or individual: 47 students (55%) had participated in group SQ projects; 38 (44%) worked on individual SQ projects. Two-thirds of the girls who responded worked in group projects. Slightly over half of 72 boys were involved in group projects (see below). When asked what type of project (individual or group) they would prefer to work on, no students would abandon group for individual work. Five students would have preferred group to individual work.

Table
SQ Students Actual and Preferred Project Structure by Gender

Gender	Group Projects		Individual Projects r		Row Total		Percent	
	Actual	Prefer	Actual	Prefer	Actual	Prefer	Actual	Prefer
Female	8	9	4	2	12	11	14.3%	13.3%
Male	38	40	34	32	72	72	85.7%	86.7%
Total	46	49	38	34	84	83	100%	100%
(Percent)	(54.8%	59.0%)	(45.2%	41.0%)				

Neither type of project appeared more likely to increase the students' outreach to schoolmates after returning to the school. The groups were equally likely to report teaching other students their new technological skills.

SQ Completion. Most of these students (62, or 81%) reported that they continued their projects after returning to their schools. Many (57) student respondents submitted to the SuperQuest Best Paper Competition, and 13 (16.9%) of those students reported winning or placing in the competition.

Positive Aspects of the SQ Program

Students were asked about their experiences at the institute through both open-ended and multiple choice questions.

Technical. These students most frequently reported that technology and technical skills were the most positive aspects of their experiences (see table below by year). In an open-ended question, 54% of students felt that technical access and hands-on experience was the most positive aspect of the institute. Twenty-eight percent of the students felt technical support was another positive aspect of institute. Some 31% noted that socializing was also a positive aspect to the Institute.

Table
Positive Aspects of the Institute
(coded open-ended question, multiple answers possible)

	SQ'89	SQ'90	SQ'91	SQ'92	SQ'93	SQ'94	Total	Percent*
Technical Access	2	1	4	13	18	6	44	54.3
Self-esteem/Prestige	1	0	1	4	2	0	8	9.9
Tech. Support	1	1	2	6	9	4	23	28.4
Group Work	0	0	0	0	3	1	4	4.9
Accomplishment/ Tech. Presentations	2	1	2	5	5	0	15	18.5
Future Opportunity	1	0	0	2	2	0	5	6.2
Getting Equipment	0	0	0	0	1	0	1	1.2
Socializing	4	1	5	6	7	2	25	30.9
Travel	1	0	1	3	0	0	5	6.2
Extracurricular	0	0	0	2	1	2	5	6.2
Internet Connection	0	0	0	1	4	1	6	7.4
College Experience	0	0	1	0	4	0	5	6.2

* Percents and totals are based on respondents.

When asked in a multiple choice format (allowing up to three selections) 51% of the students also enjoyed learning from scientists. Forty-three percent were impressed by the access to a supercomputer. Social aspects were also prominent, with 44% selecting socializing with teachers and students, and 42% liking the visit to a college campus.

Table
Positive Aspects of Institute
(closed-ended question, multiple answers possible)

	Theory Center	NCSA	UAH	Sandia	Reed	Total	Percent
Going to a College Campus	15	4	4	0	11	34	42.0%
Real Examples of Supercomputing	12	6	8	3	6	35	43.2%
Learning from Scientists	12	6	12	3	8	41	50.6%
Having Access to a Supercomputer	8	8	4	4	11	35	43.2%
Socializing with Teachers/Students	11	5	10	1	9	36	44.4%
Personal Prestige/ Winning Nat'l Competition	8	5	10	3	5	31	38.3%
School Recognition	4	1	2	2	1	10	12.3%
Other	2	0	2	0	1	5	6.2%

SuperQuest provided first exposure for these high school students to a variety of science technology and experts. This was the first exposure to supercomputers for 87% of the students. This was also the first science workshop for 60% of the students, and first exposure to the Internet for 56% of the students. One-hundred percent of these students reportedly still have access to the Internet, and 90% have access to science professionals. Only 43% of the students still have access to supercomputers.

Social. Forty-five percent of the students enjoyed "hanging out with their teachers" at the institute. Forty-two percent liked going to a college campus - in particular, Reed and the Theory Center. Thirty-eight percent of the respondents noted that personal prestige was an important aspect of the SuperQuest program.

After having left high school, a remarkably high number of responding students (88%) reported having contact with their SQ high school teachers. Likewise, 88% of the students reported having contact with their high school SuperQuest teammates, post high school graduation.

Negative Aspects of the Program

Notably, almost a third of the students (29%) reported "no problems" with the SuperQuest program. The most frequent complaint among the rest (30%) concerned some kind of technical difficulty at the institute, i.e., access to the equipment, lack of technical support, and setting up the equipment or accounts. Twenty-three percent of the students reported SuperQuest staff related difficulties, i.e., difficulty with technical support staff, negative contact with mentors, and inappropriate teaching style. The qualitative data varies across institute in how they addressed some of these issues over the course of the program. In fact, many of the reported problems were being addressed by the end of the life of the program at each institute. It appears, however, that as institutes joined the program, they mostly re-invented these start-up program problems and solutions.

Table
Negative Aspects of the Institute

	SQ'89	SQ'90	SQ'91	SQ'92	SQ'93	SQ'94	Total	Percent
Other students Lack Knowledge	2	0	3	7	4	0	16	20.3
Group Dynamics	0	0	0	2	2	0	4	5.1
No Problem	2	1	3	9	6	2	23	29.1
Technical Issues	3	1	1	7	9	3	24	30.4
Teacher Pressure	0	0	0	1	2	0	3	3.8
Difficulty with SQ Staff	0	1	2	4	7	4	18	22.8
Problems with Own Project	1	0	1	2	3	1	8	10.1
Application Process	1	0	0	0	1	0	2	2.5

On an additional question, only three students (4%) reported that they themselves had difficulty with the different academic levels at the institute. This was a different perspective from that of the teachers, above. Finally, eight students (10%) thought the summer institute was too short (6 attended the Theory Center).

Summary

SuperQuest attracted both men and women teachers, who were slightly older than the national average. They tended to be quite experienced, although a significant number were relatively new to technology in their teaching. Few were originally certified in computer science, although the largest group now teaches it, followed by those teaching physics. The majority of these teachers are innovators, involved in some aspect of curriculum experimentation or school reform.

The SQ schools tend to be relatively large urban/suburban institutions; they tend to have a relatively high proportion of white students, although a number have diverse student bodies. With the exception of a small number of schools, most students graduate from these schools, and most go on to college.

The most common reason that teachers offer for applying to SQ is because it's a competition. A relatively distant second is interest in the subject matter. In addition to the academic aspects of the program, many of the teachers are concerned with the social aspects of the work, citing group dynamics and teamwork as both attractive and challenging features of the program. Few teachers perceived the institutes to be important professional development experiences, although this appears to reflect the institute's focus on students rather than the impact the program had at the school level. All reported that they learned computational science, as did their students. They also believed that a valuable aspect of the program was students' learning teamwork. They cited programming, and the social aspects of the institute equally when identifying its most effective features. These teachers found that Internet was the most common technology used following the institute, but they also reported that they integrated programming into their curricula.

The student sample includes participants from all years, but the 1992 and 1993 groups are most heavily represented. Far more boys than girls participated in the SQ program. The parents of most of these students are well educated, and many are professionals. Most of these students remain heavily involved in science, engineering, computer science, all still have access to the Internet, and most have regular contact with science professionals. Slightly more than half of these students worked on group projects, and none of these would have preferred to work individually. Several students with individual projects would have preferred groups. Most continued to work on their projects when they returned to school, and a significant number received prizes. Most of these students report positive SQ experiences. The best parts of the program for many were access to technology, and learning technical skills. This was the first experience of supercomputers for all of them. Many also noted the experience of visiting a college campus and the program's social aspects as positive features. Remarkably, one third of these students had no complaints about the program; among those who cited problems, predictably sufficient access to technology or sufficient technical support topped the list.

Qualitative Analyses: Success Criteria and Mediating Factors

As noted above, fourteen SQ schools were selected for more in-depth review. The schools were selected in consultation with the Theory Center SQ staff, with input from the other SQ center directors, to represent a range of school characteristics for this study. These characteristics included: magnet vs. regular schools; particular Institute attended, considering both year and geographical region; schools who participated more than once and single year participants.

Table
Schools' Winning SQ Year(s)

SCHOOL	Y89	Y90	Y91	Y92	Y93	Y94
Adams HS	0	0	0	92	0	0
Buchanan HS	0	0	0	92	0	0
Coolidge HS	0	0	0	92	0	0
Eisenhower HS	0	90	91	92	93	94
Ford HS	0	0	91	0	0	0
Garfield HS	0	0	0	0	93	0
Hoover HS	0	0	0	0	93	0
Jackson HS	0	0	91	0	0	0
Lincoln HS	89	0	91	92	93	0
Madison HS	0	0	91	92	0	94
Nixon HS	0	0	0	92	0	0
Roosevelt HS	0	0	91	92	0	94
Truman HS	0	90	91	92	0	0
Wilson HS	0	0	91	0	0	0

Table
School Type

SCHOOL	GENERAL INFO	CATEGORY
Adams HS	Public	Public
Buchanan HS	Public	Magnet
Coolidge HS	Public	Public
Eisenhower HS	Public	Public
Ford HS	Public	Public
Garfield HS	Public	Public
Hoover HS	Public	Public
Jackson HS	Public	Public
Lincoln HS	Public	Magnet
Madison HS	Public	Public
Nixon HS	Public	Public
Roosevelt HS	Public	Magnet
Truman HS	Public	Magnet
Wilson HS	Private	Private

Members of the research team visited each site for a minimum of one day, interviewing teachers, students, and administrators and observing classrooms, student work, and the physical and working arrangements of technologies. These qualitative data were transcribed, assembled and then coded according to key variables.

Criteria for Success

We were interested in systematically analyzing the experiences and features of these schools in terms of success variables. The variables were derived from the data, from conversations with the Theory Center SQ staff, and from our previous studies with the integration of technologies into schools. We identified eight key variables. Some of the variables concerned students success, some teacher success and some success at the level of the school. For example, a SQ teacher may have transformed her own curriculum, but this process may not have effected other teachers within the school:

1. <u>School-wide success</u>: Substantial evidence that the SQ program has had a reasonably sustained impact on the school, beyond the immediate SQ participants;

2. Substantial evidence that the <u>SQ teacher(s) incorporate computational science into their curricula</u> in ways that reflect SQ goals;

3. Substantial evidence that the <u>technologies are being used in significant ways</u>, related to the goals of SQ;

4. Substantial evidence that <u>teachers have transformed their practice to include significant project-based work</u>; in some cases, this was already in place, but teachers credit SQ with enhancements;

5. Substantial evidence that the SQ trained teachers have reached and influenced others teachers, expanding the impact of SQ;

6. Students successfully completed their projects, and some won an SQ prize;

7. Evidence that students' choices of college majors have been influenced by SQ experience;

8. Substantial evidence that the SQ students gained social benefits from the experience.

Data from each of the schools was coded according to these criteria for success. Judgments of individual members of the research team were reviewed and moderated, where necessary, with other members of the team.

Table
School Ranking According to Evaluation Criteria

SCHOOL	TOTAL SUCCESS	RANK
Lincoln HS	8	High
Adams HS	8	High
Hoover HS	8	High
Roosevelt HS	7	High
Coolidge HS	7	High
Truman HS	6	Medium
Nixon HS	6	Medium
Buchanan HS	6	Medium
Eisenhower HS	5	Medium
Garfield HS	5	Medium
Ford HS	4	Medium
Jackson HS	3	Low
Madison HS	2	Low
Wilson HS	1	Low

Factors that Influence Success

Thus, in addition to the analysis of school success for the SQ program, the data from all the schools were examined to identify factors that appeared to be related to the likelihood that schools would be successful SQ sites. These factors were reviewed, and refined, by all members of the research team, and discussed with SQ staff. The data from each school were then coded according to the final set of factors. These factors include:

1. *The nature of support for the project from school administration*;

2. *The nature of local university connections* both prior to and after SQ institutes;

3. *SQ teachers' backgrounds and roles* (whether she is an innovator, experience in technology, and major field);

4. *SQ students roles and activities* (whether they initiated SQ competition, whether they "pushed" their teachers; whether they played technical roles in the school; whether they submitted a best paper; whether a significant percentage go on in science/ computational science, the quality of their social experiences in relation to SQ);

5. *SQ mentors' roles and activities* (whether there was a match between project and mentor's field, the quality of the contact with mentors at the institute, whether there was significant post-institute contact).

Each of these factors is discussed below; the data from the schools are presented in the accompanying tables.

Administrative Support

For any successful school innovation administration support is useful, if not necessary. It appears, however, that for the successful integration of computational science administrative support was *essential*. Since we were interested in the ways administrator's reacted to their schools participation in SQ, the initiative to enter the contest often came from the teachers or the students.

No administrative support was coded when either (a) the administration blocked teachers' efforts to integrate computational science into their curriculum, or (b) administrators refused to recognize the winning students, or (c) administrators did nothing to recognize or support the program. For example, some administrators refused to pay for continued telecommunications access in the years following SQ.

Positive support included schools where administrators (a) actively sought to free up time for the winning teachers to train other staff or develop curriculum; (b) presented SQ teachers to the district and outside communities as new resource people; or (c) started the initial SQ team efforts themselves. These administrators also often publicly celebrated the winning students.

Passive support included schools where the administrators allowed the teachers to work with the new resources, experiment with new curriculum or scheduling and/or recognized the winning students. These administrators did not support the SQ program in an active way, or promote the resources beyond what individual teachers themselves were doing.

Relationship to success. Four of the schools received no support from their administrations. Five schools received passive support. Five schools received positive support.

Of these schools, none who had no support from their administrations were judged to achieve school wide success with SQ. All of the schools who had active support were judged to have achieved school wide success. Three of the five schools with passive support also were judged to be successful.

Likewise, there was no spread to other teachers in any of the schools lacking administrative support. There was spread to other teachers in four of the five schools where the administration was actively supportive, and in two of the five where support was passive.

Table
School Support

	ADMIN	PRIOR CONNECT UNIV		UNIV SERVICE PROVDR	
SCHOOL	Support	Academic	Technical	Technical	Academic
Adams HS	1	1	1	3	3
Buchanan HS	1	1	0	2	0
Coolidge HS	1	1	1	3	3
Eisenhower HS	2	1	0	1	2
Ford HS	0	1	0	2	2
Garfield HS	2	0	0	1	0
Hoover HS	2	1	1	1	1
Jackson HS	0	0	0	1	0
Lincoln HS	1	1	0	0	0
Madison HS	0	0	0	1	0
Nixon HS	1	0	0	2	2
Roosevelt HS	2	1	1	3	2
Truman HS	2	0	0	2	0
Wilson HS	0	1	0	1	1
	0=negative 1=active 2=passive	1=prior contact		1=poor svc 2=adequate 3=excellent	1= poor svc 2= adequate 3= excellent

University Connections with the SQ Schools

We examined the types and qualities of connections each school had with university partners both prior to and after their SQ experiences.

Technical support. It is important to note that the nature of the telecommunications technology between 1989 to 1995 was in great flux. The level of connection complexity in 1989 was much greater than in 1994, having to do not only with the hardware, but also the numbers of people able to develop and support these connections. In fact, SQ was one of the first national programs to provide high school students Internet connections.

Since the Internet connections were often new to the high schools, the technical support provided by the universities to connect the winning schools was an important variable. Regardless of who created and supported the Internet connections (SQ institutes, universities[7], commercial service providers) we evaluated the high schools' service provider experience. Schools were coded poor, adequate and excellent based on the extent to which the service provider responded to the technical problems. Those universities who simply accepted the contract to wire the school but never checked to see if the connection was working were coded poor, as did universities that regularly failed to answer teachers' questions. In general, the schools without this support did not get their systems going during their SQ year.

Adequate service providers got the system up and running, but did not extend themselves beyond that minimum service. Excellent providers sent out personnel time and again, rewired the system to increase efficiency or covered the costs of hook up in the following years.

Academic support. Local university support sometimes developed into a wider relationship between the university and the high school with impact on the academic opportunities available to the high school students. As with technical support, poor academic providers evidenced no contact. Adequate providers offered some level of involvement to the winning students and teachers, allowing them to work in university labs or become apprentices to research faculty. A few schools established excellent relationships with their universities that extended to more students than just the winners of SQ. These universities helped future hopeful SQ teams to develop projects or experiment on their own supercomputers, and to participate in faculty research projects.

Relationship to school success. We looked at the relationship of this factor to SQ success in two ways: (a) according to coding for school-wide success, or spread throughout the school, and (b) according to the overall score of the school on the 8 success variables, grouping schools into high, medium, and low categories.

Three of the schools had excellent *technical support* from the universities, and these three also achieved school wide success. These three schools were also three of the five who were judged to be "high" overall. Four schools had adequate service, and three of these were rated successful school wide. These four schools were also judged to be "medium" overall. Of the six who were coded as receiving poor service, only one achieved school wide success. One of these schools was "high", two were "medium" and three were "low" overall.

A similar pattern can be seen for *academic support*. Two of the schools received excellent academic support, and both were also judged to have school-wide SQ success. Both were also in the "high" overall category. Four schools received adequate support, and two of these were coded successful school-wide. All four were judged "medium" overall.

Two schools had poor academic support, and one of these was successful school-wide. One of these was judged "high" overall, and one judged "low". In addition, 5 schools had no service in this category, and only two of them were judged successful school wide.

Teachers' Backgrounds and Roles

We were interested in what influence a teacher's pedagogy may have on school success, and student outcomes. Teachers were coded as either innovators or non-innovators. Teachers involved in school reform efforts were coded as innovators if they were involved in any of the following efforts; curriculum reform, block scheduling, group projects, or technology integration within their curriculum.

In addition, we coded whether SQ teachers had substantial experience with technology in their teaching, and their major fields.

Relationship to success. Of the 8 schools for which the teachers were coded as innovators, 6 were judged successful school-wide. Teachers in 3 of the 4 schools that were rated “high” overall were also innovators. Of the remaining 6 schools in which the SQ teachers were not coded as innovative, 2 were judged successful school-wide. In only one of the schools rated “high” overall was the teacher(s) not an innovator.

Only 3 of the 14 of the schools had teachers who were coded to be inexperienced with technology. It is interesting that 2 of these schools were rated “medium” overall, and only one was judged “low”. Thus, it was not essential that the SQ teachers be advanced technically for adequate success, nor was teacher preparedness a guarantee of success. This is confirmed when examined by teachers’ major fields. Schools in which teachers specialized in computer science were not necessarily successful school-wide (2 cases), nor were they always rated highly overall (teachers in 2 of the 3 schools rated “low” specialized in computer science).

We also examined these teacher factors and outcome variables in relation to whether students completed their projects and submitted a best paper. Students submitted best papers from 11 of the 14 schools. Students did not submit papers from the 3 schools who were judged “low” overall; in none of these three schools were teachers innovators. One of the schools had a technically experienced teacher.

Table
Teacher Experience

	Innovator	Teacher Experience	Field
Adams HS	1	1	1, 2
Buchanan HS	1	1	4, 3
Coolidge HS	1	1	4, 3
Eisenhower HS	1	1	2, 3
Ford HS	1	0	1
Garfield HS	0	1	4
Hoover HS	1	1	1, 2
Jackson HS	0	1	4
Lincoln HS	1	1	1, 2, 3
Madison HS	0	1	4, 1
Nixon HS	1	0	3
Roosevelt HS	0	1	4, 2, 5
Truman HS	0	1	4, 2
Wilson HS	0	0	0
	1=Yes 0=No		1=Math 2=Physics 3=Chemistry 4=Computer Science

We were also interested in how the factors related to specific outcomes for teachers' practices following their SQ experiences. As noted above, we coded the data for teacher success variables, including whether the teacher(s) integrated computational science, whether the teachers integrated technologies, and whether the teacher was using substantial project-based work, crediting influence to SQ.

Table
Teachers' Curriculum Experience

SCHOOL	Teacher Used Computer Science	Teachers Used Technology	Teachers Project Based Work
Adams HS	1	1	1
Buchanan HS	1	1	1
Coolidge HS	1	1	1
Eisenhower HS	1	1	1
Ford HS	1	1	0
Garfield HS	1	1	1
Hoover HS	1	1	1
Jackson HS	1	1	0
Lincoln HS	1	1	1
Madison HS	1	0	0
Nixon HS	1	1	1
Roosevelt HS	0	1	1
Truman HS	1	1	1
Wilson HS	0	1	0

Almost all of the teachers were practicing integrated computational science following their SQ experiences: 12 of 14 teachers were coded as successfully using this practice. The qualitative data suggests that the teachers involved in the SQ program were for the most part exceptional, in that many were not only interested in expanding their own and students' knowledge, but were also willing to participate in a three-week summer institute with their students. Of the two teachers who did not, neither was coded as an innovator, although one was in a school judged "high" overall, and one in a school judged "low".

All but one of the schools integrated technologies into their curricula, including all of the teachers who did not bring substantial experience with technology to the institutes. Most teachers — 10 of 14 — were also doing project-based work with their students. In only one case was a teacher judged innovative who was not doing so.

Another way of looking at these practices is in relation to whether students won prizes in the best paper contest. Students won prizes in 7 of the 12 schools for which we have these data. In 5 of these cases, teachers were using all three of the practices coded above, therefore increasing the likelihood that the school culture was reinforcing the research expected for completing a SQ paper. In the remaining two cases, one teacher was not substantially using project based work, and one teacher was not substantially integrating computational science. These practices did not, however, necessarily lead to student success: 3 schools coded as successful in all practices did not win prizes, and two apparently did not submit best papers.

Students' Roles and Experiences

Several features of students' roles and experiences appeared to be important. We were especially interested in examining the role of students' initiative in three ways: initiating participation in SQ; "pushing" their teachers once they returned from the Institutes to, for example, set up and use the technology; and, playing active technical roles in the school on their return — (a) no technical role; (b) system helpers, who assist teachers in maintaining computers and server, set up system accounts, etc.; (c) technical trainers of fellow students and teachers; (d) system operators. It was apparent during our visits that technically able students substantially increase the schools' overall technical capacity.

In addition, we were interested in whether students submitted a best paper, and in whether they go on in science once they leave high school. Finally, since many teachers and students emphasized the importance of the social dimensions of the SQ experience, we were interested in how the quality of students' social experiences at the Institute may relate to success (a negative social experience, neutral, positive, or the best thing they experienced during their high school life). The data from each school were coded for each of these factors.

Table
Students' SQ Experience

School	Number	Students Initiate SQ	Students Push Teachers	Students Tech Roles	Submitted Best Paper	Students Go on in Science	Students' Social Experience
Adams HS	4	1	1	3	1		3
Buchanan HS	4	0	1	2, 3	1		2
Coolidge HS	4	0	0	2, 3	1	3	2
Eisenhower HS		0	1	1, 2	1	3	3
Ford HS	3	1	1	1, 2	1	3	1
Garfield HS	4	0	1	2, 3	1	3	3
Hoover HS	4	0	0	0	1	0	3
Jackson HS	4	1	1	0	0	0	4
Lincoln HS		0	1	1	1	3	3
Madison HS	8	0	1	1, 2	0	2	1
Nixon HS	4	0	0	0	1	2	3
Roosevelt HS		1	1	1, 2	1	3	2
Truman HS		0	1	1, 2	1	3	2
Wilson HS	4	0	0	0	0		0
		0=no 1=yes	0=no 1=yes	1=sys op 2=trainers 3=sys helpers	0=no 1=yes	1=1 or so 2=half 3=most all	1=neg 2=neutral 3=pos 4=best thing

Relationship to success. Students initiated the SQ involvement in 4 of the 14 schools. Two of these schools were judged to be "high" overall, and also to have achieved school-wide success. The remaining two were "low" and "medium", and neither achieved school-wide success. Thus while student initiation could be helpful, it did not characterize all high-performing schools, nor was it inevitably associated with high outcomes.

Student initiative became apparent in many more of the schools following participation in the summer institutes. In 10 of the 14 schools, students pushed teachers to set up equipment and “get going”. However, this factor was not always present in highly successful schools: 2 of the 4 high performing schools did not have students pushing teachers. This may be because the teachers themselves were motivated, so did not require much student encouragement. Two of the three schools judged “low” overall had students with initiative in this regard.

Students’ also exhibited considerable initiative through the technical roles they played in the schools. Ten of the 14 schools had students acting in some technical support capacity: 6 schools had students performing the most sophisticated role of systems operator, and 8 had students performing training functions.

Two of the three “low” performing schools did not have students playing technical roles. It is interesting to note which schools had students involved in the most advanced technical roles. More schools in the “medium” (3) and “low” (1) categories overall had students who were playing the most advanced role of system operator. Only two of the “high” performing schools did so. Three of the four magnet schools gave students the opportunity to be systems operators, but so did three schools not so designated. The presence or sophistication of students in these technical roles did not appear to be systematically related to whether the program spread school wide: three schools who had students in this role did not achieve school wide success; conversely, two schools who had no students playing any technical role were successful school-wide.

Eleven of the schools[8] submitted best papers; all three schools judged low overall failed to submit papers. Of those submitting, 7 students/teams won prizes in the contest. We have data for 11 of the schools with respect to the percentage of students who go on in science. For 7 of these schools, most students go on in science in their higher education; three of these are magnet schools (missing data for the 4th magnet school in our sample). All of these schools were coded as either “high” or “medium” overall, and four of them were judged to have achieved school-wide success for SQ. For two additional schools, about half of the students go on in science. One of these was coded “low” overall, and the other was coded “medium”.

With respect to the reported quality of students’ social experience, we have data for 13 of the 14 schools. Social experience was rated negative for only two of these schools. For one school, a school that was rated “low” overall, the social experience was reported to be the best thing that they experienced in high school. Six schools reported positive social experiences at the institutes, and the remaining 4 had “neutral” experiences. One of the three low performing schools reported a negative experience, and the data is missing for the other school coded “low”. Thus, most of the “high” and “medium” rated schools had positive or neutral social experiences. The quality of the social experience does not appear to be related in any systematic way to whether SQ successfully spread school-wide.

Mentors' Roles

One unique component of the SQ program was introducing student teams to a scientist(s) or other experts in their project fields of study, and encouraging continued contact after the institute experiences. We were interested in examining whether matching mentors to students' fields of study was important, the quality of contact with mentors at the institutes, and whether there was significant contact with mentors following the institute.

Table
Mentors' Roles

SCHOOL	Proper Field	Quality of Contact	Post Contact
Adams HS	0	1	0
Buchanan HS	0	2	0
Coolidge HS	1	3	0
Eisenhower HS	1	2	0
Ford HS	1	2	0
Garfield HS	1	2	0
Hoover HS	1	3	0
Jackson HS	0	0	0
Lincoln HS			
Madison HS	0	1	0
Nixon HS	1	2	0
Roosevelt HS	0	0	0
Truman HS	1	3	0
Wilson HS	0	0	0
	1=yes	1=negative 2=moderate 3=positive	1=yes

Relation to Success. Half of the schools reported that the institute mentor was appropriately matched by field for the students' work. The other half reported that Institute mentors were not in students' fields of work. (Recall from the quantitative analysis of students' experiences, 50% reported that "learning from scientists" was a positive aspect of their institute experience; we do not have data to know whether these students also perceived that the matches were appropriate.)

Interestingly, none of the 3 schools judged to be "low" overall were matched with appropriate mentors, and all three reported negative or no substantial contact with the mentors. Conversely, for 4 of the 6 schools where students won a prize in the best paper contest (data missing for the 7th), mentors were appropriately matched for the students' fields. All 4 of these schools reported that they had very positive or moderately positive contact with their mentors. The two schools who won prizes but were not matched with appropriate mentors reported negative or no contact with them.

Of the three schools reporting very positive contact with mentors, all were appropriately matched. Two of these were judged "high" overall, and one "medium; all three schools achieved school wide spread.

However, none of the 14 schools — regardless of the appropriateness or quality of relationship with the mentor at the institute — had sustained contact with them after they returned to their schools.

Qualitative Analyses: School, Teacher, and Student Portraits

The analysis of the success of the SQ schools, teachers and students — and potentially mediating factors — provides an overall view of the implementation of the program in 14 schools. The sample was chosen to represent a range of qualities and experiences. In order to put some flesh on these interpretive bones — to help the reader to understand how these factors were woven together in particular circumstances — thirteen *portraits* are presented below.

a. Schools. Six of the portraits describe successful SQ schools, those rated “high” or “medium” overall according to the success indicators. Each of these schools was successful in somewhat different ways (e.g. some for their school wide implementation, some for the success that the SQ students enjoyed). We also provide briefer summaries of explanations for the lack of success of the three schools judged to be “low” overall.

b. Teachers. It is key to understand the experience of SQ teachers in the program, since they are central to the institute experience, and to school-wide implementation. Three portraits provide detail about the experiences of teachers in additional SQ schools.

c. Students. The SQ program design is unusual in its efforts to directly support students. A brief portrait of the experience of a SQ student is presented to illuminate that aspect of the program.

These portraits are concise; rather than presenting long and detailed case studies for each site, we present synopses of these data to illuminate the summary findings of the quantitative analysis, and the qualitative analysis of overall success features and factors.

Portraits of Schools

School Portrait: Hoover High School. Hoover was a school judged to be “high” overall, and that also achieved school wide implementation. It participated in one summer institute, in 1993. Two teachers participated in a subsequent teachers-only summer program at NCSA in 1994.

This high school was designed in 1954 for a student body of 1800; the school currently has 2950 students enrolled. The town is experiencing a population boom, described as “urban flight from Kansas City.” The greater Kansas City has a population of around 1 million, while Hoover has approximately 50, 000 people. The school district is gaining 600 students a year, with the district opening an elementary almost every year. They are completing the building of a new high school. Most of the school district is rural, but there is a growing suburban population. Approximately 85% of the students go on to college, with 15-20% of those students going to 4 year college

Jim B. and John N. teach mathematics and physics, respectively. They both attended the SQ Institute at Reed College in 1993. They also attended the teacher-only SQ workshop at NCSA in 1994. Both thought that combining the two types of institutes — student-teacher and teacher-only — was highly beneficial for their professional development. They learned how students would work in a project-based environment with high-end technology tools in the first institute. The following year, they learned how to restructure their curriculum in the teachers-only workshop to incorporate the students' project work. Neither teacher expressed a preference of one model over the other; they recommend a program that combines the two approaches. Each has strengths, and together they provide a solid foundation.

At the time of the visit, these teachers were co-teaching a block class of calculus and physics for the second time. Jim and John enjoy each other's company, joking and laughing often, while describing the importance of collaborative projects for their students.

Jim and John were aggressive in their demands that the school amplify the SQ win, broadening its impact. For example, they insisted on phones in their classrooms upon winning SQ. They developed a block class with technology integrated into its curriculum that they are now co-teaching. They have written multiple grants for technology and training. They often use their SQ win to leverage grant opportunities: "If someone is going to spend money on us, why not tell somebody else?"

John first learned of SQ while attending the SuperComputing '92 conference, where he heard Nora Sabelli from the National Science Foundation speak of the program. He thought it "sounded like a good idea." In describing SQ, Jim noted:

> "It opened our eyes... It wasn't as easy as we thought it would be. Getting everybody together was one of the hardest parts. It helped in more ways than I can express. It was definitely worthwhile."

As for the effect it had for them as professionals, John notes it helped students reach out to professionals in the science world:

> "... making contacts - finding professors that take the time. We accomplished a lot to get the project together. [A major component was] getting into the Internet for college materials.
>
> We were just really interested in our project (Study of the Retina). It was a new world... it got addictive (researching the project)."

Prior to winning SQ, John and Jim decided to develop a block class of physics and chemistry, taking 30 minutes a day for planning, working in the summer, and observing each other's class during the 1992-93 school year. Also, during this planning year they made a request to the school administration for a lab. After returning from the SQ institute and Pittsburgh Supercomputing Challenge in the summer of 1993, John and Jim implemented their first block class. They learned that they had too many students, 32, and they lost approximately 8 students, primarily they believe because these students did not realize the high level of the class work expected. The second year of the block class has fared much better. Jim and John added a calculus pre-requisite, so most students are seniors, and the currently enrollment has been steady at 17 students.

Jim and John have also started a computational science course during their second year after SQ. They report that parts of this curriculum are a direct outgrowth of their SQ experience. The course is one semester in length designed around student work with the scientific method. Steps for student research projects are outlined; their progress is tracked according to assessment periods based on accomplishing each step. The students develop and sign contracts with their teachers about how they will accomplish their projects, both as individuals and as a group. Both Jim and John feel goal setting and close monitoring is central to the students' learning.

Another important goal of these two teachers is to start to involve other teachers from various curriculum areas in these curriculum projects. For example, English teachers work with students on writing; math teachers develop related curriculum components. To date, they have worked with one biology teacher to develop experiments for their computational science class. They strongly believe that the technology excites the students to "go beyond the grade." These teachers have moved their curriculum to include project-based work, with students learning to become responsible for follow-up and individual work.

Jim and John have received some grant funding for their projects. They have also contacted a local technology firm, Allied Signal, and hoping to gain support for internships for students through relationships with their professional staff.

When asked how they would gauge if SQ was successful, they said "it effected a lot of kids, not just kids that went, it also effected these kids here at the school." Jim noted that many of the questions asked during the proposal process started both teachers thinking about school-wide planning in a new way (e.g. how would you disseminate?).

There are several features to note in this school that were likely related to its success. First, the school was flexible with respect to schedule (block scheduling was possible), interested in the development of new classes, and open to co-teaching arrangements. Second, these two teachers were actively looking for outside programs and support to help them to make changes. Third, there were two of them, and they worked well together; one was not struggling in isolation. Fourth, the teachers had the opportunity to participate in two intensive institutes over two years, one focusing on students' work, and one focusing on curriculum development. Fifth, these teachers were aggressive seekers of resources, arranging for phone lines, pursuing grants. Finally, these teachers were highly motivated to make change, and they had at least passive support from the school administration to do so.

School Portrait: Lincoln High School. This high school was judged to be "high" overall, and to have achieved school wide success. It participated in four summer institutes: 1989, 1991, 1992, 1993. The teams consisted of students who were conducting individual research projects; while group projects from the school competed for slots at the institute, they did not win.

Lincoln High School created a magnet program in 1984 within a regular high school. There are 400 students in the program; 100 students are accepted to begin the program in 9th grade. Students take accelerated coursework in math, science and technology. For their humanities work they are combined with students not in the magnet program. This program was a direct result of an integration lawsuit in the county; the magnet program was created in the most diverse school in the county. Due to crowded conditions, the school is currently planning a new building, expected to open in the fall of 1998.

All students must complete senior projects for graduation. They begin work on these projects in their junior year. Through the senior project work, students learn about research, experimentation, and formal presentation. Senior Projects requirements include:

1. keeping a lab book that details at least 180 hours of work, (documentation and research methods);

2. writing a formal scientific paper, including an abstract;

3. making formal presentations of their work during a field day/science fair. One presentation is made to a group of peers, and to parents and mentors in a poster session in the evening.

The SQ competition thus fit quite smoothly into the curriculum structure that requires students to undertake substantial pieces of research over extended periods of time. Many of these students also take part in the Westinghouse competition; their teachers are alert to experiences, especially competitive ones, that can help students to prepare for these challenges.

Lincoln submitted both group and individual projects to SQ. Many of the Lincoln students prefer individual projects to prepare for the Westinghouse in their senior year. Several teachers noted that part of the appeal to the SQ program in their school was that SQ, Westinghouse and senior projects "dovetail nicely." That is, students can begin working on a two-year project beginning in their junior year, and apply to SQ, as an initial experience of research preparation and competition. They then develop a Westinghouse project, and finally submit this work as a complete senior project. The structure of the school's work has thus favored individual student projects over group projects.

While high achieving students may prefer individual SQ projects, teachers see the benefits of group SQ projects for social and academic reasons. In group projects, students must learn to negotiate tasks and work collaboratively. Some teachers have made efforts to form after-school “clubs, ” or project focused classes that encourage student collaboration on projects in preparation for SQ. Several teachers noted, however, that it is difficult to manage group projects. Typically, a group project is one student’s idea, with other students joining to support the project. Some teachers noted that for group project, students need more guidance in the beginning; they must also learn new kinds of organizational skills to orchestrate the work on schedule.

Students played an active role in the technical support aspects of the program. Both teachers and students reported that they thought that student involvement in the summer institutes was key to the success of embedding the program in the school. Eager, demanding, knowledgeable students insisted impatiently that the equipment be set up immediately, and that they be allowed to proceed with their work. Even teachers who are SQ enthusiasts and technically adept return to their schools in the fall, harried by many competing demands. Without student prodding and technical knowledge gained at the institute, the SQ equipment and project work might well move to the background for some months in the best of circumstances.

Some of the SQ teachers suggested adding a component to the SQ program: access to a resource base of teachers who would be available through phone or e-mail that can provide discussion and guidance about SQ-related issues and problems. They also felt that SQ should require all winners — students and teachers — to do outreach technical assistance work. A resources base such as this would be one way to share their knowledge. Likewise, teachers and perhaps students might be enlisted to train others in the subsequent year.

Teachers compared SQ favorably to other computer science activities they are aware of because it integrates science and computational science well. One teacher noted that SQ attracts students interested in technology that other national competitions do not. In fact, several teachers noted that the SQ program is project, group based “which is more our interest” as teachers than other national competitions. They also noted that SQ projects tend to be “more real world” related. Most national computer competitions are short and timed programming-based tests, while SQ promotes long-term and motivates students to integrate computational science within disciplines, based on real world problems. As one SQ teacher noted, “SQ integrates science and the application of the computer, students are not just tweaking the computer.”

In addition, some teachers felt that the social aspects of the summer institutes were especially important for their students. These students tend to be very focused and successful academically, but may be less successful socially. The institutes helped these students to expand their social experiences, providing contact with students more expert socially and situations where their students could experience themselves in new ways.

A major goal of the school in next 5 years is to move outreach into regular high schools in the state. While teachers are involved in this effort, Lincoln encourages their students to train kids within the school and outside the school. Students also train teachers on the World Wide Web

> “The kids going (learning technology aspects at SQ institutes) drag us (teachers) along and also provide support. They want to use the equipment and get it up and going as soon as it came in. We wouldn’t be where we are now if it wasn’t for the kids. It’s easy to get so overwhelmed that we (teachers) wouldn’t push it when we get back to the school, if it weren’t for the kids.”

Based on the SQ students experience with research over the Internet, all magnet students are currently expected to facilitate their research using the Internet. In fact, Internet research skills are being taught in all regular high school social studies classes, beginning in the freshman year. One teacher noted: “It’s hard to think of all the things effected by SuperQuest - a big effect is what kids know and teach each other on the side.” Several teachers claim that the SQ program got the school involved in the Internet and credit SQ with early and key support for teachers, students and school. The school has now had to absorb the cost for Internet accounts. About 85% of the students have accounts. Now, almost all freshmen get accounts. Most magnet students have home computers, and the school currently has 16 phone lines into the building for computer connections.

Teachers, administration and students reported the following effects from the school’s participation in SQ:

- The SQ program allowed the school to take advantage of the Internet long before it achieved its current popularity. They thus have had the opportunity to experiment and take advantage of telecommunications for science and mathematics for many years.“ We wouldn’t have workstations, a network, visualizations and computational methods, and numerical methods — all influenced by SQ.” More teachers are integrating computers into their curricula.
- Since SQ, more students are undertaking projects in mathematics.
- More students are presenting their research projects using computational tools.
- To the surprise and delight of the teachers, “Kids are finding people (scientists, engineers, etc.) to talk to outside the metro area - that’s new, much broadening from 10 years ago.”
- Students begin to learn presentation skills in 9th grade; they learn to use “persuasion” software. Teachers saw this software at SQ and brought it to the school.

The success of the SQ implementation at Lincoln includes a variety of factors in addition to their very capable student body. Among them: (a) a teacher who was also a scientist immediately saw the value of the program and knew how to make arrangements to compete successfully; (b) the school was already well aligned for this approach to student work, requiring substantial research projects/papers for graduation; (c) the school had a tradition of successful competition in programs such as Westinghouse; (d) the school had a string of SQ wins, allowing a large cadre of teachers to attend summer institutes; (e) the school absorbed new technologies well, (e) a substantial number of teachers and students enjoyed “messing around” with new computational tools and environments, spreading and adapting them to new purposes; (f) many teachers were comfortable with students assuming substantial roles in managing the technologies, and in training other students and teachers in its use.

School Portrait: Adams High. Adams was judged to be “high” overall, and to have achieved a measure of school wide success. It attended one summer institute in 1992.

Adams High School is a public school in a town just outside of Los Angles, California. Adams College, with several highly regarded specialty colleges, is located a few miles from the high school and is one of the town’s largest employers. As the only high school in the district, Adams High has an enrollment of approximately 2100 students, and 65 full-time teachers. The average class size ranges from 36 to 38 students. Being the only high school in town, Adams High is a microcosm of California. The student population is 60% white, and 40% minority (10% Hispanic, 9% African American, 11-12% Asian, 10% other). School officials reported that the parents’ income and educational level varies greatly, from migrant and working class families living in transient housing to professionals living in large homes nestled in the foothills.

Adams High School is part of a state program which networks 100 high schools electronically. California has split the state into regions, with Adams and five other high schools and two continuing high schools comprising one such region. Due its technical capacity, Adams has assumed a leadership role as the technical resource in their region, and even beyond. This technical capability was developed by an energetic teacher with a supportive administration, along with training, access and equipment provided by projects like SuperQuest. They have, for example, participated in a teacher training program at Lawrence Livermore Energy Lab, and have received substantial support from Apple Computer. The school has held workshops for the other state teachers and administrators from within their technical district and beyond.

At this high school, the experience with SuperQuest had a somewhat different character than many of the other winning schools. The successful project deeply and substantially involved the group of winning students, their classmates, their teachers, the high school more broadly, and experts outside the school in developing a project, and then publishing an original scientific paper about it. Their SuperQuest work concerned original work on knot theory.[9]

The school has recently (following SuperQuest) begun to “wire” the campus, and is beginning to restructure the entire curriculum. One administrator notes that “SuperQuest was the impetus for change, ” for their school’s technology development planning. They are also moving toward a core curriculum for all students. The administrators stated that many students are more technically advanced than the teachers, and several serve as technical support staff for the school. Their Internet connection is paid for by a local college (part of Adams College), and includes 10-12 incoming telephone lines.

In 1991 Robs M. received a mailing from the Lawrence Livermore Energy Lab teacher program, in which 50 teachers were given computer accounts on a little-used Cray Supercomputer. After attending a summer workshop at Lawrence Livermore, Robs started a supercomputer special interest group - a club - which attracted some 25-30 students. The club was part social and part academic, where students were exposed to operating systems, e-mail, ray tracing, and rendering. While the group was mostly boys, a few girls (4-5) also joined the club. (Robs, like many teachers we talked to, felt that girls encounter some barriers in math - noting that this appears to be a “societal/cultural thing.”) After several months, a small group of boys “wanted to do more intense stuff, “ these students had “high interest”, and were “good students, college bound, and had home computers.”

A boy from this smaller group brought a SuperQuest flyer to school and asked Robs if they could apply. Building on the students’ enthusiasm, Robs approached several friends and colleagues and asked them to talk to these students regarding possible SuperQuest projects. A mathematician, Jim H., from Adams College, was “heavy into knot theory, “ and presented the topic to the SuperQuest club. Approximately 8-10 students began to “kick around math and science project ideas” with Robs, and decided to pursue the knot theory project as a basis for a SuperQuest project. A basic problem with the SQ proposal emerged from the very beginning, Robs had too many interested students. There were 6-7 students, each writing similar knot theory proposals, but the SuperQuest program limited the proposal to four students. Robs’ initial solution was to submit two proposals of three students per team. The full team of six students continued to meet together with scheduled activities twice a week, where they reviewed readings and Jim H. gave lectures.

One of the teams was awarded a trip to NCSA in 1992 and Adams moved on to the next phase of its SuperQuest experience. Prior to attending the SuperQuest institute, Robs’ expectations were relatively small: getting a few computers and learning to program in C. Initially, he had been excited by the concept that SuperQuest offered talented students an opportunity for advancement, but he had begun to feel that the teachers were not learning enough for them to incorporate these new technologies and approaches into their classes. If the program were to target teachers there would be a greater chance for “continuity.... if you can engage teachers, they’re more likely to pass it on to other teachers.” He noted that this tension in the program’s mission was apparent at NCSA in the amount of time dedicated to students’ activity and the amount dedicated to discussing curriculum approaches or even just teaching system operations to the teachers.

At the Institute, the three students who attended got a big push in their project: the orientation staff were great hosts, there were special tours to machine rooms, NCSA centers, chip fabrication, and demonstrations of NCSA software. The social activities were all great. The students were so motivated at the Institute that Robs even felt there was a point when they knew more than their graduate student mentor.

While they were at the institute, NCSA shipped the DEC 5025 to the school for delivery by the end of September. Robs called his local phone company to begin the installation process from NCSA. From prior experience Robs knew that something like SuperQuest needs a lot of “front-end” preparation “even before they walk into the research center.” With high school students it is important not to lose precious momentum because the machinery can not be set up on time. Fortunately, Robs was experienced enough to contact NCSA whenever he needed their expertise back at the school and he sent “lists of stuff” bombarding the doctoral student assigned to his project.

Back at school in the Fall, the full team of six students reconvened to begin work on the paper. The experience gained by the three students at the institute was shared with the rest of the team and even with younger students who joined the project for the first time. The team also continued working with professors from Adams College - thus strengthening a bond between the high school and the college that would benefit all the students at the high school.

The success of group project extended beyond just placing second in the Best Paper Contest. The group pushed knot theory boundaries to one more “crossing.” A prior theory by Thistlewante (a knot theoretician) had proved the possibility of 12 and 13 “knot crossings, “ and the group project calculated the possibility of completing up to 14 crossings. The students had the excitement of seeing their paper published in an academic journal. They now have a publication on their resumes.

Why was SuperQuest was successful at Adams? When asked what excited the students about the SuperQuest, the teacher responded: “Cash, 3 weeks away, supercomputer and being special.” As many other SuperQuest teachers noted, most high schools do not offer chances for recognition and success outside of sports. Intellectual excellence and the training needed to attain it are seldom recognized publicly. SuperQuest offered a unique opportunity for these particular students to excel and be rewarded in their field of interest, computer science. SuperQuest is also one of the few chances for students to struggle for academic excellence as a team and to learn the importance of group work in solving problems and pushing farther than an individual students could do.

Robs believes that SuperQuest changed the perspective of the SQ students’ peers and the group took on a leadership roles once back at school. The group spent at least 3 hours a week on the project during the school year — continuing to meet twice a week after school. Robs noted that the adults on the team (he, college professor and a computer science teacher) “spent a lot of time figuring out if we could do it (the project).” But the students were interested because they thought it was neat and they wanted “to work on something real.” The students maintained their motivation because they perceived that their project was on the “cutting edge” of knot theory and they were in contact with some of the leading math researchers in the field. It is also a major accomplishment that this group of high school students developed a research project that extended over a two year period, a project that required them to learn new skills to solve problems that they themselves identified.

Overall, the teacher views his SuperQuest experience positively, emphasizing that this was a very important life experience for his students. For the students directly involved in SuperQuest, the team worked through various group dynamic problems and gained a deeper understanding of each other. The students received recognition during their graduation, and got to participate in the “adult” world of science by attending a conference, and corresponding with several research experts. The cumulative effect was to boost their confidence in their academic and social skills. For the students who came after, Robs has incorporated group work and research oriented projects into his curriculum. Adams High is revamping its technology infra-structure, along with a closer connection to Adams College. The SQ teacher felt that the most important aspect of the SQ experience was a growing knowledge that high school students can do real science.

A number of factors appear related to the success of the program at this high school. Among them: (a) the SQ project was very well structured from the outset, helping students to be successful and to maintain momentum throughout two years; (b) the teacher successfully recruited appropriate outside experts to help students with project ideas and structure from the very beginning; (c) given these supports, the project was largely student-driven with useful constraints and boundaries supplied by the adults; (d) the teacher attended the summer institute with clear expectation about learning for himself, he had expectations for what he wanted out of the institute and made demands; (e) the project continued to be highly structured after the institute, and students could receive independent study credit for their participation; (f) the teacher was given release time to work; (g) the work on original publishable research was tremendously motivating to the students, and completing this “circuit” was a very powerful experience for them and their peers; (h) the school administration saw SQ as an opportunity to experiment with approaches to technology integration, and drew on the expertise of the SQ teacher to aid in that goal.

School Portrait: Eisenhower High School. This high school was rated overall as “medium” with respect to success. The program did not have a school wide impact. Eisenhower participated in five summer institutes: 1990, 91, 92, 93, 94. This assures us that multiple experiences does not itself lead to comprehensive success.

Eisenhower High is a public high school in the township of Eisenhower, Illinois. Eisenhower is both a suburb of Chicago and a city in its own right. As a suburb, has control over its own affairs. Also, as a suburb, the Board can pass school tax levies - cities have a hard time doing so these days. The average income of the residents means that the school can not get “need based” grants. Yet, since Eisenhower has many of the benefits of a city they also have a diverse ethnic / racial population. Northwestern University and a host of professional and scientific companies are around to serve as resources for the school (both in human capital and in financial/material donations).

Current enrollment in the high school is 2700. The school building was expanded in the 1960s to accommodate 6000 students.

The high school currently has two T1 lines into the school, which connect to two rooms: the Supercomputer Center and the room that houses the CoVis[10] project. At the time of our visit, neither line extended beyond or connected with any other room in the school. The technologies in the school are not well coordinated across programs. There is no school-wide LAN or network. Eisenhower did not have a Web site at the time of our visit. The most advanced students at the school can model cell death in the human immune system through technology provided by SQ, but the honors physics students clack away on four Apple II e's in their physics lab.

The SQ students at Eisenhower have a very strong sense of tradition. The unusual aspect of the Eisenhower portrait is the degree to which the SQ program is part of the *student* culture of the school. The students themselves play large roles in maintaining the SQ technologies and the program, passing the traditions on to a new cohort of students. While teachers are certainly involved, they play a more background role than in most other sites.

After winning multiple years, SQ has become as coveted and as storied as a sports trophy for these academically motivated kids. Two features that strengthen the sense of tradition and, perhaps, contribute to the continued success of Eisenhower students in SuperQuest. First, the faculty at Eisenhower allows the students to "own" SQ and the equipment it has brought. Right next to the Science Department Office is a converted "broom closet" that is Eisenhower's Supercomputing Center. The Supercomputing Center has the feel of a clubhouse, with small number of students "hanging out" throughout the school day, as well as after school hours, working and socializing together. Above the door is a bronze plaque listing each of the six years the school has won SQ, along with each individual student's name. This is where the SQ students and the other students in the chemistry and physics programs hang out, do their work and teach each other. Students were in charge of the initial wiring of the SQ awarded workstations, and a student earns the system operator role each year.

A second aspect of the tradition is the strong feeling of inter-class solidarity that exists among the students. Since the Supercomputing Center is mostly a kids-only territory, questions are often directed to the older students. SQ winners pass on their knowledge to younger students. Although the Eisenhower students do not work on team projects, they do help each other throughout the projects. For example, the current system operator will graduate after next year, but he and another senior are training a ninth grade girl to be the next system operator.

Eisenhower's SQ program was unusual in that only 11th graders attend the SQ institutes This has meant that all four students return to the school for one more year - seen as a critical component to the Eisenhower computer culture. SQ students have one more year with the computers, one more year in the Supercomputer Center, one more year doing a specific science project, and one more year of mentoring their younger peers. As strongly emphasized by Eisenhower science teaching staff, “These students return to a class culture where one’s prestige is built up by being able to teach other students.”

Thus, Eisenhower is a school where SQ has had a major impact on establishing a tradition of involvement of students in this form of achievement. It successfully competed for institute slots in five consecutive years, and is the core of a vibrant, albeit circumscribed, student culture. It did not, however, spread more broadly through the school. Among factors related to its success: (a) the intensive resources and intensive teacher time that could be brought to bear on the program, drawing in an especially talented group of students; (b) many students also compete successfully for Westinghouse awards, and like Lincoln students, these students saw SQ as a way to gain experience useful for the later Westinghouse competition; (c) there was significant school-wide acknowledgment of SQ winning students, including their names being added to a permanent plaque outside the computer room. Students thus felt quite honored for academic achievement throughout their home school; (d) the main SQ teacher was quite research-oriented and spent some of his summers researching topics that could be used by students as seeds of SQ projects. The students were talented, but the teacher was especially helpful in stimulating ideas, helping them to stay motivated. This teacher provided the same kind of design constraints as the teacher at Adams, seeding ideas but letting the project be student-driven, providing limits and structures for the inquiries; (e) students participated in SQ in the 11th grade, allowing time for a student culture to develop, and expertise to spread.

The SQ experience failed to have a school wide impact however, never advancing beyond a club-like activity for a devoted group of students each year. Among the factors influencing this: (a) the administration knew little about the SQ activity, leaving it to few teachers to run; (b) the school overall appeared to be quite segmented with respect to programs and connectivity of equipment; there was relatively little coordination across particular initiatives; (c) students had to make a commitment to SQ activity fairly early in a year, and to “qualify” as part of the team to get access to the advanced equipment.

Portraits of Less Successful Schools: Key Factors

Particular factors appeared to account for the lack of SQ impact in the three schools that were judged to be “low” overall, and without school wide impact. Since there were relatively little SQ activity in each of these schools following the institute there is little to describe of the post-institute effect. The quite brief portraits thus focus on the impeding factors.

School Portrait: Jackson High School. This high school attended the 1991 SQ summer institute.

Jackson School District is located in an agricultural community of apple growers and a few vineyards for the New York wine industry. The district has approximately 200 students in three elementary schools, one middle school and the high school. The high school is relatively small with a staff of 40 teachers and roughly 600 students. The school day is composed of nine 42 minute periods. The student population is predominantly white; with approximately 5% of the students are either African-American or Latino.

The district's technology infrastructure has been developed along the lines set out in its "Computer Plan" written in 1983, according to the district computer director. The Plan was to start putting technology into the three elementary schools, moving gradually into the middle school and than the high school. Each school building now has a LAN, and the elementary school has a LAN terminal in every classroom. A couple of the elementary classes have more PC's because of IBM's Writing to Read and Writing to Write programs. The middle school now has a prodigy grant for a modem linking its LAN to America Online. But until the grant, the middle school had not been nearly as computerized as the elementary schools. As of our visit, the Plan has not yet arrived at the high school in full force, although they are now 12 years into the Plan. The high school has one computer lab for students, and technical administrators are now just beginning to purchase computers for individual classrooms.

Jackson won a slot at the summer institute during the first year that intensive efforts had been made to recruit schools who did not necessarily consider themselves to have outstanding science students. The teacher felt that his students were especially valuable in the social climate they helped to create at the institute; socially able, they helped other students who were not.

The winning SQ teacher felt that 1991 SQ win might have created an image of the high school as a "leader" in computers. But, the administration was unable or unwilling to provide the type of support to take up the momentum of SQ. As noted above, the year following SQ the administration did not allocate the $10, 000 needed to keep the router and the net connections. The community support was not there for such an expense. While the SQ teacher felt that computational science and technology interest was raised by SQ, it was still seen as a program for a "small group of elite kids" among school administrators. The administrators did not choose to "honor" the SQ students for their achievements. Members of the school staff noted that the school lives within a small farming town, is more focused on sports and local heroes than on education and technology projects. Also, there was some suggestion that SQ came "too early" in that the Computer Plan had not yet reached the high school, while the district was committing financial technology resources to the lower schools.

Thus, the program did not have a tradition of project-based science work or academic competitions to provide context in a school with relatively little support for academically talented students. The administration did not support the program, and in fact could be considered to be somewhat hostile to it.

But, the impact of a program like SuperQuest on the lives of students can also be measured from the perspective of where the students started. The SQ program appears to have had a substantial impact on the students who directly participated in it. Jackson is a small rural high school not known for its science training. The administrators at this high school reported that few students attend college. The majority of the college-bound students attend the local community college. The SuperQuest winners appear to have broken this mold. Two brothers who were on the winning team both went on to college: one is studying engineering at the University of Florida; his brother is pursuing graduate work in history at the University of Delaware. The life of the third member of the SQ team member was tragically altered when he was involved in a highway accident, which left him partially paralyzed the year after high school graduation. He is now working in Norway studying technology and developing software for physically impaired persons.

School Portrait: Wilson HS. Wilson High is a private high school in Ohio and attended the 1991 summer institute.

Wilson HS decided to compete in SQ largely motivated by the interest of the father of a student at the public school in the town. This parent was especially interested in having his son attend such a program, but failed initially to raise the interest of his son’s public high school, Ford High. Wilson HS decided to compete for the program, as eventually did Ford. Both schools won slots in the 1991 summer institute.

The young SQ teacher at Wilson High apparently had a difficult time at the institute he attended. In a decision unrelated to SQ, he abruptly decided to leave the school for another job. The original parent’s enthusiasm did not extend to the whole school, beyond his individual son’s experience, and thus there was little “institutional memory” to carry the program forward in post institute activities (The son, incidentally, went on to become a Westinghouse finalist). Ford High, by contrast, was judged “medium” overall, although the SQ program did not achieve school wide impact there either.

Indeed, soon after the 1991 Institute, boxes of equipment arrived at Wilson HS. But, no one at the Wilson HS even opened them upon their arrival. The Dean of Faculty remembers that the school waited in vain for the promised “installation” visit form UAH. At that point, there was no administrator or teacher who had the experience to carry the SQ program forward locally. Another young computer science teacher was hired to replace the one who attended SQ. He opened the boxes, but was relatively new to the field, and without specific SQ training, did not know what to do with the equipment. He eventually incorporated the technology as the backbone of a computer lab he created.

The story does not quite end there. In the Fall of 1994, 3 years after the SQ institute, an administrator from University of Alabama called the high school to say that Wilson HS had a free Internet connection and were they ever going to use it? The replacement computer teacher wisely took UAH up on their offer.

This school is not doing any computational science, per se, but is interested in using the Internet for its social sciences curriculum

School Portrait: Garfield High School. Garfield participated in the 1993 summer institute, and was rated “medium” overall. SQ impact did not spread to the school.

This high school successfully competed in SQ supported by a very enthusiastic husband/wife team who attended the institute. They were especially interested in integrating the research process into the school curriculum, focusing on projects in computer science classes.

The project floundered, however, on not being able to get timely and sufficient technical help. The only serious complaint a SQ winning teacher had about the SuperQuest program was the lack of technical support after the institute. While this teacher noted that an SQ director and his assistant helped the school get the workstation and Internet connection up and running — even working with the students on-line during the school year — technical support was problematic. The school received a DEC 5000, “cool” monitor, and laser printer, and was networked to a large university.

During the school year following the institute, the school did not experience any technical problems, and the students finished their SQ project. However, the following summer, less than one year after receiving the workstation, they started having “connection” problems. The teacher could not diagnose the problems, but suspected that the technical issue was on the high school end. The equipment remained nonfunctional for 5-6 months.

After the one-year of SQ support (financial and technical), the high school did not have a budget line to hire a technical consultant at a reported $500 a day to visit the school and diagnose the technical problem. The teacher had contacted several technology companies, and at the time of the site visit was looking for a volunteer from a local technology corporation to come to the school’s aid, but the program stalled for lack of technical sophistication in-house, and inability to locate and pay for external support.

Teacher Portraits

Teacher Portrait: Kathi H. of Nixon High School. Kathi H.’s SQ experience changed her practices as a teacher, and contributed to her growth professionally. She revamped her curriculum, acquired new technical skills, was motivated to earn a Master’s degree and is currently working on her doctoral dissertation. Nixon High was rated “medium” overall, and the SQ program was judged to have school wide impact.

Nixon High School is located in the town of Nixon (population 8500). It is considered a “suburb” of Waco, Texas although it has the feel of a rural town. The major industry in Waco is a Chrysler Technology plant, along with some other smaller technology firms. There are approximately 570 students in the public high school (approximately 150 per high school grade). The school district is relatively poor. There are few students of color (85% white, 9% Hispanic, and 6% African-American), reported to be a limiting factor in obtaining state and federally funding. The school successfully retains students: the "drop-out" rate is less than 2%. There are 45 teachers (5 science and 5 math teachers) making for a 20-to-1, students/teacher ratio. The school spends approximately $3000 per student across the district. The principal reported that 85% of the students are involved in extra curricular activities. Seventy-one percent go to college. The school does not currently offer a computer science class. One was taught in the past, but too few students enrolled and the math teacher who taught the class left the school.

Kathi H. is a science teacher (biology and chemistry), and has been teaching for over 10 years in this public school. She has never taken a computer science course and does not consider herself a programmer, although she has taken workshops, such as 'Introduction to Hypercard.' Kathi is thus a self-taught computer user. Kathi was one of the first teachers from a "ordinary" public school to attend a SQ institute in 1992. She has since developed her novice computer skills, becoming an advanced computer-using teacher. She has also developed her science curriculum to include project-based experiments and computational science.

Kathi first heard of SuperQuest in a "little blurb" in a science teacher magazine. For a year she could not drum up student interest. The following year she encouraged a female student to participate; the student's father was involved in computers at a local university. They identified a list of other potential students who were "good in computers." They recruited three more students, including one boy who had programming knowledge. The group began to meet after school and during lunch to discuss possible projects. Kathi noted that the compelling reason for the adept programmer to join the group was the money and the challenge. They came up with the topic, Marching Band Array, by finding a common interest — they were all in band — and working on how to "make it science." They began by looking at band movements and Kathi began to see how physics could fit through movement philosophy, direction vectors, scalars. Each member of the group took on specific tasks, including science research, proposal writing and programming.

Kathi believes that SQ directly effected the winning SQ students in evolving their understanding of the relationship of computer science to both science and math. The winning year, four students (one team) applied to SQ. The following year interest spread, and 16 students (4 teams) in grades 9-12 developed projects on their own.

As a direct result of SQ, Kathi has also become a resource for other local schools and schools across the State, fielding questions from administrators and teachers regarding her technology setup, how she obtained the technology, and general issues regarding the technology.

The main impact of SQ at the school level has been access to the Internet. Kathi evaluates SQ success in three ways: (1) if the resources were still being used; (2) if they were being used in more than one place in the school; and (3) if the students that went to SQ were going on with “it” [technology resources], or if “they motivated other kids to do something with it.” She felt that her own and students’ experience was successful because she and her students since 1992 have had access to the SQ equipment, and that the students involved have moved on to college with a technical knowledge for their future studies.

Kathi has not seen enrollment to her science classes increase since SQ, but students are more often using computer science in their science projects. She attributes this to her growing knowledge of computational science which was sparked by SQ. She has noticed that increasing numbers of students are asking for Internet accounts. Approximately 30-40 students had accounts at the time of our visit, which she attributes to word-of-mouth within the school of the Internet access and increasing popularity of the Internet through mainstream media.

Kathi is developing a computational science curriculum and is seeking her State certification to teach the new course. She is also working on her doctoral dissertation. Kathi credits SQ for opening up a new field of study, as well as new experience as a professional:

> “It (SQ) has opened up a new area for me. The computer has been a resource within itself because I can go anywhere. I’ve done my dissertation research on the computer. It has also given me a link to the community. I have been able to do a lot more with computers and other people because I am able to help them and they are using me as a resource.”

Kathi’s science courses include project-based work, and she has created a bio-lab management class directly based on her SQ experiences - this includes computer bibliography work, hardware and software product reviews, cursory understanding computer languages, hypercard development, history of computer paper and assignments on the DEC or the Newton bbs.

Kathi would prefer student-teacher SQ institutes because it brought her “closer to her students, and helped her learn about many things.” Although she acknowledges she may have learned even more without the students, she strongly believes that the student-teacher interaction was an important factor to her inspired SQ experience.

Teacher Portrait: Kathleen G. of Coolidge High School. This high school participated in the 1992 summer institute. It was rated “high” overall, and there was evidence of SQ impact at the school level.

Coolidge High is a public high school located in Salt Lake City. The school has four grades and 1, 900 students enrolled. 26% of the students are minorities (12% Latino, 2.5% African American, 2% each Asian and Native American). There are some 200-250 computers distributed between 7 networked labs (math, writing, business, graphics, alternative, science and the computer labs). Six of the labs are linked to the Internet. Coolidge has over 200 Internet addresses. The school policy is that all computers are available for the students. There are 90 teachers on the faculty, 27 science and math teachers. Slightly over half of the teachers use computers in their teaching.

The principal has helped snowball the SQ win into new funds and partnerships for Coolidge High. Because of the fame of their SQ win and the strength of Coolidge High's computer base, they are often asked to be a "high school partner" with local/regional universities. The State is currently trying to boost the technology available in all schools and is putting in T1 lines. The initial plan is to put one line into each district in the State. In most cases, this has meant a connection to the district office. However, the District of Salt Lake City decided to capitalize on Coolidge High's current infrastructure and selected Coolidge to get the initial T1 line.

Kathleen G. has been teaching for 26 years. Her original educational training was in German and counseling. Today, she teaches programming, computational science and has written her own curriculum guide for a class on the Global Internet. Before SuperQuest, Kathleen was basically a programming teacher and her interest in SQ grew out of that. She had always used national, regional and local competitions as a motivational tool in her classes. In fact, the walls of her classroom are covered in plaques from the American Computer Science League competition.

The school applied for the original SQ contest in 1988 because she had one really qualified student, but their team did not win. Kathleen took the initiative to recruit students for the first application. She was persistent. They applied again in 1990 (no success), and then in 1992, when they won.

During the application stage in 1992, the team visited the supercomputer lab at University of Utah to get ideas from staff. Although the team's project proposal was not the topic the kids had pursued with the supercomputer people, the school had developed a very good relationship with University of Utah computer lab's staff. One of the school's SQ teams had also worked with a planner from the city's Department of Transportation on a project for timing the traffic lights. This *rapport* between the school and outside institutions (University of U, city officials etc.) greatly benefited the students.

Kathleen credits SQ with exposing her to the Internet and developing her technology skills. After the SQ Institute she returned to her high school not just to assist the SQ students with their SQ project, but to encourage other students, local teachers and professionals to use the Internet. Kathleen has achieved this by developing a class curriculum for the Internet, as well training her high school colleagues on use of the Internet. She has been involved with in-service technology training for her district and neighboring areas.

Often her students become technology/Internet trainers in their own right. At Coolidge High the students have been successfully incorporated in the school's technical support staff. The high school's technical coordinator (formerly a part-time consultant) employs student aides to help cover the school's technical needs. These aides are usually students who like computers but who do not yet have a strong knowledge of computers. Being an aide is a way for these students to learn about computers.

Kathleen has become somewhat of a local celebrity, speaking on local television about her Internet classes. Because of her appearance on a local television show, the Department of Health recruited her as a teacher for their employees. Kathleen now has a class of Health employees who come in after school to learn the Internet. She also sends one of her students to the Department of Health offices to train the managers and troubleshoot.

Kathleen credits SQ for have a positive and lasting impact on her career in education. She is especially grateful to SQ staff and facilities for enabling her to create high school science curriculum that use computer simulations to explain complicated science phenomena, and base course work on computer science experiments. She reported that her expectations for her students have grown after seeing the efforts of other students at the SQ Institutes.

Teacher Portrait: Jane J. of Buchanan High School. This high school participated in the summer institute in 1992. It was rated to be "medium" overall, and there was evidence of school wide impact.

Buchanan is a magnet public high school, located in Kentucky. There are 25 high schools that serve 92, 000 students throughout the district. 1700 students attend Buchanan; all students are considered gifted and talented in performing arts, math & science, or verbal/communications. Each year, over 1400 students apply to the school for 400 openings. Selections are based on the student's application and teachers references — test and grades are not part of the admission criteria. Currently, there are 450-470 kids in 9th & 10th grades, and 330 in the 12th grade; the school is increasing in size to respond the great demand for their programs. There are 86 teachers, with class ratios around 22-to-1. The magnet began in 1982 and provides a "strong, academic program" to its students. Remarkably, the annual expense per student is $1,800, and the school has a $4 million annual state-based budget.

The school is very involved in a multifaceted statewide reform. A Kentucky technology program, KETS (Kentucky Education Technology System), is attempting to put "every school on line, with district connection to Frankfurt (state capital)." This model was developed through the University of Kentucky, and has been implemented in 20-30% of the State schools. The hardware goal of KETS is to provide one computer for every 6 kids in every school building, with at least one computer in every classroom. The criteria for installation are based on the age of the school's equipment, size of building, and number of students per teacher. Since Buchanan had received substantial amount of federal support for the startup of the technology magnet, along with acquired hardware through grants and competitions, they currently do not fit the program criteria. Ironically, at the time of our visit there was insufficient funding to maintain and support the SQ equipment.

Buchanan HS won SQ in 1992 and attended Reed College. The principal feels that SQ was important because it was a national program, and because all expenses were paid by the program. The principal reported that the real value of SQ that it “is a wonderful experience for the student - an emphasis on academic, motivation to succeed, and affirmation to kids in the technology area.” She noted that it is valuable to teachers, as well. The principal noted that Buchanan is the professional development center in the district; many other schools admire the advanced technology. She said that the district often highlights the technology of their school by hosting school board meetings on site.

For Jane J., who has been teaching for 20 years, SQ had two impacts on her life and work. Jane graduated from college with a math and physics major and began her career in the science industry working on mainframes. In 1979, she began teaching Basic programming and computer literacy classes at a private school. She joined the Buchanan’s math, science and technology magnet program created in 1985.

During the SQ application process Jane was “unclear on the type of project that would be acceptable and the depth of investigation necessary” to produce a winning proposal. Once at the institute, Jane found that other teachers and technical consultants, along with her own students were the people most important to her work. She stated that the “interpersonal opportunities, hands on computer time, opportunity to ‘see’ a broader picture of what is going on, and extending programming skills” were for her the most positive aspects of the Institute. Like many teachers, Jane felt that the scientists were teaching over the heads of the high school students. She reported that her students were intimidated by them. Jane noted the value of being with her students but she thought that teachers “should have had more separate times.”

Beginning at the SQ institute, Jane realized that computational sciences hold great potential for high school learning. Noting that SQ was “one piece of many that was moving me to a project based curriculum in computer science.” Jane’s computer science curriculum now emphasizes project-based learning where students use modeling technologies. She incorporates Internet and networking concepts into all her classes. She does note that she still has not “tied project based curriculum to math and science to the depth” she would like. Jane strongly believes that SQ gave her “the nerve to have a class doing all kinds of different things.”

Jane reported problems on the technology-management front. While she reports she did well in helping students to become thoroughly involved in project research work, and in use of the Internet, she did not at first encourage students to be systems operators. She herself felt overwhelmed by the work required to keep the system running.

A theme that emerged during our site visits was how the teachers distributed the system operations tasks. There were roughly three models of systems operations: (1) teachers run the system, with or without some help from students; (2) students run the system, most often with support from teachers; and (3) school hires part- or full-time professional systems operator.

Buchanan is now an example of teachers running the computer system with significant student help. Students do certain operations tasks, like installing software, with several students serving as technical assistants. They draw their assistants from among the students with the least experience with computers. The technology teacher gave two reasons for this: these students have more to learn; and, they don't have enough technical knowledge to do a lot of damage to the system. Buchanan now sends some of these students to the District office as technical support to help keep the central system running. These are similar attitudes as Coolidge High in Salt Lake City and contrast to the approach of Eisenhower, Chicago. At Eisenhower, students have major control of the system; the faculty did not appear to fully understand the system.

Jane has come to realize that strict programming is not for all students. Some students excel in the other facets of computational science projects, like organization and structure, and work with visualization. The second change for Jane is professional. She has become a resource person for school, her district, and the state in questions of technology integration and Internet. At the time of the interview, Jane was considering leaving the school and moving to a State-level technology position.

Students

Many of SQ students who responded to the survey noted that they received awards either directly from SuperQuest or as a result of their SuperQuest experience. Fourteen respondents won awards in the Best Paper Contest (honorable mentions, first and second places). Fourteen students also reported applying to Westinghouse, and 9 reported placing as finalists or semi-finalists in that competition. (From our site visits we know of other students who also placed in Westinghouse.) The majority of these students' Westinghouse work was begun with their SuperQuest projects. In a personal interview, one student confessed that his Westinghouse paper (a semi-finalist) was actually the same paper he handed in to SuperQuest. Many of the SuperQuest students who completed the questionnaires were involved in local science fairs, and three students noted local computer science fairs. Seven students were involved in state competitions, four in regional competitions, four in national competitions, and four in international competitions (i.e., Science and Engineering Olympiad).

The students surveyed also considered that their involvement in SuperQuest was a big aid when it came to college admissions. Seven students credited their SuperQuest project in helping them receive scholarships to college, and three reported that their SuperQuest experience helped them with college admissions. Four students mentioned their current involvement in mentorship or internship programs as directly related to their SuperQuest work.

While many students have had “successful” academic stories, we felt it was important to profile a student whose educational choices were broadened by his SQ experience. Therefore, we briefly profile one individual student, because his story illustrates additional aspects of success for students.

A Student Portrait: Aaron. Aaron was a 1992 SQ participant from a high school in San Diego. He attended Reed College for the SuperQuest Institute. He is now enrolled in Reed College as an undergraduate, where we interviewed him.

Aaron learned of the SQ program during a computer class, taught by a science teacher. He had participated in the Science Olympiad and decided to join a group applying to SQ. Their team developed individual project proposals. Aaron’s project was a computer music composition, a project he called “The Computer Composer.” The group of four boys came together because they were close friends and had all worked on science fair projects. This technology-savvy group of students had also written a five-year technology plan for the school. Aaron reported that he selected the project topic and completed the proposal with little teacher assistance.

Aaron was surprised the team won, and he recalls that he did not have any particular expectations for the institute. He enjoyed the Reed Institute, particularly the Institute staff’s perspective on technology. That is, during his high school studies, prior to SQ, Aaron expected to be “ a big computer science programmer.” But he realized at Reed that the equipment was somewhat “off to the side”, actually, and that there were other things to do beside computing. However, the people at the institute whom he recalls as most important to his work were the technical consultants, who manned the computer labs, assisting students with their programming and Internet research efforts.

After the institute, Aaron became quickly frustrated when the DEC station arrived in the teacher’s classroom, but the teacher let the box sit un-opened. After pressing his teacher for several weeks, Aaron set up the hardware and installed the software himself. For several months, Aaron stated that he was the only student using the DEC in the school. Eventually, a handful students learned of the workstation and asked Aaron to use it.

Thus, Aaron did not support the idea of designing SQ as a teacher-only institutes because, “during the 3 week workshop, the kids are doing things and the teachers are doing things. Back at school, the kids are running the technology.” In fact, Aaron reported that he did not complete a paper for the SuperQuest Best Paper because he was involved in developing his high school’s technology plan. Two other SQ students, however, did complete their Best Paper, with one of those students placing third in the SQ competition.

Aaron noted that SQ afforded him an opportunity that he would not have gotten in any other high school activity. Some of the most positive aspects of his SQ experience were “making new friends with complete strangers, living in a dorm, working with UNIX and the net rather than just playing with it, and being exposed to new things." The strength of SQ according to Aaron, "it puts computing in a more academic light."

Aaron reported that he changed career goals, hence his educational path, based on his SQ experience. As a result of the institute, he realized that he did not want to pursue "the life of a programmer", and that "there was more to education than programming classes". The institute experience alerted him to the fact that computational science was most exciting for him as a tool for solving problems in other fields. He has thus broadened his interests and educational choices, choosing a liberal arts institution and broadening the range of courses he selects. Aaron is a technical assistant in a lab at college, and he has stayed connected to technology in his work at Reed. He sees it now, however, embedded in other kinds of questions.

SQ Institutes: Summary of Interviews with Institute Staff

Members of the Institutes that sponsored the summer workshops were interviewed during site visits. Several themes emerged in these data from the Institutes' perspectives about the design of the SQ program:

In general, the Institute staff members perceived teachers to be more "intimidated" by the technology than the students. While there was a range of teacher expertise represented across institutes, teachers' apprehensions should be considered more fully in the design of the program.

Staff members reported that the assignment of teams to particular institutes was done centrally, and relatively late in the process. They felt earlier assignment, and some involvement in the selection process, would enable them to be better prepared for the projects they were going to have to support. This could help them to better select and assign appropriate mentors, and to be alert to the particular knowledge and talents students bring (e.g. which programming languages they knew, and the like).

There was often misalignment of expectations on both mentors' and students' parts. For example, some mentors expected that the students would contact them after the institute, but they did not do so. And, students were upset that mentors did not contact them. This is an understandable confusion, based on the different cultures of high schools and research universities. In high schools, students are accustomed to teachers who initiate contact and elicit information from them. At universities, faculty are more accustomed to student initiated contact. A further difficulty emerged in establishing on-line relationships. SQ was the first exposure to Internet for most students, and they knew little of the social conventions of this medium. Likewise, while faculty were often experienced Internet users, it was most commonly used to communicate with professional colleagues. They knew little of the role of on-line mentor to high school students. The mentors and students also often had relatively infrequent contact at the institute itself.

Mentors often suggested that the scientific aspects of the institute experience should be emphasized more than the technical supercomputing topics. In addition, some mentors believed that it was important to expose students to material that was “over their heads, ” but that “you must bridge the gap between complexity and understanding.” Some of the faculty were concerned that the SQ projects were described as “research”, since few actually explored new territory. As a response to this concern, the name for the activities was changed to “investigations.”

Many of the mentors were especially motivated to work with high school students, and less so to work with teachers. Some felt that skills other than academic ones were required to work with the young people, and would appreciate coaching in this regard.

There were some diverging experiences across the different institutes. Among them: NCSA and UAH experienced a lack of in-depth teacher involvement, and evolved toward a model program that focused on teachers only. They also perceived this approach to be more cost effective in that it could reach more people. The Theory Center and Reed experienced the same kinds of issues with teachers, but strongly felt is was important retain the student/teacher program, with special teacher-only workshops during the institute. They perceived that the students play key motivating and training roles upon their return to the schools.

From teachers’ perspectives on the institutes, there were relatively few complaints. Many focused on the technology and follow-up support. Many teachers wanted to have more hands-on experience with the actual equipment they were to receive at their schools. Reed College developed a process of having teachers setup the actual computer they were to receive at the institute, and then shipping it to the school at the end of the institute. Most students and teachers experienced some minor technical problems, in most cases a phone call was enough to right them, but in some cases there was some difficulty getting a person at the Centers to respond.

Many teachers remarked that now that they are trying to implement group projects, they needed a better understanding of group dynamics, goal setting, and assessment.

While many teachers reported they enjoyed the time with their students outside of high school setting, several stated that they spent too much time chaperoning their students. However, the most productive teams seemed to have the most involved teachers. Many teachers thought that the college scientist/faculty had to learn about the cognitive and social lives of high school students, so they could teach classes on a more appropriate level.

In attempting to integrate “ordinary” students into a highly competitive contest/ institute, some of the magnet students felt slighted. The institutes had to accommodate a range of experience and expertise, and sometimes expert students felt their level of skill was not being acknowledged. However, the less academically expert students often seemed to bring a more normalized, less competitive, social environment to the institute. As one Reed staff member said:

" they are just high school kids — they are not any more exceptional than a bright college student."

There was interest among teachers and students to "stay in touch, " in fact several students sent us requests for e-mail addresses of other students who attended their institute.

Summary and Recommendations

The experience of the SuperQuest program was remarkably positive for many of the schools, teachers, and students involved. Examining the data gathered from 50% of participating teachers between 1988 and 1994 who represent 30 of the 42 sites, from 35% of the SQ students during this time period, and from close examination of the success and mediating factors in 14 of the schools, it is apparent that SQ had a substantial impact for many of them. Several factors appear to be related to success. There were also critical circumstances that appear related to lack of success, and several noteworthy issues that lead to recommendations for modification in program design.

Among the factors that appear to be associated with success:
As with other innovations in education, a supportive school administration is key. Positive support is most welcome, but at a minimum passive support that permits teachers to define programs and experiment with changes is needed. The schools who did not enjoy at least this level of support from the administration in our case analyses were not successful. In addition, administrative or school-wide recognition of the winning students was perceived by many to be a powerful incentive for academic efforts of this sort.

Adequate technical support is also key. Successful schools were able to arrange the needed support either locally or through university connections. Lack of timely and cost effective technical support was the key reason why some of the schools were not successful after the institute experience. In a number of cases, students played major technical support roles. For many, SQ provided the first, and early, contact for the school and students with the Internet. This aspect of the SQ technology appeared to have especially valuable repercussions in many cases, helping the students and their projects, helping the teachers and their professional expertise, and helping the schools to be local leaders in early experiments with connectivity.

With respect to teachers, qualities of innovation and experimentation appeared to be more important than the particular technical or disciplinary experience that teachers brought to SQ. Many of the teachers at the successful schools were innovators, involved in new approaches to curriculum or in school reform. None of the teachers in the three schools judged to be "low" overall were innovators. It is not surprising that these innovators were the teachers who initiated or could be recruited to a program such as this. While lack of technical or scientific sophistication at the outset for some could cause them to feel daunted at the institute itself, this did not appear to especially hinder school success.

Student involvement and initiative both before and after the institutes was critical in some but not all successful schools. Students pressed busy teachers to set up equipment and continue SQ activity in the majority of schools after the institute. Students also played key technical support and training roles in the majority of schools. Students took on the most advanced roles more often in schools judged "medium" and "low" overall than in the "high" performing schools. While student involvement in these ways appears important from all perspectives, and in relation to outcomes, it did not guarantee that SQ had impact overall.

An interesting finding is that students that attend the institute at the age of 16, appear to contact and engage with scientists before and during the institute more frequently than students younger or older. Since older students were most likely newly graduated seniors, their engagement may have been limited due to conflicting academic and social obligations. Whereas, younger students may not have achieved the social maturity to effectively engage with scientists.

Institute mentors appeared to play relatively minor roles in the program. In many cases, there was relatively little contact with mentors either during or after the institute. However, it is interesting to note that appropriately matched mentors for project subject matter, and adequate to positive relationships with mentors, are associated with school success. None of the low performing schools had appropriate mentors, and all these schools report negative relationships. While it is not clear that this misalignment can be attributed to the program or to the mentors or both, this is a part of the SQ program that might be given closer scrutiny and redesign. Probably the most successful case of SQ mentoring we encountered involved local mentors who provided guidance from initial problem selection through publication of an original scientific paper.

In addition, schools that already had a tradition of requiring and supporting students' research work in science and mathematics, and a tradition of succeeding in academic competitions, were more likely to absorb the SQ program easily and well. It required less administrative support and teacher effort to add this program to an already existing competition-structure than it did for other schools to launch this way of doing things anew. The experienced schools also generally saw SQ as a traditional science contest, and as a way to promote individual merit-based achievement. This made it harder for them to field group projects, and to use it as a way to improve the school program overall.

For schools who were not steeped in the tradition of science contests, SQ could function as a way to distinguish themselves in their communities, to experiment with technologies, and/or as a means to improve their programs overall. The tension between science contest/individual merit and overall school goals could also backfire, as it did in the case of one school who saw no reason to continue to support a program that was perceived to reach only a handful of "elite students".

Finally, while the contest motivation was primary for some, leading them naturally to complete their project papers, for others it was a less critical goal. Compared with the perceptions of SQ staff, teachers and students perceived the completion rate to be quite high. It is likely that they mingled their perceptions of winning a slot at the institute with successful completion of the final project back at the school, or completing but not submitting the project to the contest. The SQ schedule did not always work, especially as many of the students participating in the summer institutes returned to their schools as seniors. They were often swamped by competing demands of college applications, both large work loads and less academic pressures because college acceptance does not rely on senior year performance, and the spring social whirl of the high school senior. The two year time frame from beginning the application to completing the project is also a new kind of commitment for many students ("wow — two years, that's one eighth of my life!"). For some, completion of group projects was challenging if the group dynamics were difficult or if some members lost interest. Thus, while extending the completion of projects was seen as a solution to the length and heavy competition of the initial SQ institute, this solution raises its own design challenges.

The overall best experiences were had by teachers and students who set goals for their SQ experiences. For teachers, this might include wanting to get their students into group projects or to reinvigorate their science curriculum. For students, goals could be somewhat fuzzier, yet equally important, such as having access to a supercomputer, meeting graduate students and other "smart" high school students, going to a college campus - hanging out!

Recommendations and Design Implications

Based on these analysis, we suggest some design implications for SQ and similar projects.

1. The SQ program is somewhat unusual in that both teachers and students were sponsored to attend the institutes. While teacher-only institutes would be more cost effective in reaching more teachers, there is evidence that the involvement of students in this program was important for its stability and spread back at the schools. Students often provided the initiative and energy to launch the technology-enhanced program, and they also served in the very key technical and training roles. Some teachers felt that it was the students who motivated them. It is unclear whether the program work would have been sustained in many places if busy teachers had to carry the full burden. The technical training of students-as-workers appeared to be a side benefit of the institutes. This aspect of the program — students' responsibilities at the school as a result of the investment made in them — might be foregrounded as part of the program.

2. That said, the institutes' programs for teachers should be refined. While it is important for the teachers to work with the students on their projects, given the varying levels of teacher expertise, it also appears important to design a teacher-only component of the institute experience. Among other things, it should include system

operations, how to organize technical support, curriculum development, and on-line community building.

3. Schools must be made technically-able quickly following the institute. There is some advantage to providing connectivity even before the teams arrive at the institute. Slow technology arrival or faulty machines or connectivity saps motivation for project continuation quickly.

4. Rethink the “mentor” role. It would be advantageous to more closely match mentors with expertise needed for student projects. If possible, it would also be useful to match the mentors and teams on dimensions of work style and interests. Plumbing research on effective academic mentoring might be helpful in this regard, to refine selection and questioning that might aid the matching process. Mentors also require some training, preparing them to deal both cognitively and interactionally with high school students. Many felt that the students should not be thought of as apprentices to the work of the mentors, but that mentors needed to act as guides to students, focusing and providing design constraints for their projects. Mentors, students, and teachers should also receive training — perhaps together — in conducting on-line relationships after the institute.

5. Incorporate the labs into the decision-making process for assigning winning teams to institutes. This would insure a better match between teams and institutions, would allow better preparation on the part of the institutes, and would give them a further “stake” in the success of the teams they find most compatible. The main issue is that program planners, center directors, and selected staff should increase communications. This could be facilitated by allocating funds for the facilitate center directors to meet, face-to-face, at least once a year.

6. Facilitate an on-line community of SQ teachers. Such a community could include past winners, and could provide support, guidance, tools to teachers new to the program.

7. There was some difficulty getting girls involved in the program. The institute staff members did not know what to do about this. Teachers generally didn’t know either, and some conjectured it was the responsibility of the family to support the girls in science. Two exceptions were Hoover and Eisenhower, where male teachers recruited girls and worked to keep them involved. Attention should be given to this issue, and we suspect, recruiting minority students as well. Application materials might contain encouragement and guidelines about this, perhaps pointing teachers to information and training concerning diversity and science.

Endnotes

[1] Cornell Theory Center, National Center for Supercomputing Applications, University of Alabama in Huntsville/Alabama Supercomputer Network, Reed College,and Sandia National Laboratories.

[2] The names of the schools have been changed for confidentiality purposes.

[3] IBM and Digital Corporation were major hardware contributors to the SQ program.

[4] The figure is based on 1992-93 estimates.

[5] These number is the percent of high school sophomores who plan to attend college after high school.

[6] 42 teachers responded to the question on positive aspects of the Institute; 24 teachers responded to the question about negative aspects.

[7] Some of the none-participating SQ universities provided Internet connections gratis.

[8] We coded a positive paper submission if there was one instance, either individual student or a team of students, from a school having submitted a paper.

[9] Arnold et al (1994). “Tabulating Alternating Knots Through 14 Crossings” in The Journal of Knot Theory and Its Ramifications (JKTR), Vol. 3, No. 4, December, 1994 [ISSN:0218-2165]). pp. 433-437.

[10] CoVis is a collaboration between the school and a National Science Foundation sponsored project at Northwestern. The CoVis project is a research and development project that, among other things, provides earth science classes with computer-supported inquiry tools, scientific visualization tools, connecting the students to current weather data and to experts around the country through high speed lines and experimental software. The SQ project and the CoVis project had little apparent connection technically, substantively, or socially at Eisenhower.