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ABSTRACT

This report is the third of three volumes describing the results of the evaluation of the National Science Foundation (NSF) Local Course Improvement (LOCI) program. This volume describes 12 project case studies undertaken as part of that evaluation. Three projects were designed to increase individualization of college science teaching; two involved applications of computing aids in teaching; four involved the design of laboratory materials with two of these being inquiry; and three were attempts to update the content of science courses. The projects chosen for the case studies were determined in two different ways. Two projects were chosen on the basis of reporting successful outcomes. The remaining 10 projects were chosen without knowledge of the outcomes from over 100 projects to represent types of settings (universities, four-year colleges, and two-year colleges) and academic backgrounds for the project directors. These were chosen at random after being categorized by school and program. The case studies represent a synthesis of on-site visits and study for the project proposals, reports, and materials. (GS)

Evaluation of the National Science Foundation's Local Course Improvement Program

Volume III

Case Studies

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Chapter 1

Introduction

This report describes 12 case studies undertaken as part of a comprehensive evaluation of NSF's Local Course Improvement (LOCI) program. The report is the third in a three-volume set describing results of the evaluation. The first volume presented an overview of the evaluation and provides a summary of all project results. The second volume described detailed findings from quantitative analyses carried out as part of the project.

LOCI is one of a number of programs through which NSF's Division of Science Education Resources Improvement provides support to strengthen the capabilities of schools, colleges, and universities for science education and research training. LOCI helps colleges and universities improve their science instructional efforts at the level of individual courses or small groups of courses. The program provides up to two-thirds of the total cost of a project for maximums of $25,000 and two years. In 1976 LOCI received 169 proposals and funded 66, with an average award of $13,600. In 1977 the program received 750 proposals and funded 129, with an average award of $17,000. In 1978 it received 453 proposals and funded 135, with an average award of $16,700.

In July 1977 NSF requested proposals from educational institutions and research centers for the evaluation of its LOCI program. The request for proposals specified a project that would answer questions in several areas:

1) Need for support for local course improvement--What evidence exists that institutions need outside assistance to keep up with currently important scientific and instructional developments? How do needs differ in different types of institutions and in different scientific fields?

2) Response to LOCI--Do applicants for awards represent the full range of institutions and scientific fields? Are proposals and funded projects consistent with established needs for instructional improvement?

3) Outcomes of LOCI program--To what extent do projects achieve their objectives? Which sorts of objectives are most often achieved? What factors within projects contribute to their success? What are the most promising practices that have been developed in LOCI projects?

4) Program rationale--Are program guidelines and restrictions reasonable? Are level of support, degree of structure, and time allotted adequate? What other alternatives are there?

On the basis of our response to this request for proposals, we received a preliminary award to plan an evaluation of the LOCI program in September 1977. On the basis of the plan we submitted in January 1978, we received an award to carry out a comprehensive evaluation. The project was carried out in the period of September 1978 through March 1980.

To answer the questions posed by NSF, we collected data using several different methods with several different populations. To draw conclusions about the need for local course improvement, for example, we contacted a representative sample from the total population of teachers of undergraduate science and engineering. To determine whether the existing LOCI program was responsive to perceived needs, we used NSF documents to construct profiles of proposers and of award recipients, and we compared these to a national profile of college science teachers and to the picture of needs developed in the first part of the project. To determine whether program guidelines were appropriate, we read, classified, and analyzed proposals funded by NSF during the years 1976 through 1978. To evaluate outcomes of LOCI projects, we analyzed questionnaire responses and final reports from directors of completed projects. We also made site visits to a representative sample of these projects.

This volume presents only the results from the case studies. Chapter 2 describes results from three projects designed to increase individualization of college science teaching. Chapter 3 presents results from two applications of computing aids in teaching. Chapter 4 describes two projects that designed inquiry materials for laboratory instruction, and chapter 5 describes two projects on other laboratory materials. Finally, chapter 6 presents results from three attempts to revise or update the content of science courses.

We chose to visit the 12 sites described in this volume in two different ways. After reading final reports on approximately 70 projects, we chose two sites that had successful outcomes for our first visits. We wanted to be sure that such successful projects were well represented in the case studies. The remaining ten projects were chosen without knowledge of results from a hundred or so projects that were completed by December 1978. We selected the ten projects to represent different types of settings (i.e., universities, four-year colleges, and two-year colleges) with project directors of different academic backgrounds (i.e., tenured and untenured). Projects were selected at random within these categories.

Visits to the projects were made either by the evaluation director James Kulik or by project senior research associate Cynthia Luna or by both. Kulik made four visits alone; Luna made three alone; they made five site visits as a pair. On one of the five visits, they were accompanied by Frances Lawrenz, a member of the advisory panel for the LOCI evaluation. The visits were typically one full day in length, and they were made between the months of October 1979 and January 1980.

A typical visit included a one- to two-hour discussion with the project director; meetings with other available project staff members; a meeting with either a department chairperson or dean to discuss project effects on the institution; and meetings with faculty colleagues who may have been affected either directly or indirectly by a project. When possible, we also visited classes or facilities affected by the LOCI project. Finally, we collected any available project documents and written materials on project settings.

The case studies that are presented in this volume reflect not only our visits to the sites but also our reading of project documents and materials. Before and after our visits, we studied proposals, reports, and project materials. The case studies that follow represent our effort to synthesize a variety of materials and impressions into 12 succinct sketches.

Chapter 2

Individualizing Instruction

More than half of all projects receiving LOCI funding were designed to revise teaching methods in college science courses. A substantial number of these projects on teaching methodology were meant to individualize teaching--to adapt instruction to the backgrounds and aptitudes of individual learners. Most of the individualized systems of instruction used in the projects were mastery-oriented and self-paced, and they relied heavily on instructional materials.

In this chapter we describe three of these projects on individualized teaching. In the first project a teacher of astronomy used Keller's Personalized System of Instruction (PSI) in a sequence of upper-level courses for majors. In the second project a physics teacher developed individualized materials so that he could offer several different low-enrollment science classes at the same time. In the third project a community college teacher developed instructional materials that individualized both content and rate of learning for students in his classes.

A PSI Course Sequence in Astronomy

The site for the PSI project in astronomy was a large state university in the Southwest. Founded as a state normal school before the turn of the century, the institution is today the state's major research university as well as its major institution of public higher education. It occupies a 600-acre campus with more than 120 buildings in a metropolitan area of 400,000, and is composed academically of nine undergraduate schools and colleges, a graduate school, a school of law, and a school of medicine. Its mission is to serve the citizens of the state by offering a well-rounded education at the higher level.

The university had a recent enrollment of more than 17,500 undergraduates and approximately 3000 graduate students, 300 medical students, and 300 law students. This enrollment was nearly equal to the combined total enrollment in the state's six other public colleges and universities. About 90% of the undergraduates were residents of the state, and almost 90% of the undergraduates lived off-campus. Admission to the school was not very competitive; recently the university accepted 96% of those who applied. By the end of the freshman year, 30% drop out; between 30% and 35% remain to graduate; and about 35% of these go on to graduate school.

The full-time faculty recently numbered approximately 750 (excluding medical school), and the student-teacher ratio was 21 to 1. All faculty members reportedly held doctorates, and salaries for professors were at the national average. The university has no formal instructional or faculty development center now, but is beginning to investigate the possibility of establishing a formal program. Released time for instructional development projects is occasionally available. Faculty members apply directly to department chairpersons, and requests must be approved at the dean's level. Summer stipends for faculty have been available for many years, but these are for research rather than instructional development projects. The university administrators we talked to reported having the most difficulty providing equipment and materials for course improvement projects. Even here, however, the university's provost has occasionally been able to use discretionary funds to help individual faculty members.

The director of the PSI project in astronomy is a member of a seventeen-person department of physics and astronomy. Teaching load in the department is usually nine contact-hours per week. The department has offered the Ph.D. in physics since 1948, and the number of graduate students in physics recently numbered 56. The university does not have a separate graduate program in astronomy, and has only two full-time equivalent faculty positions in this area.

Background of the Project

The project director has had a long-standing interest in methods of science teaching. While pursuing his graduate degree in astronomy during the early 70's, he began taking courses in education to deepen his knowledge of teaching methods. One of the new approaches he learned about was Keller's Personalized System of Instruction. This method's emphasis on one-to-one interaction between a teacher and a learner seemed especially attractive to him. After attending a week-long workshop at the Massachusetts Institute of Technology in 1972 to learn more about PSI, he received support from the President's Fund for Innovation at his institution to implement this teaching method in two lower-division courses. The courses he designed were among the first astronomy courses given by PSI in this country. He developed the materials, measured outcomes, and wrote and published several papers on his work while still a graduate student.

His interests in teaching did not abate with receipt of the Ph.D. and acceptance of a position as assistant professor in 1975. In this new post, he wrote an introductory astronomy textbook, now going into its third edition. He continued to seek out opportunities to learn more about teaching, and took, for example, a course on "Professor as Teacher" given by the assistant provost at his institution. And he made every effort to continue the work on PSI that he began as a graduate student.

The teaching challenges he faced at his new university, however, were different from those he faced earlier. As a graduate student, the project director taught courses in astronomy for non-majors at one of the most selective undergraduate schools in the country. As a faculty member, the project director was responsible for teaching courses for science concentrators at a school with a wide range of students. Because his new department had only two full-time faculty members in astronomy and lacked large research programs in this area, role models were few for these majors in astronomy. But the project director decided that PSI could also help him in this new situation.

To develop a PSI course, a faculty member has a number of things to do: selection of appropriate materials for 10 to 15 units of instruction, development of study guides for these units, construction of quizzes, and revision and rerevision of materials. All these things take time, and they require supplies and materials. In 1976 therefore the project director decided to get outside help in order to introduce PSI courses in astronomy at his new institution. He prepared a proposal for the LOCI program to develop a year-long PSI sequence in astronomy at the junior-senior level. The proposal

requested approximately $10,600 from the National Science Foundation. The money was to be used largely for summer salary (two months of full-time salary for two years). A small amount of money was to be used for travel, supplies, and consultants. The proposed duration of the project was 15 months.

Project Goals

Among the project director's concerns about upper-level astronomy courses were these three: who was learning the material, how were they learning, and what were they learning. Students came to the project director's upper-level courses with a wide range of backgrounds. Some students did not have adequate preparation in mathematics and physics. The project director wanted all of his students to learn astronomy, not just those who were well-prepared for work in astronomy. He also wanted these students to learn in the way that astronomers learned--not by being told but by finding out. For the project director, the lecture classroom encouraged passivity. Informal PSI classrooms were more like astronomy labs. Individuals discussed matters on a one-to-one basis, and teachers and tutors admitted their ignorance when they were unable to answer questions students asked. And finally, the project director wanted his students to see the new vision of the universe that astronomy was providing. He thought that astronomy departments, especially when they had only a few faculty members, often failed to communicate to student majors the excitement of the field.

The project director's specific goals for his astronomy sequence therefore included:

a) to devise teaching methods and materials that would be appropriate for the wide range of students he found in his classes;

b) to make the activities of the students learning astronomy more similar to the actual activities of astronomers at work;

c) to incorporate new advances in astronomy into his courses.

In accomplishing these objectives, he hoped to create courses that would serve as working models that might encourage others at the institution to restructure their courses.

Project Activities

The two courses to be redesigned with LOCI funding formed a sequence. The first course in the sequence was The Solar System; the second was Stars and Galaxies. These two courses were fairly new to the curriculum at the project director's institution. First offered in 1974-75, they were taught by the project director in 1975-76 in a conventional teaching format. The courses were usually taken by juniors and seniors--ten to fifteen in each course each term--and they were required for the major in astrophysics.

The project was to be carried out in three major phases. The first phase was to occur during two summer months of 1976. During this time, the project director intended to define objectives, write unit study guides covering these objectives, and construct unit tests. The second phase was to cover the 1976-77 academic year when the project director intended to teach the two courses using the PSI materials. During the third phase, which was scheduled for summer of 1977, the project director intended to revise the course materials in light of student evaluations made during the academic year.

The project moved along on schedule and with no major deviation from the project director's plans. During the summer of 1976 the project director developed PSI materials for the two courses. During the academic year, he used the materials when he offered the two courses. The courses operated in typical PSI fashion. About 15 students initially signed up for the sequence. Students were sophomores, juniors, and seniors, and their backgrounds were mixed. About half had the expected math and physics background, but about half did not. During the third phase of the project, the project director undertook the revision of the course. The most serious problem he encountered was one he had not anticipated. The tests constructed during the summer took too long to complete. Revision of unit tests therefore became a major task during the third phase of the project.

Project Effects and Evaluation

In his proposal to the LOCI program, the project director described two instruments that he intended to use to evaluate the effects of his work. One was a questionnaire on PSI that he had developed earlier for use in research on lower-level courses in astronomy. The other was a general instrument for evaluation of teaching available through his present institution's office of institutional research.

For the past three years the project director has collected results from his PSI courses using these two evaluation forms. First, he collected data on the university's course evaluation questionnaire. For the sake of comparison, he presented results from the PSI sequence alongside results from the sequence before he revised the teaching method. Ratings for this astronomy sequence were quite favorable in both PSI and non-PSI formats. Students reported that they gained factual knowledge, mastered principles, mastered the discipline's methods, developed problem-solving skills, and would like the instructor for another course. The ratings for the revised course, however, were consistently higher than ratings for the non-PSI course.

The project director also collected student responses on the specially designed questionnaire. Since items on this questionnaire applied only to PSI instruction, the project director was unable to use this questionnaire in his conventional courses. For the sake of comparison, therefore, he presented results achieved in the sequence for majors alongside results achieved in earlier PSI courses he designed for non-science majors. Responses on this questionnaire were very favorable in both the sequence for majors and in the course for non-majors. But generally the responses of majors were more favorable to PSI.

On our site visit, we talked to students who had just completed the first course in this sequence, The Solar System. Their impressions of the course were uniformly favorable. The students liked the lack of pressure and the opportunity for one-on-one interaction with a teacher. The students also pointed out that the workload in the course was very heavy--about twice as much as in other courses. One student commented, and others agreed, that the teacher was important for the success of the course. He pointed out that the project director was always available and was interested in the work of each student. The student said that he could imagine this method being far less successful in the hands of other teachers. The only negative thing that the students said about the format was that it provided only limited opportunities for hearing the project director lecture. They said that this was somewhat unfortunate because they considered the project director to be a stimulating and effective lecturer.

The project director also compared dropout rates in PSI and non-PSI versions of the course, and found no difference. He also noticed no difference in course enrollments in PSI and non-PSI versions of the course or in grade distributions. He was not able to make formal achievement comparisons. The course sequence that he revised was newly introduced at the institution so there was no tradition of examinations to build on. The project director estimated that the cost of teaching the course sequence by PSI might be about 20% higher than the cost of teaching by conventional methods. The main reason for the higher cost was the large amount of time spent with students.

At conferences and meetings, the project director told other instructors at other institutions about his PSI work. A number of these instructors requested copies of the materials for examination, and several adopted the materials for use at their institutions. Although pleased about this off-campus use of his work, the project director was somewhat disappointed that his work has not had more effect within his own institution. Colleagues within his own department have not used his methods and materials, and he has had only small successes so far in convincing others outside his department to experiment with mastery-oriented teaching.

Single Instructor Multi-Level Instruction

The project on single instructor multi-level instruction took place at a nonsectarian Christian liberal arts college with a student body of approximately 1500, divided almost equally between men and women. Founded in the middle of the nineteenth century as a college for women in a small Midwestern town, the institution moved at the turn of the century to its present rural setting. Today the college occupies a 240-acre campus that includes an eight-acre lake and a woods. Nearly half of the buildings at the college have been constructed in the past five years. Although the physical campus has changed over the years, the college's commitment to evangelical Christianity has remained firm. All students, regardless of religious affiliation, are expected to attend chapel services three times a week. Community expectations include abstention from use of tobacco, alcoholic beverages, profane language, and from dancing and gambling.

About one-third of the students at the college are residents of the state, the rest are from out-of-state. About 80% of the students live in residence halls on campus. They pay approximately $4200 a year for tuition and fees, room and board, and books and supplies. Admission to the school is competitive. Recently, the college received 733 applications, accepted 640, and enrolled 452 freshmen. Entering freshmen averaged 460 on the verbal section of the Scholastic Aptitude Test and 496 on the mathematics section. At the end of the freshman year, 5% drop out; 65% remain to graduate; and about 50% of the graduates go on to graduate or professional school.

The student-teacher ratio on the campus is 17 to 1. Over 52% of the faculty members hold doctorates; and salaries for these faculty members are at the national average. The college supports the teaching improvement efforts of its faculty in a number of ways. At the request of a faculty member, for example, the dean of instruction will provide released time during the January inter-term for development of a new course, new course materials, or for other faculty development activities. A program supported by a two-year grant from the Lilly Foundation also encourages faculty development activities. During the summer of 1979, this grant provided stipends of between $500 and $1000 to about 10 faculty members to work on instructional projects. The Lilly grant also provided funds for a three-day conference on teaching held before the start of fall classes for faculty at the college. Called the Colleagues College, the conference featured mini-courses on teaching methods, on issues in teaching, and on course content.

The college has developed a sophisticated course evaluation system through which faculty members collect student reactions to their teaching, interpret evaluation results, and plan strategies for improvement. Faculty members first devise their own student course evaluation forms using a catalog of items similar to the ones in Purdue University's cafeteria system (Seibert, 1979) or The University of Michigan's Instructor-Designed Questionnaire (Kulik, 1976). Forms are computer-generated, and student responses on the forms are also tabulated by computer. Assistance in interpretation of results is available from the chairperson of the psychology department, who serves as the college's consultant on evaluation. In addition to helping individuals interpret evaluation results, the psychology department chairperson also offers training sessions for other department chairpersons on interpretation of evaluation results.

Background

The project director is presently chairman of the chemistry department at the college. When he developed his proposal for LOCI funding, his position was professor of chemistry. A graduate of the college himself, he became a member of the faculty after receiving his Ph.D. in 1966. In addition to teaching in the chemistry department, the project director holds joint appointments in the departments of physics and information sciences.

The science departments at the college are generally small in size. Chemistry is a three-person department; physics also has three department members. In 1975 when the project director prepared his LOCI proposal, only four or five students were graduating each year with a degree in chemistry, and only two or three students a year graduated with a major in physics. Good science facilities have been available at the college, however, since the completion of a science center in 1968. The science center consists of a rectangular four-level structure, a lecture-room complex, and a solarium-animal wing. The building houses the departments of chemistry, physics, mathematics, biology, and information systems.

In 1975 the project director was concerned about the future of three of the courses he taught: a physics course (Introduction to Electronics); a chemistry course (Scientific Instrumentation); and a course in information systems (Mini-computers). The three courses were upper-division courses that used expensive equipment. Each required a heavy investment of time from a teacher, who had to supervise laboratories and the use of equipment. Although the three courses were important elements in science programs at the college, each served a very small number of majors each year. Introduction to Electronics, for example, was offered four times between 1970 and 1975. This course had enrollments of three in 1970, five in 1971, four in 1972, and three in 1973.

The project director felt that these courses could serve larger numbers of students if they were offered at several different levels at the same time. Introduction to Electronics, for example, might appeal to medical technology students in addition to its more traditional clientele of chemistry and physics majors; Mini-computers might attract students majoring in chemistry and physics as well as its more traditional audience of students in mathematics, computer science, and business; Scientific Instrumentation might appeal to premedical students with a variety of majors and backgrounds. To serve the varying backgrounds, abilities, and interests of students, the project director proposed what he called Single Instructor Multi-Level Instruction for Low Enrollment Courses (SIMILEC). This approach was meant to enable a single instructor to offer simultaneously several sections of a course directed toward different audiences.

SIMILEC was to use educational techniques similar to those used by Keller and his colleagues in their Personalized System of Instruction (PSI). Keller and his associates originally used their method with lower-division courses with fairly large enrollments, but by the mid-seventies PSI had been adapted to a wide variety of areas and teaching situations, and the project director began to wonder about its applicability to courses with very small enrollments. He finally concluded that techniques such as those used in PSI might enable a single instructor to offer two or more small enrollment courses in the same place at the same time without overloading the instructor or impairing the overall effectiveness of his or her teaching. There was nothing novel about students working in the same college classroom on different units of material. Keller and others had shown many times that this could be done. But in Keller's classes all students were working through material that was part of the same sequence. What the project director wanted to demonstrate was that different students could work on different sequences of course material in a single classroom at the same time under the direction of a single teacher.

The project director requested $20,600 from the LOCI program to implement his ideas about single instructor multi-level instruction. Staff members for the SIMILEC project were to include the project director, another faculty member from chemistry, two faculty members from physics, and one from the biology department. Most of the NSF funds were to be used for full or partial summer salaries for these faculty members. A small part of the NSF money was to go for laboratory and instructional materials. As its contribution to the project, the institution waived all indirect costs and provided secretarial support for the project. The project director proposed a 15-month duration for the project--from July 1976 through September 1977.

Project Goals and Activities

The main objective of this project was to increase the enrollment in three science courses by making these courses accessible to students with varying needs and backgrounds. The project director hoped to increase enrollments without increasing instructional costs and without impairing the quality of instruction. The project director hoped that the material he devised for low-enrollment courses would also be useful for students in independent study courses. Finally, he expected to be able to use SIMILEC modules to train high-ability students to work as assistants for certain phases of advanced science courses. For example, Cell Physiology and Animal Physiology were senior biological courses at the college for which there were ordinarily no qualified assistants. The project director intended to use SIMILEC modules to train high-ability students in certain areas of interest so that these students could then serve as assistants in these areas when they took the senior biological courses.

From the first, the project director planned to involve his colleagues in SIMILEC activities. The involvement of other faculty members would bring several different perspectives to the modular materials. When offered in the conventional manner, for example, the project director's course on scientific instrumentation presented the expertise and perspective of a single discipline. As a modular course, scientific instrumentation was to reflect the viewpoints of faculty members in several departments. In addition, the project director thought that involvement of several different faculty members in SIMILEC would increase the use of the materials.

The project director began writing materials for his three courses during the summer of 1976, and he continued writing through the summer of 1978. By the beginning of the 1976 academic year, he had completed enough material to offer Introduction to Electronics and

Scientific Instrumentation through SIMILEC. Progress on the course in Information Systems was somewhat less smooth. Computer technology advanced rapidly during the years of the SIMILEC project. At the start of the project, mini-computers were an exciting new development in computing; by the middle of the grant period, microcomputers were snatching attention away from the mini-computers. Instead of writing materials for a course on mini-computers, therefore, the project director developed materials for a new course, Introduction to Microcomputers, and offered this course for the first time during January 1978.

The faculty members in chemistry, physics, and biology also authored modules on the project. The faculty member in biology developed six modules on the use of the physiograph, three on the atomic absorption spectrophotometer; and two on use of the oscilloscope in recording bioelectric potentials. The two faculty members in physics wrote modular materials on electron microscopy and on X-ray fluorescence spectroscopy. Finally, the faculty member in chemistry wrote modules on enzyme kinetics.

The materials were revised after their initial uses, and are today employed in various ways at the college. The project director uses the materials in regularly scheduled multi-level instruction courses. One of the physicists who worked on the project uses his material on X-ray fluorescence in a supplemental mode in his course; the other uses his material with independent study students. The faculty member from chemistry who worked with the project director on SIMILEC uses the material he developed on enzyme kinetics to substitute for lecture teaching for one week in his course. The biology professor uses his materials with independent study students.

Evaluation

Although the evaluation planned for SIMILEC had several components, its major focus was on student enrollments. The project was meant to increase the number of enrollments and the diversity of students in three courses. The project director planned to compare enrollments and majors in these courses before and after SIMILEC as a way of evaluating the effectiveness of his work. He also wanted to be sure that the quality of his teaching did not suffer with SIMILEC so he planned in addition to collect student evaluations from the revised courses.

The project director's summary of enrollments in his three courses shows the impact of SIMILEC. Before the use of this teaching method, enrollments in Introduction to Electronics, for example, were three or four students per year. The students were physics or chemistry or mathematics majors with good preparation for this course. With the use of limited SIMILEC materials in 1975, Introduction to Electronics was offered at essentially two levels. One level was taken by six students with a strong background in electronics--two students majoring in physics, two in chemistry, one in mathematics, and one in biblical literature. The section for students with less preparation was also taken by six students--one student majoring in biology, one in philosophy of religion, two in biblical literature, one in business and information systems, and one in medical technology.

In subsequent years, the project director has continued to offer multi-level instruction in Introduction to Electronics--two sections in 1976, two in 1977, three in 1978, two in summer of 1979, and two in the regular term of 1979. Enrollments in this course were: 12 in 1976; 13 in 1977; 13 in 1978; 6 in the summer of 1979; and 12 in 1979 during the regular term. The other courses offered through SIMILEC--Scientific Instrumentation and Microcomputers--showed a similar growth in the number and diversity of student enrollments.

The project director also collected, tabulated, and interpreted student evaluation forms from the two levels of Introduction to Electronics in 1975, 1976, and 1977. In general, students responded favorably to the class and to the teacher. Reactions were especially favorable in the level of the course taken by students without strong backgrounds. Out of the six students signed up for this section in 1976, for example, two responded "strongly agree" and four responded "agree" to the course evaluation item, "Overall, this course is among the best I have ever taken." Student evaluations received from other revised classes were also favorable. The project director noted, however, that student reactions to the three courses were neither more nor less favorable than reactions to these courses before they were offered with SIMILEC materials.

Student evaluations of the SIMILEC courses showed one area of dissatisfaction, however. A number of students commented that these courses required too much time and work. Students with strong backgrounds for Introduction to Electronics were especially emphatic about this point. In an effort to improve this aspect of his course, the project director has recently asked students to keep "daily logs"

of the time they spend on the course. The project director hopes to be able to use the data to schedule course activities in the future. Workload is also a problem in the other two courses--Scientific Instrumentation and Microcomputers--and it has occurred as a weak point in evaluations of other courses that the project director has offered. The project director has a reputation of being an excellent but demanding teacher.

Finally, the project director wanted to establish for himself that students learned as much in SIMILEC courses as they had in the courses offered before they were revised. He therefore included on the progress quizzes for students with a strong background in electronics some questions similar to those used on tests given before development of SIMILEC materials. Since student performance on progress quizzes was satisfactory, the project director felt confident that students working with the new format were mastering material similar to that mastered by students who had taken the course in the more conventional format.

An Individualized Sociology Course at a Community College

This project took place at a community college located in the downtown area of one of the major cities in the South. Established in 1966 as the first institution in a seven-campus district, the college has in the years since earned a national reputation for some of its innovative approaches to education. The mission of the college is to meet the varied educational requirements of the growing metropolitan community that it serves. To meet these needs, the college tries to develop educational programs tailored to each student's needs, abilities, and ambitions.

Like other community colleges, the programs at this institution fall into three broad classes. Some of the programs are for students majoring in traditional academic fields with courses transferable to senior colleges and universities; others are for students majoring in technical-occupational programs designed to give the student a degree and a job in one or two years; and still others are for students who enroll in continuing educational or non-credit courses because they want to enrich their lives either vocationally or avocationally. In addition to its more conventional offerings, the college offers classes in downtown office buildings for employees, classes in the county jail for both inmates and jailers, and classes at both public and private high schools for seniors.

The college had a recent enrollment of approximately 6000 students, and the students were of all types. About one-third were enrolled as full-time students, and two-thirds were enrolled part-time. Fewer than half the students were between the ages of 18 and 25. Two-thirds of the students were women, and approximately half were from minority backgrounds (43% Black and 9% Hispanic). Recently 1500 students applied for admission; 99% were accepted; and 65% of those accepted enrolled. Approximately 63% of the freshmen returned the next year, and 45% of the entering class graduated.

The faculty consists of approximately 160 full-time faculty members and 190 part-time teachers. Most full-time faculty hold the master's degree. The college helps support the instructional improvement and professional development activities of these faculty members by making available productivity awards and summer project awards. The productivity awards provide funds for instructional materials, supplies, and equipment, but do not provide salary support. The summer project grants provide stipends for faculty members working on course development during the summer months. Additional help on instructional projects is available from the college's instructional development specialists, who consult on development of materials, and from its technical specialists, who provide help on printing of materials. Released time is generally not available for course and professional development activities. Faculty members are expected to develop and improve courses as part of their regular workload.

Background of the Project

The faculty member who directed the LOCI project is currently an instructor in the social science division. He received his master's degree in sociology in the mid-sixties, and taught at the high school and community college levels before taking his present position in 1973. The social science division that he joined includes the disciplines of psychology, police science, government, history, and sociology. There are ten full-time faculty members in the division.

In 1974 the project director received from the chairperson of his division some literature from the National Institute of Social Sciences describing a program of grants to be awarded to colleges and universities for experimental programs in experiential education. The project director prepared a proposal in response to the solicitation, and in 1975 he received funding for his project. The purpose of the project was to design and implement a course to meet the educational needs of both law enforcement officers and pre-professional students serving limited internships in social agencies. The course was to include both seminars and work with individualized materials, called alternative learning packages.

In his report on this project, the director wrote that the seminars "were probably the most rewarding experience he had ever had as an educator." The seminars did not cover a "lot of material," he wrote, but he felt confident that they produced changes in participants that would be of enduring value. The flexibly scheduled work on alternative learning packages, on the other hand, assured the project director that the program participants covered course content. The two elements--seminars and individualized work--seemed a potent combination to the project director.

The success of this effort stimulated the project director to think about redesign of his introductory sociology course. He hoped to extend the seminar approach to this course, and to design the individualized materials that were necessary for the success of the seminars. But he needed money for materials and supplies, and he needed free time to construct materials and to lay out the course. The project director therefore contacted the resource development office at the college district headquarters to learn about external funding agencies that might provide support for this project. He learned that NSF's LOCI program was a possible funding source.

His LOCI proposal described a project to develop a self-paced system of instruction for introductory sociology. The proposal requested $7300 from the National Science Foundation. The institutional contribution to the project was listed as $3600. NSF funds were to cover released time for the principal investigator during the academic year, salaries for an assistant and a secretary, and costs of instructional materials. The project was scheduled for completion in seven months and was to start in September 1977.

Project Goals and Activities

The purpose of the project was to design materials for a self-paced and individualized course in introductory sociology. These materials were to include:

a) A Teacher's Manual--This would contain instructional materials, references, reprints, and ideas about ways to implement a self-paced course.

b) A Student Resource Manual--This would list non-print media material, relevant readings, paper topics, research topics, and other elements that a student might use to construct an individualized study program.

c) A Guide for Studying Textbook Material--This would contain objectives and self-tests for seven textbook modules.

The project director expected these materials to be helpful to other teachers of sociology, especially staff members on the three new campuses of the college district, whether or not they chose to teach a self-paced, flexible entry course.

The project director, however, intended to use the materials in a truly individualized fashion. His idea of individualization went far beyond the conception embodied in Keller's Personalized System of Instruction. The Keller plan allows students to move through a course at their own individual rates, but all students follow the same sequence of course material. Content is not individualized. The project director planned to individualize both pacing and content in his sociology course. In consultation with the course instructor, each student was to develop an individual contract, specifying papers to be read, slide-tapes to be viewed, seminars to be attended, and so on. The only common requirement for all students in the course would be demonstration of competence on seven units of textbook material. Resource manuals for students and teachers were necessary because the individual contracts were based on the materials in these manuals. Guides for studying textbook materials were also necessary because of the requirement of mastery of textbook material.

The project director also intended to permit flexible entry into his courses. In this respect too, he went beyond many users of individualized systems of instruction. He hoped to be able to let students enroll in his proposed course on the first day of each month. Learning contracts would then be signed, and students would proceed through their individually designed programs at their own rate in their own fashion. Students would exit from the course when the terms of the contract were fulfilled.

The project director completed project activities on schedule. He wrote the manual of resources for teachers, the manual of resources for students, and the guide for studying textbook material. He also purchased copies of films and slides for an individual study center, and obtained copyright waivers for materials to be duplicated. Support from college personnel was necessary for completion of the project on time. The college's instructional development specialist assisted the project director in developing seminar presentations and in writing sections of the learning packages. Secretarial staff provided the help necessary for technical preparation of the materials.

The resulting documents represent an impressive achievement. The 343-page Resource Collection for Sociology Teachers contains:

a) 15 seminar topics, each with suggested questions for a discussion leader;

b) 19 exercises for testing student ability to analyze and synthesize concepts and theories of introductory sociology;

c) 41 learning packages, each consisting of a learning source (e.g., an audiotape or reading), a list of objectives specifying what is to be learned, and test questions to measure mastery of the objectives;

d) 12 designs for overhead transparencies;

e) 4 appendices containing forms used in individualized instruction, such as learning agreements and agreements on flexible entry;

f) numerous guides to use of these and other materials in teaching.

Additional materials that complement those in the manual for teachers were contained in the 45-page Resource Manual for Sociology Students and the 56-page Textbook Study Guide.

When the project director teaches introductory sociology, he uses these materials in the individualized manner. He has, however, had to make some accommodations to institutional policies in the use of the materials. The state's formula for funding on the basis of "headcounts" on certain dates, for example, constrained the project director's use of flexible entry into his course. Complete flexibility in entry into the course might have caused some reduction in funding. So far, however, the project director has been able to meet such requirements without compromising his original vision of individualized learning programs for his students.

The project director is sure that he will get continued use from his materials in his courses in the future. Institutional changes could change the way that he uses these materials, however. A possible reduction in services available from the college's individual study center, for example, would affect testing in his course. But his project materials are diverse and open to many kinds of uses so the project director doubts that any institutional change would make the materials completely obsolete in the foreseeable future.

The project director has not yet seen much use of his materials by his colleagues. One part-time and one full-time instructor in another community college in the district uses the materials in teaching introductory sociology, but full-time instructors on the project director's campus have not made any use of the materials. In the future the project director intends to make a greater effort to inform the part-time instructors in sociology about his approach to teaching. He believes that these instructors would profit most from use of project materials.

The project director's methods have influenced instruction at his college quite substantially in another way, however. The college recently received a grant from the NSF's program on Comprehensive Assistance to Undergraduate Science Education (CAUSE) to restructure five courses in the divisions of social sciences, and science using the project director's format for the restructured courses. The CAUSE project involves 14 faculty members who teach courses in developmental psychology, psychology of personality, marriage and family, anthropology, and ecology. An important feature of the grant is provision of released time to faculty members to develop these learning packages. The director of the LOCI project in introductory sociology is also project director for the CAUSE grant.

Evaluation of the Project

The project director did not propose a formal evaluation for his project. His proposal stated simply that he would submit his materials to NSF as proof of his project's accomplishments. In addition, he proposed writing a general evaluation of the project based on his experiences.

Nor did the project director carry out a formal evaluation. His assessment of project outcomes was informal and impressionistic. Based on his own observations and student reactions expressed on course evaluation forms, the project director concluded that his approach is most successful with students who are initially highly motivated to learn sociology. The interactive seminars appeared to reduce the barrier between the instructor and these students. The project director reported that more of these students dropped by to talk to him during office hours as a result of his new approach to teaching, and a number of the students seemed to show more enthusiasm about college in general as a result of the self-paced format. On the other hand, fewer students used filmstrips and slide presentations than the project director had expected. A few students with underdeveloped verbal skills especially did not participate in seminar activities with any enthusiasm.

Reactions to NSF

The directors of the projects on individualized instruction reported that the LOCI program met their needs. They could think of very few areas in which program guidelines could be improved. The project director at the liberal arts college said that he was glad that a final project was required. While writing the final report on his project, he had the opportunity to reflect on what he had accomplished. The project director at the community college said that interactions with LOCI personnel were especially helpful on the administration of his grant.

The sociology teacher at the community college suggested two areas where NSF might revise guidelines and procedures. First, he recommended that NSF staff scrutinize more carefully the workloads of project directors to ensure that project plans are realistic. Second, he recommended that evaluation guidelines be made more clear and specific. He thinks that all proposals should include a plan for evaluation of project results, and he thinks that his own proposal was inadequate in this respect. He suggested that NSF play a more active role in providing assistance and consultation on evaluation of projects.

Summary and Conclusions

The three projects on individualized instruction clearly had positive outcomes. The project directors produced the instructional materials that they had intended to write. They used the materials in their courses and are continuing to use them regularly. The use of these materials has changed substantially the teaching approaches in the courses. In addition, two out of the three project directors carried out formal evaluations of their projects, and the results of these evaluations were positive.

Results from these projects were consistent with results from other projects involving individualized instruction. Our analysis of final reports (described in Volume II) showed that many project directors who carried out formal evaluations of their projects had worked with individualized approaches to teaching--especially Keller's Personalized System of Instruction. A number of the final reports stated that use of Keller's teaching method led to more positive student attitudes toward courses.

A number of factors probably contributed to the success of these projects. Among these are the following:

a) The projects used a simple "low" technology--printed instructional materials. This media did not present great obstacles to teachers. They did not get trapped by hardware.

b) The projects were primarily oriented toward revision of specific courses taught by the project directors. LOCI projects appear to be most successful in bringing about changes in specific courses. They appear to be less successful in bringing about broad changes in departments and colleges.

c) Clear models were available for the project directors for development of individualized instruction. Two of the project directors attended workshops where other science teachers taught them how to design individualized courses. The other teacher, who was at an institution with a special commitment to individualized instruction, had expert consulting help available on campus.

d) Clear models for evaluation of individualized instruction were also available. Many college teachers have evaluated their individualized courses in recent years, and reviewers have summarized results of such evaluations time and again. At least seven major reviews of effectiveness of Keller's Personalized System of Instruction have appeared in the last few years, for example. This tradition of evaluation may influence college teachers working in the area to document the effects of their work.

Computing Aids in Teaching

The computer played a major role in approximately one-third of all LOCI projects designed to revise teaching methods. The projects used the computer in a variety of ways. In some projects the computer served as a tutor, patiently presenting programmed information. In some the computer managed instruction. In other projects the computer presented models of social or physical reality for students to explore. In still other projects the computer served as a problem-solving tool.

The two case studies in this chapter describe projects on computing aids in teaching. In the first project a faculty member at a community college attempted to use work on programmable calculators to enrich the mathematics learning of his students. In the second project a teacher of engineering attempted to design application programs for a "smart" terminal system (or microcomputer system) of his own design.

Computer Aids in Engineering

The project on computer aids for students in engineering took place on the main campus of a large state university in the Midwest. Founded in the early nineteenth century, the school has since become one of the leading research universities in the country. On the institution's main campus, located in a city of 110,000, there are 18 separate schools and colleges. Branch campuses are located in two nearby cities.

The university's main campus has an enrollment of 30,000 undergraduate students and 10,000 graduate students. Admission is very competitive. Recently, 11,500 students applied for admission, and 70% were accepted. The average score of entering freshmen was 520 on the verbal section and 590 on the mathematics section of the Scholastic Aptitude Test. About 5% of the students drop out at the end of freshman year, and over 70% remain to graduate. Expenses at the university are high compared to expenses at other state universities. Total costs were recently estimated at $3800 for residents of the state and $6100 for nonresidents.

The university faculty has 2400 full-time members, nearly all of whom hold doctorates. Salaries for professors are well above the national average. Among the faculty members are many nationally and internationally known researchers and scholars. At most schools and colleges of the university, exceptional promise in research and scholarship is required for hiring and promotion.

In the early sixties the university established an institution-wide center to help its faculty adapt to new developments in teaching and learning. Since then, this center has developed programs that provide information, consultation, and funding for faculty members interested in exploring new approaches in education. The center today offers approximately 25 workshops each term to help university teachers develop their instructional skills or learn new approaches. It also makes awards of up to $5000 each to faculty members for instructional and faculty development projects. Awards total nearly $100,000 a year, but even so only one-third of the proposals received are funded by the center.

The instructional development center at the institution also supports course evaluation activities. Individual faculty members, departments, or colleges may use the center's catalog of course evaluation items to design student rating forms appropriate for their courses. The center then prints individualized evaluation forms, tabulates results, and returns copies of results to instructors. This course evaluation system is used in approximately 2000 classes each term at the university.

Background of the Project

The faculty member who directed the LOCI project on computer aids in engineering is a full professor in the department of electrical and computer engineering. He received his Ph.D. in 1960 from a major research university in the Midwest, and moved to his present position in 1966. He is author of three books and more than 40 articles in his field. His department dates back to 1895 when it was called the department of electrical engineering. The department received its current name in 1971. The department currently has 52 faculty members, most of whom are actively engaged in engineering research or professional consulting.

Although a number of university-wide resources for teaching improvement are available at the project director's institution, the project director perceived resources for instructional improvement as low in his college. Although individual departments in the college are sometimes able to provide released time for instructional projects of faculty members, such released time is rarely available in the project director's department. In addition, the project director reported that resources for purchase and maintenance of equipment are inadequate in the college of engineering, and that faculty members have to compete to receive yearly equipment awards. Finally, the project director reported that the college places highest priority on "pure" research projects and on attracting external funding to support faculty and graduate student research. The project director said that there was little external incentive for faculty members to conduct instructional improvement projects on undergraduate teaching.

A number of factors stimulated the project director to develop his proposal on computer aids for students in engineering. First, he had a long-standing interest in computer technology, and was following closely developments in the field of microprocessors. In the mid-seventies, new developments in microprocessing seemed to be especially promising, and the field was filled with excitement. Second, he was interested in the application of computer technology in instruction. He had previously received an NSF award for a large-scale project on display-based instruction. As a part of that project, he had developed exercises in book form which could be run on a microcomputer. Previous efforts to introduce these and other exercises in large-scale computer-assisted instruction in his department had failed because the efforts depended upon the availability of the university's time-shared computing system. The project director thought that microcomputers would free faculty members from dependence on the heavily used terminal system and deliver feedback to students more efficiently. With these ideas in mind, he prepared a proposal for the National Science Foundation.

The total amount requested from NSF was approximately $19,000. Institutional contribution to the project was to be $2500. NSF funds were to pay for two months of full-time summer salary for the project director; three months of full-time summer salary and nine months of one-quarter-time salary for a programming assistant; and computer costs. The project was to begin in June 1976 and was expected to be completed in 15 months.

Project Objectives and Activities

The major objective of this project was development of application programs for a locally built "smart" terminal system (or microcomputer system). The locally built terminal system was reported to be in operation at the time of the request for NSF funding. It included a keyboard, a microprocessor (Intel 8080), a TV monitor, and a memory device, with a total cost of approximately $750. The application programs would make this microcomputer system useful in the undergraduate electrical engineering curriculum. Proposed use of the application programs were for: laboratory exercises in courses, classroom demonstrations, and independent laboraboty projects.

The project activities were to occur in three phases. During the first phase the project director proposed to develop:

a) graphics system software and a small interactive operating system;

b) a cross-compiler so that future application programs could be developed more rapidly;

c) six application programs.

The second phase of the project was to take place during fall and winter 1976. During this phase the application programs were to be used in the electrical engineering department, and decisions were to be made about the best mode of use of the programs. During the final phase of the project--one month in the summer of 1977--programs were to be documented, and a manuscript describing the system was to be prepared for publication.

Project activities did not follow this proposed schedule. The project director's decision to change the schedule at the very outset of the project was based on the rapid development of microcomputer technology in the months before the project was funded. By the time the project began, a kit to build a small personal computer became available. Instead of relying on the hardware described in his proposal, the project director decided to buy a kit and assemble this computer for the project. The project director thought that in the long run he would avoid hardware problems by using the commercially available microcomputer kit.

It turned out that he simply exchanged one set of hardware problems for another. He and his graduate assistant first spent valuable time waiting for delivery of equipment from the manufacturer. They then spent additional valuable months trying to assemble the microcomputer. The project director finally concluded that the kit was defective and that the microcomputer could not be assembled. After a year of delays, the project director finally abandoned the purchased hardware in frustration.

The project director secured a time extension for the project, and assessed his situation. By the summer of 1977 computer technology had already advanced beyond the capabilities of the microcomputer kit he had purchased. Microcomputers were now available already assembled and at reasonable costs. Under pressure to complete the project, the project director purchased a Radio Shack TRS 80 with his own funds and donated the equipment to the university to complete project goals. With a working microcomputer system now available, he began to write the application programs whose development had been put off for so long.

Because of the delays in purchasing and repairing equipment, however, the project director had little time left in which to develop these programs. Although he wrote the six application programs which he had proposed, he was able to develop only one program for an experiment in his course on introductory circuits. The experiment involved measurement of transistor parameters, use of these parameters to calculate the transfer characteristic of an inverter, and comparison of calculated and measured characteristics. This experiment was a part of the project director's laboratory course before the microcomputer application program became available, but at that time students had only the university's computer available as a computational tool for the experiment. Today students use both the university's time-sharing terminal system and the microcomputer that the project director programmed for this experiment. All students in Introductory Electrical Engineering, perhaps 300 a year, complete this experiment over a three-week period.

In the years since this LOCI project began, the project director has demonstrated microcomputers to groups of professional engineers, members of the computing community, and to faculty members at a microcomputer workshop within the college of engineering. According to the associate dean of the college, the project director has influenced other faculty members to experiment with computers, and use of microcomputers has increased at the college. One of the project director's colleagues in the department of electrical and computer engineering, for example, currently uses a microcomputer in teaching both introductory and upper-division courses. In response to the interest of engineering faculty, a college-wide seminar was conducted last spring on the use of microcomputers. Overall attendance at the seminar was high and response among the faculty enthusiastic. Recently a microcomputer laboratory was also established within the industrial and operations engineering department of the engineering school.

It is difficult to attribute the growth of enthusiasm for microcomputers solely to the LOCI project. The associate dean of the college, however, identifies the project director as an "opinion leader" who has led the way for faculty in the college to purchase and utilize microcomputing systems. The administration of the college is currently considering the issue of overall use of microcomputers in undergraduate engineering instruction. The associate dean attributes this examination, in part, to the project director's leadership in the use of microcomputing systems.

The project director, however, does not plan to develop further his use of microcomputer systems in teaching. His personal research interests are now in other areas, and no funding is available from his college for development of new programs or for purchase and maintenance of computing equipment. He and his colleagues, however, plan to continue to use their existing simulations and equipment in electrical engineering courses.

Reaction to NSF Programs

Overall, the project director thought that the LOCI program met his teaching needs. Program guidelines were clear and understandable. Time allotted to complete project activities was reasonable. The project director was grateful for the time extension he received to complete his project. The project director thinks, however, that LOCI restrictions on amount of awards may no longer be realistic. Grants of $25,000 are too small for large-scale projects in most universities today. The project director would be unable to pursue his current interest in research and development with the amount of money available from LOCI. Larger grants are essential, he believes, to assist faculty in staying on the leading edge of innovation within their fields.

Programmable Calculators as Teaching Aids

The second computing project took place at a community college that serves a midwestern city of about 26,00. The college was established in 1927 as a junior college under the juristiction of the city schools, but in 1966 it became part of a ten-county community college district. The main campus of the college is located on two hundred acres of rolling farmland. Nearly all arts and sciences programs and many of the vocational and technical programs of the college are housed in a modern, air conditioned building complex, constructed during the past ten years.

The objectives of the college include providing a sound, economical, and convenient education at the college level for high school graduates, and providing career and adult education to complement college parallel or transfer programs. The college offers credit courses both on- and off-campus. Its programs are in areas such as secretarial science, practical nursing, medical office assistance, dental assistance, engineering, graphics, environmental chemistry, and others.

Approximately 1000 students are enrolled at the college. About two-thirds of these students attend the college full-time and about one-third are part-time students. About one out of every four graduates of area high schools attend the college, and one of every two graduates of the public school district enroll. Nearly two-thirds of the students attending the college commute from their homes, and the remaining one-third live in rooms and apartments near the campus. Also enrolled at the college are a number of out-of-state and foreign students.

Like most public community colleges, the institution operates on an open-door policy. A student who is a high school graduate or the equivalent is eligible to apply for admission. About half of the students at the college plan to transfer to four-year institutions; other students are enrolled in self-contained programs of 9 to 20 months in duration. Tuition for full-time students who are state residents is $200 per semester; tuition for non-residents is $300 per semester. Typical student expenses for a full academic year for a non-commuting student would be approximately $2000 and it would be approximately $1000 for a commuting student.

The faculty at the college consists of more than 50 members. Most of these faculty members hold the master's degree. Institutional resources to support teaching innovations of these faculty members are not extensive. The college does not have a special faculty or instructional development center. Nor does it provide mini-grants to support innovation in teaching. Released time is not ordinarily available for work on teaching improvement projects, but half-days are occasionally available for faculty development activities, with total released time amounting to no more than three or four days a year.

Background of the Project

The LOCI project was carried out in the three-person engineering and mathematics division of the college. This division has had unusual stability in faculty composition over the years. Each of its three faculty members has been at the school for about fifteen years. These faculty members provide courses both for students in transfer programs and for students enrolled in self-contained mechanical and electronic technology programs. Students in the college parallel courses usually take pre-calculus, calculus, engineering graphics, and engineering problems. Students in mechanical and electronic technology take a three-semester sequence called Applied Mathematics I, II, III.

In the early seventies a computer study committee was formed at the college to help develop a policy on computers. The committee members explored three options. First, they studied the possibility of purchase of a computer to provide services for instruction at the college. Second, the committee considered the option of purchasing terminals for telephone access to a distant computer. Finally, the committee looked into the feasibility of investing in programmable calculators as an alternative to computers. The third option was the one recommended for the college by the committee.

Soon thereafter the division of mathematics and engineering made its first major investment in programmable calculators. The model selected was marketed by Wang Electronics, was about typewriter-size, and had a neon display for output. After some experience with this initial machine, the division purchased another calculator made by Wang, this one equipped with a column printer and a cassette tape. The two machines proved valuable in teaching and demonstrating concepts in courses ranging for general mathematics to calculus. In 1975 the NSF's Instructional and Scientific Equipment Program (ISEP) provided $3500 for purchase of a plotter that would be compatible with the programmable calculator. The plotter helped students interpret calculator input and introduced engineering graphic students to automated drafting.

At the beginning of 1976, therefore, the division had about $7000 worth of equipment for calculation. The faculty member who was to become director of the LOCI project felt that problems existed that kept this equipment from being used widely in the department. First, the equipment was not easily moved. It did not receive optimal usage simply because of its lack of portability. Second, even if the equipment could be used easily, setup was not simple. And third, students could not see and read output easily in large classes.

This faculty member thought that the division was approaching the problem in the wrong way in moving the machine to students. He thought that it would make more sense to move students to the machine. Instead of using the machine in group instruction, he wanted to explore use of the machine in individualized teaching. To provide for individualized use of the equipment, handouts and guides would be necessary. The request to the NSF's LOCI program was for funds for development of these guides.

The formal LOCI proposal was developed jointly by the three members of the division of mathematics and engineering. They asked for approximately $8000 from NSF. The institution's contribution to the project was to be approximately $4000, bringing the total costs of the project to $12,000. The money was to be used to cover faculty salaries for the three project staff members for a six-week period during the summer of 1977.

Project Goals and Activities

The proposed project had goals in two major areas: faculty development and instructional development. The project was to contribute to the capacity of the department members to teach using modern technology in computing and calculating, and it was also to result in materials for use in specific courses in the mathematics and engineering curriculum. The formal proposal gave the greatest emphasis to the goals in instructional development.

In discussing the project today, the project director emphasizes its contribution to faculty development. The three faculty members who participated in the project had each received their training in mathematics and engineering in the fifties or early sixties. At that time, computing was just past the stage where programs were hardwired. Each of the three faculty members had some contact with computing since then--in summer jobs or in avocational pursuits. But each, as it turned out, needed to devote more time to learning about calculating and computing machines and about instructing students in the use of such machines.

One of the faculty members especially needed to bring himself up to date on programmable equipment. His role during the summer months was simply to learn about the equipment, to try programs, and to find out what could be done with such programs. The other faculty members were building on stronger foundations in computing, and they were able to move faster and farther in learning how to instruct students in mathematics and engineering using computers.

The other major goal for the project was construction of instructional materials. The two faculty members with the strongest background in calculating and computing reviewed existing literature, broke tasks into component parts, and wrote instructional materials and programs. One of the faculty members wrote a manual that made the Wang more accessible to students. The other faculty member wrote programs for storage on cassettes, and also wrote study guides documenting these programs and making them useful for students.

The project's members anticipated three sorts of uses of these materials: (a) in demonstrations in regular classes in mathematics and engineering; (b) in individual projects undertaken by students; (c) in laboratory assignments made in courses. They planned to start using the materials to in the 1977-78 academic year, and to continue using them in the years following. The project director anticipated that over 1000 students would be affected by the project during a five year period.

In the two years since the project ended, materials were used in different ways at the college. The impact of the materials, however, has been less than expected. First, classroom demonstrations using the programmable calculator and the plotters, begun at the college before LOCI funding was available, have continued in the years since, especially in calculus classes. Better use of the plotter in classroom demonstrations was not a major goal of the LOCI project, but the project did enable faculty members to learn more about the equipment and so they are now in a position to use it more easily and confidently in demonstrations. Written materials generated by the project also help make classroom demonstration easier to do.

The second use of the project materials today is in independent work by students. Occasionally students who see the plotter used in classroom demonstrations become interested in further work on the programmable calculator. The library of materials created during the LOCI project makes it possible for such students to pursue independent projects on their own. One student in a calculus class, for example, became interested in programming the plotter to draw a hyperbolic paraboloid. After independent work with the calculator and plotter, he was able to achieve his goal. The student now is planning to major in computer science. The location of the programmable calculators and plotter in the college's learning resources center makes student access to the equipment simple.

The third area of expected impact was on courses at the college. The impact in this area was expected to be especially great. The courses expected to be affected were Engineering Problems and Engineering Graphics--two courses for pre-engineers--and Applied Mathematics I, II, and III (a sequence of courses for technology students). The type of revision was to be function of the course. In Applied Mathematics I, for example, the project was to generate a series of practical problems from various fields that would be difficult or time consuming to solve without recourse to programmable equipment.

It turned out that only one course has been substantially revised because of project activities. The revised course is Applied Mathematics I. Before the project, this course was offered in a lecture format. During the LOCI project, the teacher of this course became convinced that students needed more guided laboratory work in programming. He therefore revised the format of Applied Mathematics I, and starting in September 1979, he has offered this course in a lecture-laboratory format.

The laboratory section of Applied Mathematics I does not use the Wang calculator or the plotter, however. The course instead uses small portable programmable calculators available on loan at the learning resources center. It is not hard to understand why the Wang machines are not used in this course. Calculating equipment increased in power and decreased in cost since this LOCI project began. The original Wang machinery used in the project today sits in a small room in the learning resources center. By today's standards, it seems bulky, cumbersome, and slow, and it is not surprising that it is little used today. The library does a brisk business, however, in lending out small portable calculators for use by students in Applied Mathematics.

Nor does it seem likely that the Wang calculators, printing device, and plotter will recieve greater use in courses at the college in the future. The swift and steady development of microcomputers seems to have sealed the fate of these bulky machines. The college recently bought four PET microcomputers, and faculty members see these

machines as having many advantages. They are programmed in BASIC, a programming language that is used in many other installations. The PET microcomputers are relatively inexpensive, and they are more easily moved than the calculator and plotter. These microcomputers are also flexible, and useful in a wider variety of settings than the programmable calculators.

Evaluation of the Project

The proposal for the LOCI project contained a description of a plan for evaluating results. The division intended to evaluate changes in: student understanding; efficiency in learning; and attitudes toward program-oriented approaches to problems. Faculty members were also to write evaluations of the instructional materials after they were first used. The critiques were to be used primarily for revision of instructional material.

The evaluation that took place was far less formal than the proposed evaluation. Instructional material developed during the summer months was critiqued and revised on the basis of comments made by the project team. As students worked through materials, there were other opportunities to incorporate feedback from use into the redesign of course material. But no formal evaluation was carried out on the impact of the project on courses. The project director felt that formal comparisons involving control groups would not be very meaningful because intorduction of programming into courses changed the content of these courses as well as the teaching methodology. Informal evaluation for the sake of revision of material was all that seemed feasible.

Impressions about project outcomes were all that was available. The project director and his colleagues had the same overall impressions. They agreed that a good deal was accomplished on the project in terms of faculty development. The project helped faculty members with heavy teaching responsibilities to devote a sustained period to work on incorporating programming into their courses. It brought these faculty members up-to-date in a quickly changing field so that they could respond confidently to new developments. This was an especially important task because of two special characteristics of the community college where the project took place. The school has a stable faculty without much turnover, and teaching loads are relatively heavy. Given these characteristics of the school, sponsored projects such as this one seem important as a way of keeping faculty up-to-date and growing.

The project director and his colleagues also agreed that the project was less successful in making maximum use of the calculating equipment owned by the division at the time the project started. One problem may have been that expectations about what could be accomplished were too high at the start of the project. Faculty members had been teaching in a certain way for many years, and students were used to certain ways of learning. One piece of equipment was a slender base on which to build a major revision of teaching methodology involving hundreds of students a year. Technological developments that occurred while the project was underway also affected the size of the project's effects. In the years since the project was funded, programmable calculators became available at lower and lower cost, and microcomputers appeared on the market—less expensive and more powerful than anyone could have anticipated. The microcomputer immediately established itself as the calculating tool of the future at the college, and it circumscribed sharply the role that other calculating devices could play.

Reactions to NSF Programs

The project director and his colleagues thought that the LOCI program was an appropriate one for the needs of their department. The program did not require excessive paperwork from their institution, and the grant was therefore relatively simple to administer. The program would be improved, however, if project directors were notified more promptly of decisions about awards. With late notification, summer schedules are almost certain to be disrupted by receipt of awards.

Summary and Conclusions

The two projects on computing aids differed in many ways. The first was the work of an individual faculty member; the second was carried out by an entire department. The first took place at a large research university, the second at a small community college. The first project was long in duration, the second short. The first involved microcomputers, the second programmable calculators. But in other ways the projects were similar. Both projects had less impact on teaching than was originally anticipated. The equipment for both projects quickly became outdated. The most important contribution of each of the projects may have been to faculty development.

Two factors that sometimes play a role in determining outcomes of computer-oriented projects are:

a) Documentation: Computer technology advanced more rapidly than computer documentation. Faculty members working with innovative computer technologies often find that new equipment is not described well enough in manuals supplied by manufacturers. Faculty members can waste valuable project time simply trying to learn about new equipment.

b) Obsolescence: Instructional programs written for the latest computers may be obsolete after a few years. Instructional programs that are not oriented toward a specific piece of equipment may have a better chance of survival.

Chapter 4

Inquiry Laboratories

Many of the LOCI projects funded in recent years were designed to revitalize science laboratories. The directors of these projects thought that existing science laboratories were too regimented. Rather than promoting inquiry, conventional laboratories seemed to stifle it. The laboratories that the project directors proposed to develop to replace conventional ones were more open-ended. The project directors wanted to give students simple laboratory problems and have the students work out solutions by themselves without using step-by-step directions.

The two projects described in this chapter resulted in inquiry-oriented laboratories in physics. The first project redesigned teaching materials in an existing inquiry laboratory, and tested the effectiveness of the revised materials. The second project, originally designed as a research investigation on intuitive models used in solving physics problems, led eventually to construction of inquiry-oriented laboratory materials for a "pre-physics" course.

Inquiry-Role Approach in Laboratory Teaching

The site for the first of the inquiry-oriented projects was a comprehensive state college in the Midwest. Founded in 1905 as a normal school, the college still plays an important role in training teachers for the state, but today it also offers complete programs in the liberal arts at the bachelor's and master's levels. Located on a 235-acre campus, the college is situated in a town with a population of about 20,000. The campus contains 32 buildings, including ten residence halls and apartments for students.

The undergraduate student body numbers about 4,600. About 500 additional students are enrolled in master's degree programs. Approximately 98% of the students attending the college are state residents. Estimated annual costs for students are $1600 for in-state students and $1950 for others. Recently, the college received 2500 applications, accepted 92% of them, and enrolled 1964 freshmen. Average total SAT score was approximately 900 for these freshmen. Approximately 40% of the students entering the school drop out by the end of their first year, with 33% remaining for graduation.

Faculty members at the school typically teach four classes per term. About half of the faculty members hold doctorates, and their salaries are somewhat below the national average. Faculty members that we talked to on our visit stressed that the school is primarily a teaching institution. Although research and development activities may help a faculty member win promotion in some cases, such activities are not an absolute requirement for promotion. No faculty or instructional development program promotes the idea of teaching innovation on campus, and released time, summer salary, and teaching grants are not available to faculty members working on instructional improvement projects. No research-development office smooths the way for faculty seeking support for proposals from foundations and agencies. Faculty members, therefore, sometimes feel that development of proposals is an add-on activity at the institution.

Background

In 1976 when the LOCI project began, the project director and co-director were associate professors in the department of physics and physical sciences. This department occupies the first floor of the college's modern science building. In addition to well-equipped laboratories and classrooms, the department has a planetarium, observatory, meteorology station, darkroom for photographic work, and a well-equipped "shop" available to students working on special projects. The seven members of the department of physics and physical sciences have actively sought funds to support development projects in education.

The project co-directors arrived at the college in the late sixties. Both had been high school teachers in the Midwest before receiving their doctorates in science education. The project director came to the college after completing his doctorate in 1966, and the project co-director moved to the institution after finishing his doctoral work in 1970.

These two faculty members soon learned that they had similar ideas about science education. Each thought that science education could be improved if science teachers would put less emphasis on transmitting information in the classroom and more emphasis on student inquiry. In lecture classes, students did not act like scientists, the two faculty members noted. With less emphasis on lectures and traditional textbooks, they thought, students might inquire more freely into scientific problems. They believed that students should be free to produce the data, concepts, and principles for science courses.

One form of inquiry-oriented teaching that was especially interesting to the project directors was the inquiry-role approach (IRA), originally developed for the field of biology under the direction of Richard Bingman. IRA was a learning methodology designed to develop inquiry skills by stimulating greater classroom participation. In inquiry-role teaching, students were assigned roles in four-member teams that worked on structured laboratory investigations, open-ended laboratory investigations, and applications of results of laboratory investigations.

While still completing his dissertation work, the project director traveled to the Mid-Continent Regional Laboratory in Kansas City, Missouri, to learn more about this new development in inquiry-oriented teaching. The project director brought Bingman's ideas back to his own department and eventually discussed them with the project co-director. They realized that incorporating Bingman's approach and validating it in their physical science courses would require special resources. They decided therefore to apply to NSF for funds to help them accomplish the task.

Their LOCI proposal requested approximately $14,000 in funds from NSF. Institutional contribution was to be approximately $12,000. The NSF funds were to cover summer salaries for the project directors and salaries for a secretary and a student assistant. Institutional funds would cover academic year salaries of project directors. The project was scheduled to begin in June 1976 and to be completed in 12 months.

Project Goals and Activities

The two major goals for the project were: a) to create materials for inquiry-role activities; and b) to validate these materials.

The project was to proceed in two major phases. During the summer of 1976, the project directors were to develop the materials. During the academic year that followed, they were to use the materials in their course in physical sciences for general education students and for elementary education majors. In this second phase of the project, they were also to evaluate formally the effectiveness of the materials.

The project directors were able to follow their original schedule for project activities. During the summer of 1976, they designed inquiry-role materials on several topics in physical sciences: heat and temperature; electricity and magnetism; optics; earth sciences; and so on. Written materials varied from topic to topic, but usually contained the following:

a) Directions for structured laboratory investigations--These investigations were to be carried out by four-person teams.

b) Discussion questions--Students working in teams reached consensus about the best answers to questions relating to the investigation.

c) General problems for open-ended laboratory investigation--The teams designed their own investigations to solve problems that were posed without directions for solution.

d) Inv[illegible]s to inquiry--These gave students some experimental resul[illegible] and invited the students to interpret, apply, analyze, and synthesize data.

During the academic year, students began to use these materials in classes in introductory physical science. The students worked in four-person teams and used simple laboratory materials. One student acted as team leader, directing all team activities including discussions; another student, acting as technical advisor, was responsible for obtaining and setting up equipment; a third student, the data recorder, organized data; and a fourth, the team evaluator, evaluated the efforts of members of the team. While students worked, the teacher moved from team to team providing necessary assistance. The teacher often helped clarify issues, but did not provide answers. Typically, teams worked on a topic for two or three days before turning in both group and individual laboratory reports. Following teamwork, the teacher conducted a large class discussion in which groups shared differences of opinion on concepts, roles, and teamwork.

When the LOCI project ended, the project co-directors revised their course procedures somewhat. The revisions were designed to improve the teaching in their courses. First, they reduced the number of individuals in the teams from four to three by eliminating the position of team evaluator. Second, they greatly simplified role directions--from a manual of detailed descriptions of each requirement in each exercise to a page-long description of general responsibilities. And finally, they gradually refined the laboratory exercises to increase their clarity and effectiveness.

Evaluation of the Course

The project directors also carried out the evaluation of their project during this academic year. Before receiving the LOCI award, they had not been able to carry out a formal evaluation of their work in inquiry learning. The LOCI project therefore gave an important new focus to their investigations. Their evaluation compared gains in critical thinking, formal thinking, and knowledge of scientific process of students taught with and without the inquiry-role approach to teaching. To measure critical thinking, the project directors used the Watson-Glaser Critical Thinking Appraisal. To measure knowledge of scientific processes, they employed the Process of Science Test. To measure changes in formal thinking, they used the Burney Formal Reasoning Test.

Their evaluation showed that inquiry-role teaching contributed significantly to students' formal thinking abilities, to their capacity for critical thinking, and to students' knowledge of scientific processes. In each of these areas, the gains of students taught by the inquiry-role approach were greater than gains of students taught in lecture-discussion classes. On each of the measures inquiry-role teaching raised test scores by between one-quarter and one-half standard deviation.

There were probably other positive effects on students beyond those measured by the project directors. Almost everyone we talked to at the college mentioned the positive effects that inquiry-role teaching has on student attitudes toward courses. The physics department chairman pointed out that inquiry-role sections are always the first sections of Introductory Physical Science to fill up. As department chairman, he reported hearing only positive things about these sections from students. An educational psychologist we talked to also reported that students who have taken the inquiry-role courses commented favorably on them in their educational methods classes. A chemistry teacher who also teaches classes in Introductory Physical Science pointed out that student attendance is always very good and that students seldom are absent from inquiry-role classes. The project directors pointed out that student evaluations collected at the end of their classes are almost always favorable. Finally, the students that we observed in Introductory Physical Science classes taught by the inquiry-role approach were attentive and involved in laboratory activities.

In general, costs of teaching Introductory Physical Sciences by the inquiry-role approach seemed comparable to costs of lecture classes. With 35 to 40 students in a section, laboratory size is fairly large, and each section is handled by a single teacher without a separate lab assistant. Two things make it possible to teach laboratory sections of this size without special help. First, carefully constructed materials free the teacher from having to provide detailed explanations. Second, evaluation of the work of teams rather than of individual students reduces the amount of time necessary for grading. Another factor contributing to the low cost of these laboratory sections is the simple, inexpensive equipment that the laboratories require.

<u>Other Project Effects</u>

The project directors also pointed with pride to other positive effects of their work. In their view, the LOCI project and their related projects, some of which were supported by NSF, also influenced: (a) teaching in other classes in the physics department; (b) teaching in other courses in the college; and (c) teaching in the community outside the college.

It is easy to find other effects of this project in the physics department. First, other teachers in the department are now using some of the inquiry-role materials in Introductory Physical Science classes. Second, in addition to using this approach in their introductory classes, the project directors have adapted inquiry-role teaching to their other courses at the college. Third, courses in general physics also use some of the inquiry-role activities. The chairperson of the department, for example, introduces metrics measurement with some of the inquiry-role laboratory exercises. Because the exercises can be carried out with very simple equipment, these activities tend to be attractive to other teachers in the department.

The inquiry-role approach is also used in some form in a number of other departments at the college. One chemistry teacher, who first learned to use inquiry-role teaching in Introductory Physical Science, introduced the method into chemistry department courses. The chemistry department now uses the inquiry-role approach in its classes for students without a strong background in chemistry. An educational psychologist with a long-standing interest in inquiry teaching adapted the role approach to his own inquiry-oriented classes. A sociologist who has collaborated with the project directors in work on research grants has also used some of their ideas in teaching sociology.

Finally, this work has had an impact on teaching at the elementary and secondary levels in the state. The project directors used the inquiry-role approach in teaching elementary and secondary school science teachers in projects supported by the National Science Foundation. They reported that this teaching method was very popular with school teachers taking workshops and courses in these programs. Some of the teachers adapted the approach for use in their elementary and secondary school classrooms. The approach has been used with some success at grades as low as the second grade. In addition, the project directors may have influenced teachers at other institutions of higher education. They presented their results at one national and two regional meetings of the National Science Teachers Association. They received inquiries after each presentation, and also received inquiries after the project was named in a listing of work sponsored by NSF.

Reactions to NSF

The project directors reported being pleased with NSF, and they had very few suggestions for improving its programs. They felt that LOCI guidelines were clear, and comments from program managers were helpful. They would be receptive to closer monitoring of NSF projects through site visits, but they wondered whether site visits would prove cost effective. The one point that they felt strongly about was early notification of awards from NSF. They reported that is was very important that project directors be notified as soon as possible about awards so that they could stick to their schedules in carrying out project work.

Physical Conceptions Used in Problem Solving

The second of the projects that produced inquiry materials for a physics laboratory took place at a state university located in a New England town of 15,000. Established in the mid-nineteenth century, the university has since grown into a multi-campus institution. The campus on which the project took place occupies 1100 acres and 150 buildings, and is the original site of the university. In addition to this campus, the university includes a metropolitan branch campus, a medical campus, and a separate campus for its agricultural school.

The mission of the university is to provide a well-rounded higher education for residents of the state.

Total enrollment at the campus recently numbered 18,000 undergraduates and 3000 graduate students. The university gives preference in admission to state residents, and only 5% of the students are nonresidents. Estimated annual costs at the school were recently $3000 for resident students and $4000 for nonresidents of the state. Recently the university received 12,000 applications for admissions, and admitted 75% of these students. The average Scholastic Aptitude Test scores of entering freshmen were 475 on the verbal section and 525 on the mathematics section. Approximately one-half of the students in an entering class remain for four years and receive degrees.

The student-faculty ratio is maintained at 18 to 1. Approximately 80% of the faculty hold doctorates, and salaries for these teachers are at the national average. Until recently the university provided special support for instructional development activities of its faculty members. An instructional improvement center supported by university funds sponsored workshops for faculty, assisted in course evaluation, and managed a grant program that provided awards of up to $1000 to individual faculty members and up to $2000 to departments for instructional improvement projects. A second center for improving university teaching, located in the school of education and supported by foundation grants, provided consultation on teaching to faculty members throughout the university. This clinic used micro-teaching, video feedback, and systematic observations of teaching as a basis for consultation. Funding losses, however, have eliminated these formal programs of support for teaching improvement at the university.

Background of the Project

The original director of the LOCI project was chairman of the department of physics at the time he submitted his proposal. He was to have overall responsibility for the project and to serve as a member of the project advisory committee. Much of the organization and actual work of the project, however, was to be handled by a staff associate in the department. This staff associate later became research director for the project after the original project director became dean of natural sciences at the university. When the proposal was being written, the staff associate was completing his dissertation in the university's graduate school of education. His field of specialization was instructional applications of computers and mathematics education. He also had extensive experience in Piagetian interviewing.

Several years before the LOCI project began, the project director's interest in educational research and development was stimulated by experiences he had as a member of a university committee charged to deal with freshman writing. Various members of this committee initially had different assessments of the seriousness of problems in freshman writing. Some felt improvement of freshman writing should be given highest priority at the school; others disagreed. When teachers of writing brought in samples of actual freshman compositions, however, disagreements vanished. Committee members agreed that the quality of the writing was very low, and courses needed strengthening. The project director came away from the experience convinced that teachers should look closely at student performance and design instruction that meets students at their level.

The project director was therefore eager to become involved when an educational psychologist who had just received his degree at the education school described his ideas for a problem-solving laboratory at the university. Through the physics department, the two faculty members submitted a proposal for a one-year project to the Fund for the Improvement of Postsecondary Education. When the proposal was funded, the project director and his associates began to collect taped interviews with students on topics in physics. Although the interviews did not systematically explore students' conceptual models, these interviews were useful for suggesting ideas to the project staff and for introducing other faculty members to the work of the research team.

The project director wanted to follow up on the work begun in the problem-solving laboratory with a more systematic exploration of students' conceptual models. He felt that his department was in a strong position to undertake this task. His research team had carried out preliminary studies in this area, and team members knew how much effort was required to catalog conceptual models. Also available in the department was a skilled interviewer--the graduate student who was completing his doctoral degree in education and who became staff associate and then research director on the project.

The project director requested a total of approximately $18,000 from NSF. These funds were to cover salaries for the staff associate and the secretary; subject fees for 20 students, each of whom were to be interviewed for 10 hours; and costs of videotapes and audio cassettes. The project was scheduled to start in August 1976 and to be completed in 12 months.

Project Objectives

The main objective of the project was to produce written documents describing models that students use to conceptualize basic physical laws. The documents were to describe the models in enough detail so that readers would be able to understand how students using these models view the world. The written documents would include appropriate transcripts, and audiotapes and videotapes would be available to illustrate some of the models. Finally, the written documents were to include suggestions about instructional techniques that could be used to lead a student into seeing the weakness of a model or the need for an improved version.

The proposed objective was an unusual one for the LOCI program. The project director explicitly stated that his project was to be a research investigation. Although the project was to result in documents that might be useful to teachers, the proposal did not describe these documents as instructional materials and did not contain an explicit plan for using the documents to improve science teaching locally.

Project Activities

During fall of 1976 the project's research director planned to conduct 10 one-hour interviews with 20 student volunteers from the freshman physics course. These students were to be asked to solve simple physics problems and to investigate simple physical devices. The same procedures were to be repeated during the spring semester with "experts"--10 junior level students and 10 graduate students.

Tapes were to be made of each interview, and the most interesting sections of the interviews were to be transcribed.

In the year following receipt of the LOCI award, the research director carried out the interviews with 18 freshmen in the introductory physics course, and wrote technical reports on students' concepts in several areas of physics: Newton's laws, work, energy, the distinction between mass and weight, and elastic force. A typical technical report consisted of a discussion of the problem used in eliciting student solutions, a classification of students' answers to the problem, excerpts from transcripts of interesting answers, a discussion, and several complete transcripts of responses.

The research director found that students exhibited a variety of misconceptions about concepts of physics. For example, one of the problems used in interviewing students about their concept of energy was:

> Which of the following can be thought of as places where energy is stored? A battery? A highway? A wound watch? A pillar holding up a roof? Food?

Among other things, the research director found that a total of 69% of the students thought that energy was stored in a pillar holding up a roof. Students explained that the pillar "resists compression," "exerts force," or "is under stress." Some of the students said that the pillar exerted an active force--the pillar was "acting on" the roof, the pillar had "energy of motion because it was doing work," and the pillar was "doing work holding the roof up." The research director concluded that students did not distinguish between notions of force, force of resistance, elastic force, and energy in the same way that physicists did. He also concluded that some students understood the role of the pillar in an anthropomorphic way, assigning to the pillar the same properties of "doing work" that they would assign to a man holding up a heavy object. The research director recommended that physics teachers place greater emphasis on the distinction between concepts of energy and force and that they make sure students separate their own feelings of doing work in holding up a heavy object from a physicist's concept of work.

These were the conceptions of students who had not completed college physics. How did more "expert" problem solvers look at these problems? The project director also conducted pilot studies with more sophisticated learners in several of these areas. But he gave less emphasis to this aspect of his project than he had originally expected. His results showed that intuitive conceptions of physical concepts are fairly resistant to change. For at least three quarters of college freshmen, for example, misconceptions about physical force are not changed by a conventional physics courses.

Other Effects

This project was one of several links in a chain of interrelated projects carried out in the physics department. Further support for the work of this research group has come from the Fund for the Improvement of Postsecondary Education, NSF's Research in Science Education Program, and a combined program of the National Institute of Education and NSF on Research on Cognitive Processes and the Structure of Knowledge in Science and Mathematics. The projects of the research group have contributed to instructional theory, to methodology for studying cognitive processes, and to courses and course materials. Courses affected by the research group have been in physics, mathematics, and engineering. As one of the first steps in a concerted effort at research and development, the LOCI project has made important contributions to the shape of the subsequent work of the research team.

The research findings from the LOCI project, for example, strongly influenced the direction of a departmental effort, supported in part by other funds, to develop an introductory "pre-physics" course for freshman engineering students. This four-credit, one semester course included a two-hour laboratory session each week. Rather than emphasizing proficiency with formulas, the laboratory emphasized qualitative physics. In the laboratory, students manipulated simple concrete objects and discussed such concepts as force, velocity, acceleration, mass, and momentum. Students worked in pairs in the laboratory, and the instructor circulated among pairs, spending less than two minutes at a time with each pair of students and returning to each pair several times during the laboratory period. The instructor tried not to spend time giving extended explanations of the "correct" point of view. He provided answers to questions when asked, but more often he simply asked pairs what they had found, suggested a related question, and moved on to another group without waiting for the students to work out an answer to the question.

The findings of this LOCI project have been documented and are being widely disseminated. The basic sources for the project findings are the technical reports written by the research director. But results from the technical reports have been presented to a broader audience in a variety of ways. One important outlet for project results was a national conference on cognitive processes held at the university and sponsored by this research group. Papers from the conference were collected and are available as a book. The research group also recently produced another book on problem solving, and has produced numerous papers and articles on its work. One important paper on project findings was presented to an audience of approximately 200 at a meeting of the American Association of Physics Teachers. Finally, the research team has presented more than 30 workshops at various colleges and universities on its approach to teaching.

Evaluation

The proposal for this project was basically a research proposal. Although the proposer described plans for disseminating his findings, he did not describe plans for implementing project results locally. Nor did the project director propose a formal evaluation of project results. It turned out, however, that project results strongly influenced instruction in a course at the university. The course that incorporates the LOCI materials is a new one in the physics department, and so evaluation has presented some difficulties. Nonetheless, in an effort to evaluate course effectiveness, the LOCI research director has recently collected answers to physics problems from students who have completed this new course, and he has compared these answers to answers from the same students before they took the course and to answers given by students who have taken other physics courses. To date only preliminary results from a pilot evaluation are available; a more careful study is now underway. The research director found, however, that the new course is successful in overcoming some misconceptions that students hold, but misconceptions in other areas--force and acceleration, for example--are hard to overcome.

Reactions to NSF Programs

The research director thought that the LOCI program helped him achieve certain of his goals in research and in teaching. He thinks, however, that the amount of support LOCI provides is sufficient only for fine-tuning of courses. LOCI awards do not seem large enough to bring about major changes in courses or departments. Such changes usually require several years of concentrated effort--and more support than LOCI can provide.

Summary and Conclusions

The two projects described in this chapter had a good deal in common. Both projects resulted in inquiry-oriented laboratories for introducing students to concepts of physics. By any standard both projects were highly successful. One project had an especially strong evaluation; the other was especially strong in dissemination. Both projects contributed substantially to instructional programs in their departments and colleges.

Two factors that may have contributed to the success of these projects are:

a) Both projects were carried out by individuals in science education. The projects were consistent with career goals of the project directors. LOCI work did not represent a diversion from their regular scholarly activities.

b) The LOCI projects were an integral part of larger research and development activities in the departments. The LOCI projects grew out of earlier funded activities of the project directors; the projects contributed to their later funded efforts.

Chapter 5

Other Teaching Methods

The majority of the LOCI projects designed to revise teaching methodology used the approaches to instructional improvement described in the preceding chapters. The project directors revised their courses to incorporate either self-pacing or computer-based teaching, or inquiry laboratories. Not all LOCI projects designed to revise teaching methods, however, were of these three types. Some projects were hard to categorize or fell into classes of their own.

In this chapter we describe two such projects. The objective of the first project was to design desktop kits for chemistry students to use during lecture classes. The kits were to contain models, chemicals, and other materials that students would use while a lecturer gave explanations. The second project asked for "seed money" for a department to use to explore ways to improve its science laboratories.

Aids to Abstraction in Introductory Chemistry

The first project took place in a community college located in the South and serving a metropolitan area of approximately 100,000. Originally established in temporary facilities in 1967, the community college grew rapidly into a multi-campus institution. It moved to a permanent 180-acre site in 1971, created an open campus that operates at more than 200 locations in 1974, and established a third campus on an 80-acre site in 1975. The college now serves over 20,000 residents of the area each year. It offers these learners transfer programs, career education, community services, and general education programs.

The college also provides guidance and counseling for all students and developmental programs for students needing academic assistance.

The student body at the college includes an equal number of full- and part-time students. Recently, enrollment was approximately 3200 full-time students and 3400 part-time students. Tuition at the college was modest, approximately $190 per year for residents of the state and $650 per year for nonresidents. The faculty at the college includes more than 200 members, most of whom hold master's degrees.

In addition to conventional programs supporting faculty development--sabbatical leaves and a tuition-reimbursement program--the college has a distinctive program of support for instructional and professional development activities of its faculty. Each year 2% (or $150,000 in 1979-80) of the college funds are used for staff and professional development awards. Faculty members submit proposals for projects involving either individual professional development or development of courses, curricula, or instructional media. Proposals are reviewed by a committee composed of faculty members and members of the college's administration. Awards have ranged from $700 to $20,000.

Background of the Project

Before joining the faculty as a science instructor in 1968, the project director taught chemistry for four years at a local high school. At the time she submitted her LOCI proposal, she held a master's degree from a leading research university, and was a doctoral candidate in education at a university in the region. She received her doctorate in 1977 and is currently leader of the chemical and biological sciences cluster at her college. There are 11 faculty members in this cluster.

The main stimulus for development of the project director's LOCI proposal was an instructional problem at her institution. The project director thought that too few of the students in Introductory Chemistry actually grasped the concepts and chemical principles that the course was designed to teach. Too many students failed the course. The project director wanted to improve the course's effectiveness.

Some awareness of the character of Introductory Chemistry and of the students who enroll in it is essential to an understanding of this LOCI project. Introductory Chemistry covers material that parallels content covered in two semesters of high school chemistry. The course is considered a prerequisite to General Chemistry for students who have not completed high school chemistry during the last 5 years. Introductory Chemistry is also either prerequisite or part of the curriculum for many two-year associate degree programs at the college, such as fire technology and various paramedical programs. The majority of students enrolled in the course are the first members of their families to attend college. Many of them are older citizens, employed in the area. Many are women. In general, the students are relatively unsophisticated in the sciences and often are less talented academically than the average high school chemistry student.

The project director thought that the concepts of chemistry as ordinarily taught were too abstract for these students to grasp. The students lacked concrete references for the words spoken in lectures and printed in textbooks. The project director thought that these students might grasp the concepts better if they could handle materials such as measuring devices, elements, compounds, and mixtures on their desktops during lectures instead of waiting for laboratory periods.

Another important factor in the project director's development of her proposal was her experience as a doctoral candidate in education. As part of a course requirement, she developed a proposal that described her ideas about improving learning of abstract chemical principles. When the teacher of the course suggested that she submit the proposal to a funding agency, she began searching for an appropriate funding source. She soon discovered that the funding priorities of the LOCI program matched her objectives, and with the help of her college's office of resource development, she prepared her proposal for submission.

Her proposal requested a total of $16,500 from NSF. The institutional contribution to the project was listed as approximately $3000. NSF funds were to cover salaries for two-thirds time for the project director and one-quarter time for a clerical worker for the ten-month duration of the project. NSF funds were also to cover costs of travel and instructional materials. The project was scheduled to begin in September 1976.

Project Goals and Activities

The project director's assumption was that many Introductory Chemistry students would understand abstract ideas only if the ideas were first expressed in concrete ways. She thought that these students could be led toward abstract levels of thought if they carried out concrete operations related to the abstract ideas that

were being discussed. The project director had two specific goals in mind for her project:

a) to develop desktop kits that would help students grasp abstract concepts of chemistry;

b) to demonstrate the effectiveness of these kits by comparing the level of thinking of students taught with and without the kits.

The project was to be carried out in two major phases. The first phase would occupy the last four months of 1976. During this phase the project director would design the desktop kits and the tests to be used in the evaluation of these kits. The second phase of the project was to occupy the first six months of 1977. This was to be the time for implementation of the project. Classes were to be offered using the desktop kits; data were to be collected; statistical analyses were to be run; and the final report was to be written on the project.

The project director made good use of local and off-campus resources in designing the desktop kits and evaluating their effectiveness. Off-campus, she attended a workshop on application of desktop experiments, and she consulted with members of her doctoral committee on design of the project evaluation. On her home campus, she found a colleague in chemistry who agreed to offer experimental and control sections of Introductory Chemistry for the project. She also found two faculty members at her institution who were able to provide help with statistical analysis of her results.

During the first four months of the project, the project director designed the desktop kits for Introductory Chemistry. Each of the kits contained materials for 28 lectures. Kits consisted of an assortment of containers, chemicals, measuring devices, and model-building materials. The project director constructed 60 kits (at an estimated cost of $25 per kit) so that each student in two classes of thirty would have an individual desktop kit during lecture periods.

During this first phase of the project, the project director also designed the tests that she would use in the evaluation. She decided first to classify all students according to level of intellectual development as determined by performance on three Piagetian tasks. To measure student achievement, she decided to look at several variables: scores on a comprehensive final examination adjusted for initial differences in student knowledge; total instructor-assigned points obtained by students in the experimental and control classes on tests, quizzes, and homework assignments; and instructor-assigned grades. As her measure of student attitude, the project director decided to use responses to two individual questions. These questions asked students to identify the degree to which they liked chemistry and the degree to which chemistry was easy for them to understand.

The final task of the first phase of the project was selection of an experimental design. The project director decided to use two instructors in the experiment. Each instructor would teach two sections of Introductory Chemistry: an experimental section and a control section. The project director intended to use standard statistical tests to compare performance in the control and experimental groups.

Evaluation of the Project

The differences that the project director discovered between experimental and control groups favored the experimental group, but differences were not always large enough to be considered statistically reliable. On the comprehensive examination adjusted for initial knowledge, however, differences were clear and statistically significant. Adjusted scores of the entire experimental group were higher than those in the entire control group. In a separate analysis carried out on students at the concrete level of operations, the experimenter obtained the same result. She also obtained the same result in a separate analysis restricted to students at the formal level.

Results were far less clear in analyses that depended on instructor-assigned points and instructor-assigned grades. Total number of points accumulated by the experimental group was significantly higher than total points accumulated by the control group, but the same pattern was not obtained in the separate analyses for students at the concrete and formal operational stages. In addition, there was no significant difference in proportions of students receiving instructor-assigned grades of A, B, or C in experimental and control sections. The proportion of students receiving these grades in both the experimental and the control section was about equal to the proportion who had received these grades from the instructors in the past.

There was also no difference in student responses to the two questions: "I like chemistry" and "Chemistry is easy for me to understand." Although students in both groups developed more positive attitudes toward chemistry during the course, the amount of attitude change as measured by these questions was similar for both experimental and control groups. Informal comments from students, however, provided additional feedback about the effects of the kits on students' attitudes. Use of the kits seemed to increase student enthusiasm. The kits "refreshed" students and provided variety during the lecture-discussion format.

Other Effects of the Project

The effects of the LOCI project extended beyond the original classes in which the kits were used. In addition to the project director, two instructors of Introductory Chemistry at the college are now using the project materials. One of the project director's colleagues is using the kits in both Introductory Chemistry and in a new course titled Chemistry for Everyday Life. Another colleague added his own instructional materials to reflect the requirements of his course. In addition, the project director has received inquiries about her project from faculty members at other colleges and universities. The kits are now being used on some of these campuses, and at one university in the Midwest, a science educator is carrying out a study to replicate her findings on the effects of manipulation aids on concept learning.

The project director has presented her findings at both regional and national meetings of professional associations in chemistry. A paper describing project results will soon appear in the published proceedings of one of the associations. In recognition of her efforts, the project director recently received a national award for good teaching in community college chemistry from the Manufacturing Chemists Association. Recently the project director submitted a proposal to the Department of Energy to develop workshops for high school teachers. She anticipates that her experience as director of the LOCI project will help her in the review process for this proposal.

Reaction to NSF Programs

The project director considered the LOCI program to be an excellent one. She thought that the program guidelines were clear, the amount of money allotted for projects was adequate, and the time allowed for project completion was generous. She considered the requirement for evaluation of project results to be a reaonable expectation of the LOCI program. The project director offered no suggestions for revision of LOCI program policies. She did report, however, experiencing some difficulty in submitting her final project report to the appropriate division of the Foundation, and she suggested that efforts be made to improve coordination between the various divisions of NSF.

Laboratory Instruction at a Liberal Arts College

The setting for the second project was a coeducational church-related liberal arts college founded in 1826. About 20 years ago the college moved to its present 750-acre campus just outside a Southern city of 100,000. Located at the foot of a mountain in one of the South's most scenic regions, the campus includes a 30-acre lake, an 18 hole golf course, a rose garden, a Japanese garden, and many fountains and pools. The campus contains 22 buildings, all completed since 1958. The major buildings are faced with handmade Virginia brick and many have columned porches.

The student body numbers approximately 2500. Although most states are represented in the student body, more than three-quarters of the students come from the South Atlantic states, and most live in the college residence halls. Estimated expenses for students are about $5,400 per year. The admissions policy is very selective. In 1979 the college received 1845 applications for the freshman class, and enrolled 674 students. The entering class averaged 1078 in combined SAT scores. Approximately 15% of freshmen do not return for the sophomore year; approximately 65% of the entering freshmen remain to graduate; and approximately 75% of those who graduate continue their studies in graduate or professional schools.

Many of the students are interested in science. Freshmen, for example, choose biology as their field of interest more often than any other field. Many of these freshmen, of course, are interested in careers in medicine, and their interests shift by the time they declare majors. Of the 390 degrees conferred in 1979, 19 were in biology; 15 in chemistry; 11 in computer sciences; 7 in geology; 6 in math; and 1 in physics.

<u>Background for the LOCI Project</u>

The LOCI project was one link in a chain of interrelated activities at the college. These activities started three or four years before the LOCI project was funded when the college received grants from the Exxon Education Foundation and Ford Foundation to support work in planning. To determine curricular goals, one of the planning procedures developed under these grants used the analogy of a trip. Departments tried to answer questions asked by travelers: Where are you now? Where are you going? Who is going with you? How will you know when you get there? Another planning procedure developed at the college required departments to identify their strengths, weaknesses, opportunities, and threats (or SWOT's) in key planning areas. Exxon and Ford grants had an important influence at the college, and each year each department uses procedures developed under these grants in curricular planning.

Another important link in the chain of events leading to the LOCI project was a grant for faculty development in academic planning received from the Kellogg Foundation in 1975. This grant helped faculty members follow systematic procedures in developing curricula, courses, and new instructional strategies. The Kellogg grant provided faculty members with released time and other support services to work on problems identified through the SWOT's analyses and other goal-setting procedures. Participation in the Kellogg program was voluntary, but in the three years of the project, a total of 58 out of 145 faculty members participated.

In 1975 the biology department identified laboratory instruction as a key area of concern in its SWOT's analysis. An associate professor of biology was identified as an individual who would work on the problem. He knew that the Kellogg grant could provide support to a faculty member working on instructional and curricular change at the college. He also knew about NSF's LOCI program. He decided to try to obtain funds from both sources to work toward a solution to the problems of laboratory instruction in biology.

One distinctive aspect of the proposal this faculty member developed was its exploratory character. Like other college teachers, this faculty member had heard a great deal about individualized instruction--audiotutorial teaching, computers, modules, mastery learning, personalized instruction, and so on. His major objective was to determine which of the practices and materials would work in laboratory instruction at his university. In his proposal, he requested funds for both a period of exploration of alternatives and a period of implementation.

The proposal requested approximately $6500 from NSF. The project director's institution was to contribute another $4000 to the project. The major item on NSF budget was summer salary support for the project director and an assistant director; other small items were student assistance, secretarial help, travel, and materials. The project was expected to begin in June 1976 and to be completed in 15 months.

Project Goals and Activities

The LOCI project had two major objectives: exploration of alternatives available to the department and use of selected alternatives in laboratory instruction at the college. Within one year of the start of the project, the project director had completed both major tasks. He and his colleagues had explored major alternatives in laboratory instruction, and he and his students had completed 30 slide-tape presentations on topics in biology.

To compare alternative methods of laboratory instruction, the project director arranged for workshops, site visits, and demonstrations. First, he invited Samuel Postlethwait of Purdue University to campus to conduct a workshop on audiotutorial instruction. Although the department reached the conclusion that audiotutorial instruction could not be used in all laboratories, department members felt that some features of audiotutorial instruction could be incorporated into their new program. Second, the project director and his associates visited other campuses in order to study their methods of laboratory teaching. Third, they attended workshops on a variety of topics, including computer applications in the classroom, competency-based education, alternative modes of instruction, and Keller's personalized system of instruction. Finally, they obtained a number of commercially available materials and looked into ways of using these materials in individualized laboratory instruction.

To begin implementing more individualized instruction in the biology department, the project director had students prepare slide-tape mini-courses on basic laboratory procedures and topics. The library of 30 slide-tapes that resulted from this project served as a core of materials for individualized laboratory teaching. In addition, the activity of developing slide-tape mini-courses proved to be useful in itself since it allowed faculty and students to interact on a one-to-one basis while making slides and planning mini-courses. Peer review of preliminary slide-tapes helped refine final products and also served as valuable learning experiences.

All the slide-tapes are now available at the biology department's learning center two years after the completion of the LOCI project. The tapes are neatly cataloged, and easily obtained by students. Faculty members in the biology department today use the tapes in different ways. Some use the tapes to supplement instruction--to enrich the content of lower-division courses or for remedial teaching in upper-division courses. A faculty member simply mentions the availability of a slide-tape, and students have the option to use it if they want to. In other cases, faculty members require the use of slide-tapes in courses. Instructors assign the tapes to minimize the amount of lecture time spent on routine teaching or to minimize the amount of individual instruction necessary on laboratory procedures. The project director reported that during the course of a year all instructors in the biology department would use the slide-tapes in one of these two ways. He also reported that the rate of use of the slide-tapes is increasing. While it is not so great as he had hoped, use is greater than he had expected.

An important outcome of the LOCI project was increased awareness at the college of options available for science teaching. This awareness helped shape the science division's successful 1977 proposal to NSF's program on Comprehensive Assistance to Undergraduate Science Education (CAUSE). The director of the LOCI project made important contributions to this proposal, and served as CAUSE project director for one year. The two-year project required more than $200,000 of NSF funds and more than $125,000 of institutional funds, and involved the seven science departments at the college: biology, chemistry, computer science, geology, mathematics, physics, and psychology. The effects of the CAUSE project are quite visible in many of these departments today. Attractive and popular learning resource centers function in the departments of biology, mathematics, and computer science. A modular mastery course is thriving in the mathematics department. Laboratories in some courses went from a cookbook approach to a more individualized method of teaching. The use of media in science increased.

The physical changes in departments brought about with NSF funds seem to be a source of pride to the science faculty. Many science teachers became deeply involved in project activities, and their attitude toward the project today is very favorable. Most of the changes that took place at the college, however, occurred after the CAUSE award was made. The LOCI project director, in fact, mentioned that he had some trouble in involving others in course revision before the CAUSE award was received. He also felt constrained in what he was able to do with the amount of money available from LOCI. The CAUSE grant solved both these problems. Because of the availability of summer salary and the growing scope of the project, the project director received fuller departmental cooperation on the CAUSE project. He was also able to buy the equipment he needed--not just a single audio-slide viewer but the ten that were necessary for a learning resources center.

Evaluation of the Project

The proposal for the LOCI project did not contain a separate evaluation section; the evaluation activities described in the proposal were informal. The project director was to gather questionnaire data on project effectiveness from students and laboratory assistants and to present progress reports to the biology department faculty at departmental meetings. The purpose of the evaluation was to improve the implementation of the new laboratory procedures.

The evaluation that took place was informal. The project director reviewed student reactions to the slide-tapes with his colleagues. Overall, they judged the tapes to be of generally good quality. Some seemed "better than commercially available"; others seemed fairly rough in finish. Discussion of these and other reactions to the initial project played an important role in development of the CAUSE proposal.

Reactions to NSF

The project director felt certain that without NSF support, the college could not have gotten so far in laboratory teaching so quickly. Without LOCI and the related CAUSE grant, it would have taken five or six years to make the changes in attitude and in facilities that were made during the grant period. In general, therefore, the project director felt very pleased with NSF programs that made these teaching improvements possible.

Small changes, the project director thinks, might improve the clarity of NSF program guidelines. The guidelines for final reporting, for example, were not completely clear. During the grant period, the project director felt out of touch with NSF. Because of rotating staff at the agency, he did not know whom he should contact about problems when they arose. He suggested that NSF install an 800 number so that calls could be made to NSF without expense.

The chemistry department chair and former dean at the college also made a number of comments about NSF programs and guidelines. He thinks that small planning grants are a good idea, and he hopes that foundations will continue to provide small grants before making large final awards. He does not think it appropriate to use "innovativeness" as a criterion in making awards for improvement of science education. He prefers grant programs where project directors are allowed flexibility and responsiveness in use of funds; likes the low visibility of NSF once awards are made; and recommends greater clarity in NSF guidelines and requirements. The last point seems especially important to him. He feels that requirements of specific programs are not made clear enough to project directors. Changes in requirements are not always communicated promptly and clearly. He thinks that program managers should provide a letter on specific requirements to project directors, and should update the letter as necessary.

Summary and Conclusions

Although both these projects took place in the South and both made contributions to their institutions, they had little else in common. The two projects were carried out at different types of institutions with different types of student bodies. One project had a departmental emphasis; the other emphasized improvement of a single course. One project emphasized exploration; the other emphasized outcomes. One project contained a strong evaluation design; the other gave little attention to formal evaluation.

The juxtaposition of the two projects helps make the point that LOCI projects are diverse. The program provided seed money for a department to explore alternatives for redesign of laboratories, and at the same time it provided support for dissertation research on development and evaluation of materials for teaching introductory chemistry. Both projects proved to be of benefit to their institutions.

Chapter 6

Curricular Projects

In the preceding chapters we described LOCI projects designed to revise the teaching methods used in science courses. In addition to supporting projects on teaching methods, LOCI also funded projects designed to revise or update the content of science courses. In 1976 approximately 30% of all awards were for curricular projects; in 1977 curricular projects were 40% of the total; and in 1978 they were 47% of the total. Some of these curricular awards were for projects to update introductory courses, some were for revision of advanced courses, and some were for development of sequences of courses.

In this chapter we describe three curricular projects. The first was a project to design laboratory exercises using the same set of materials for two different biology courses so that learning in one course would reinforce learning in the other. The second project was to design an interdisciplinary, problem-oriented course on transportation. The course was to introduce freshmen to the major areas of science in a single, team-taught course, and it was also to serve as a prototype for a total unified science curriculum. The third project was to revise the content of a course in computer science. The revised course was to cover microcomputer technology in a hands-on environment.

Integrated Laboratories at a Liberal Arts College

The first of the curricular projects took place at a private, nonsectarian liberal arts college located on a ten-acre campus in one of the major metropolitan areas of the East Coast. The college was established at the turn of the century to prepare women for specific

careers, either immediately upon graduation or following postgraduate education. To achieve this goal today, the college offers programs that combine the liberal arts and sciences with professional preparation.

The undergraduate student enrollment consists of some 1700 women, and the graduate enrollment consists of about 1000 women and men. About 50% of those attending the college are in-state students. The majority of the others are from the North Atlantic states, but almost every state and over a score of foreign countries are represented in the student body. About 60% of the students live on campus, and the others commute. Resident students pay approximately $7000 in tuition and fees each year; commuting students pay nearly $5000.

Recently, 1420 applications for admissions were received at the college; about 82% were accepted; and 422 freshmen enrolled. The entering class averaged 480 on the verbal section of the Scholastic Aptitude Test, and 500 on the mathematics section. About 75% of these freshmen are expected to graduate in four years; and about 20% to 25% of the graduates are expected to go directly to graduate school.

The faculty at the college consists of 150 full-time members, approximately 50% of whom hold the doctorate. Salaries for these faculty members are above the national average. Their teaching load is 12 contact hours per week; student-faculty ratio is 12 to 1; average class size is 15 students. There is no formal faculty development or instructional improvement center on campus, and released time is not usually available for course improvement projects. Faculty members are expected to work on course and curricular revision as part of their regular teaching duties or to do more concentrated work on curricular revision during sabbatical years.

The LOCI project was designed to affect courses in biology, a department with eight full-time faculty members housed in the school's modern science center. This department's concentration program prepares students for immediate employment or for further academic specialization. Students majoring in biology take a two-semester core biology program, and then select from defined groups of courses those that will best suit their own interests and goals. Students may choose an animal track, botany track, a mixture of the two, or a double major. In the junior year, biology students design independent study projects which are completed in the senior year.

Background of the Project

The faculty member who developed the LOCI proposal came to the college as an assistant professor in 1975. After receiving her Ph.D. in 1957, she taught and carried out research at several research universities. In addition, during the sixties, she sought out opportunities for retraining and reeducation to keep abreast of her field. She was perceived by the biology department chairperson as an individual who could advance rapidly at the college.

This faculty member brought with her perceptions of her new role that were consistent with her earlier background in research. She was knowledgeable about grant proposals and proposal writing, and on arriving at the college she made it a point to learn about funding programs in education. During her first year at the college, she developed proposals and received awards for research and development projects from NSF's LOCI program and its Women in Science program.

Although her faculty colleagues supported her in her LOCI work, they initially had some reservations about the project. First of all, the courses to be redesigned with LOCI funding were courses taught not by the project director but by other faculty members in the biology department. To put together her proposal, the project director had to convince her colleagues to revise their courses. Second, the department chairperson felt that a great deal of laboratory revision could be carried out strictly with department funds without a heavy investment of government money on salaries and equipment. The LOCI proposal requested more than $17,000 from NSF for faculty salaries, student salaries, and equipment to design or redesign four laboratory experiments in two courses--about one-third of the laboratory work in these courses. The department chairperson at first wanted the future project director to wait and see what could be done with local funds before requesting outside money, but the department chairperson too eventually offered support for the LOCI proposal.

Project Objectives and Activities

The proposed project was designed to coordinate the laboratory work of students in two separate courses, Chemistry and Biology of Cells and Genetics. Before the project began, students at the college often took the two courses concurrently, but the courses were taught independently by two different faculty members. No special effort was made to relate the content in one of the courses to that in the other. The purpose of the proposed project was to interrelate the learning experiences of the students by providing coordinated and complementary laboratory materials for the courses. In the proposed approach, each course was to be presented autonomously and each teacher was to function independently, but the materials used in the two courses were to overlap to a significant degree. The proposed project was therefore meant to give students a more unified view of the biological world.

The proposal identified four major areas for this integrated approach. Coordinated laboratories were to be designed for each of these areas. One of the areas, for example, was use of electrophoresis to characterize proteins. In the laboratory in Genetics, students were to mate strains of fruitflies differing in electrophoretic mobility of prominent enzymes; in the laboratory in Chemistry and Biology of Cells, they were to examine the properties of these same enzymes in detail. Other laboratories involved the same sort of coordination and work on common materials.

The activities of the project were to be carried out in two major phases. The first phase was scheduled for completion during the summer of 1976. During this phase the two courses were to be reorganized, and laboratory exercises were to be designed for the four areas. The second phase was to be completed during the spring of 1977. Second phase activities were classroom testing of the laboratory exercises and evaluation and summary of project results.

The first phase of the project moved along according to schedule. During the first weeks of the summer, outlines were written that coordinated topics both in the laboratory and lecture sections of each course and in the laboratories in Cell Biology and Genetics. During the remainder of the summer, laboratory guides were developed for the four areas of the courses. This work was the joint effort of three faculty members in the biology department and three student assistants. The faculty members provided the basic outlines for the laboratories. The students tested laboratory procedures and contributed to the inevitable reworking and refinement of these procedures. During this phase of the project, necessary equipment and supplies were ordered for the laboratories.

Several events occurred during the second phase of the project that curbed the smooth flow of project activities. The first of these was a lower-than-expected joint enrollment in Genetics and Cell Biology in the spring of 1977. The project director had expected a joint enrollment of 35 in the two courses, and expected also that other students would enroll in only one of the courses. The enrollment common to the two courses, in fact, was only four students. The number of students to be affected by the project was clearly less in this term than the project director had hoped it to be.

Two other events occurring in the spring of 1977 were equally important for the long range outcome of the project. First, the project director resigned from her position at the college. She presently holds a full-time research position at a major research university. Second, the assistant professor responsible for the course in cell biology, then in his sixth year at the college, left the institution for another position. With the final report on project outcomes only a few months away, the project lost two-thirds of its faculty, and had involved only about one-tenth the number of students that was anticipated.

The one remaining project staff member became project director, and he decided to give the project another year before drawing conclusions. Genetics and Cell Biology were scheduled to be offered concurrently again in the spring of 1978, and so there was another opportunity to show the value of the coordinated laboratories. The number of students enrolling concurrently in the two courses in the spring of 1978, however, slipped to two. With only two enrollments common to the two courses, there was even less point than previously in coordinating the two laboratories. There was also less possibility of coordination since the new teacher of Cell Biology was a visiting faculty member who knew little about the LOCI project. And finally, with the departure of the original director, the project lost the driving force behind coordination. The idea of coordinated Genetics and Cell Biology laboratories died a quiet death.

Project Outcomes

The proposal for this project described a controlled evaluation of project outcomes. Controlled evaluation seemed possible because the project director expected to be able to locate four different groups of students. These groups were: students who had taken the two courses before any revisions were made; students who would be taking both courses concurrently; students who would be taking only Genetics in the revised format since they had previously completed Cell Biology; and finally, students who would be taking only Cell Biology in the revised format since they had previously completed Genetics. The project director planned to develop and administer a questionnaire to students in each of the four groups. In addition, the two faculty members teaching the pilot courses were to compare student performance in the revised courses with student performance in the courses before they were revised to evaluate the impact of the changes.

With a far smaller enrollment than anticipated, the new project director decided to abandon plans for formal comparisons in favor of a less formal evaluation. In the first year of the coordinated laboratories, he solicited written comments about the project from the four students who were enrolled in both Genetics and Cell Biology. The two students who turned in written statements were both positive about the integrated laboratories. The two students who did not turn in written comments also indicated that they too liked the integrated labs. In the second year of the revised courses, only two students took Genetics and Cell Biology concurrently. Both students reacted favorably to the idea of integration, but neither submitted written comments about the laboratories.

The faculty member who teaches Genetics is convinced of the value of the experiments developed under the LOCI grant, and he is presently using these laboratories in his course. No attempt is presently being made, however, to coordinate these experiments with laboratory work in Cell Biology. It is possible, however, that in the future the integration of the two laboratories may be given greater emphasis.

We were unable to find any evidence that this project had an impact on courses other than Genetics and Cell Biology at the college. Nor could we find evidence that the project had an impact outside the college. The project did not affect institutional costs. Nor did it affect the college's service to a broader community. We could find only one unintended effect of the project. The dean of science reported that she would scrutinize grant proposals more carefully in the future and try to make sure that proposals went forward only when they had a reasonable chance of success.

NSF Programs

The original project director considered the LOCI funding program to be an excellent one. She found program guidelines clear, and the amount of money, time allowed for completion, and reporting requirements all excellent. The second project director agreed with her on all major points. He felt, however, that there should be greater scrutiny of projects for commitment and ability of personnel to see the projects through to the end. The dean of science at the college agreed with him on this point.

The dean of science also pointed out that many curricular revision projects can be carried out with departmental funds and without supplemental money from government agencies. She recommended that government agencies and foundations give priority to two types of teaching improvement efforts. First, she emphasized the need for support for development of new programs. To remain vital, colleges need to develop new programs, but it is often difficult for deans and chairpersons to find money for new programs. Federal government agencies and foundations can help by providing funds. Second, she emphasized the need for money for replacing, upgrading, and maintaining equipment. In the tight economic circumstances of higher education today, few colleges have all the equipment that is needed in scientific laboratories. Most colleges could use help in equipment and upgrading their teaching laboratories.

A Unified Science Course at a Community College

The second LOCI curricular project took place at a private two-year college in the downtown area of a New England city of 200,000. This two-year college grew out of the education program of a local YMCA at the turn of the century, and to this day the college uses some of the physical facilities of the Y. About ten years ago the Board of Trustees of the college established a separately chartered upper-division college, and today the upper- and lower-division institutions share facilities and administration and work toward a common purpose. Together the two divisions aim to be, and hope to be seen as, a "no frills," low-cost, community-oriented, independent educational institution presenting quality programs consistent with the needs of the employing community.

Enrollment in the two divisions of the college numbers approximately 1200 students. Of these, approximately 300 are full-time and 900 are part-time students. In a recent class, one-fifth of the students were women, and two-fifths were foreign. The institution today is trying to increase its enrollment in all categories except foreign. Its greatest current emphasis, however, is on increased enrollment of part-time commuter students.

The typical full-time student at the college is low in academic skills. The average Scholastic Aptitude Test verbal and mathematics scores of a recent entering class, for example, were 384 and 419 respectively. Given this low level of academic ability, attrition has been a problem. About 25 to 30% of the students who enroll full-time graduate in four semesters, and another 5% graduate after one of two additional semesters. The majority of those who graduate from the lower-division college, however, go on to four-year colleges. About 70% of the students currently enrolled at the college are in engineering or engineering technology programs. Nearly 20% of the students are studying business, and only about 10% are currently enrolled in liberal arts and science curricula.

Before 1975 seven full-time faculty members taught in the three science departments of physics, chemistry, and biology. In 1975 the three departments were merged into a unified physical sciences department. Subsequently, two members of the mathematics faculty were brought into this department, and it was re-named the natural sciences department. Because of the small number of science students at the college, the major task of this department is to provide service courses for other programs. The engineering program, for example, requires students to take three courses in physics offered in the natural sciences department.

Teaching loads at the college are typically 12 contact-hours per week. The institution is not ordinarily able to provide released time for faculty members to work on course development. Nor does it have available many special resources to support this kind of work--consultants, a mini-grant program, or summer salary for curricular projects. Outside help is therefore important for sustained instructional or curricular development, but before the LOCI grant, the college had never received government money to support instructional research and development activities.

Project Goals and Activities

The faculty member who developed the LOCI proposal first came to the institution in 1975 as chairman of the newly formed department of physical sciences. He had previously worked for one of the East Coast's largest research and consulting firms, and he was knowledgeable about development of proposals and administration of research grants. One of the college's expectations was that its new chairman of physical sciences would develop grant proposals in the science area for the school.

The proposal that this faculty member developed for the LOCI competition was to design a one-year problem-solving course focusing on a single issue--transportation. The proposed course was to introduce students to central problems in the physical sciences, mathematics, and engineering in a single, team-taught course. The course was also to serve as a prototype in the development of a unified science curriculum at the college. In the first sentence of the proposal to LOCI, in fact, the proposer stated his intention to use the course as the basis for a more comprehensive proposal for support from the NSF's program of Comprehensive Assistance to Undergraduate Science Education (CAUSE).

The proposed project was to be short in duration. It was scheduled for completion within three months of the starting date, and the author of the proposal required less than $6000 to complete the project work. The money was to be used to cover the salary of the project director during the summer of 1976 and to pay a small amount for a consultant's time. The anticipated outcomes of the project, on the other hand, were substantial. They included a basic course outline, descriptions of teaching strategies to be used, lecture notes, and laboratory programs for the course.

During the three months in which the project received formal funding, the project director planned for the course on transportation, and created drafts of preliminary planning materials for the course: a number of flow charts, an extensive taxonomy of engineering concepts, and a grid that related these concepts to several substantive areas in engineering. The basic outline, lecture notes, and laboratory programs were not put into final shape during the three-month period of the project, and the proposed course on transportation was not offered in the 1976-77 academic year.

Although the LOCI project described in the proposal to the NSF was meant to be a three-month project, the LOCI program in 1976 gave project directors a generous amount of time to complete their work. Final reports were due at the NSF by December 1978 on all projects begun in the 1976 fiscal year. At the end of the three-month funding period, therefore, the project director still had ample time to get material into shape, offer the course on transportation, and complete the project successfully before a final report was due at NSF. But before December 1978 events occurred at the college that radically changed the course of the project.

In September of 1977 NSF's CAUSE program provided funds for a unified science curriculum at the college. The amount of funding (over $100,000 provided by NSF) was large; the duration of the project was relatively long (14 months); and the project was ambitious in scope. It described a project to create a problem-oriented, team-taught science curriculum that would require a 12-credit-hour, one-year commitment from students. The curriculum was to focus on four areas: communications, transportation, modern hospitals, and municipal government.

In the eyes of the project director and of administrators at the college, the CAUSE project did not follow a smooth course. A number of factors were probably to blame. It is impossible to describe all of them in detail, and at any rate an extensive description of the CAUSE project is outside the scope of this report. But since the LOCI and CAUSE projects were closely linked in time, in content, and eventually in fate, it is probably necessary to give an account of some of the major occurrences on the CAUSE project.

In retrospect, it appears that the base of support for a unified science project was probably too small to begin with. The idea for a unified science project came primarily from the chairman of the physical sciences department and from the dean of the college. There was apparently little or no support for the idea among the engineering faculty--a key group at the college. Faculty in the physical sciences department knew little of the proposed project until it received funding. Although these faculty members were reported to be supportive of the project once it began, they had little input into the proposal or into the design of the project. Ownership of the project was in the hands of the project director and the college dean.

Just as grant activities were getting underway, there was an important change in administration at the college. A new president and a new dean came on board. With this change in administration came a new set of institutional priorities. The new president defined as his top objective the strengthening of the college's engineering program. This program had been a candidate for accreditation for ten years, and for the continued financial viability of the institution, accreditation was a necessity. The institution turned out to be successful in this effort to strengthen engineering. Its program recently received accreditation, but to achieve this objective the college had to use all available resources in this single major effort.

To the new administration, the unified science program looked like a very costly approach to teaching. It required expensive equipment, and it required a costly form of team teaching. The expenses were particularly troubling since the institution was using all its available resources to upgrade its upper division program in engineering. The unified sciences program could hardly compete successfully for funds. Other aspects of the program also raised serious doubts. Students taking unified science would be opting for 12 credit-hours per term of science as freshmen; unified science would be practically their total program. Administration members thought that such a program would be unbalanced and would not be appealing to the students it desperately wanted to attract to its campus. The new administrators at the college therefore refused to make unified science a requirement for entering freshmen.

The project director resigned from the college before his project was completed, and the unified science course he envisioned was never taught. In its place the department offered another two-term, 12-credit-hour course. This course was also interdisciplinary and team-taught, but it was not so broad in scope as the course originally planned. It focused on the modern hospital only--not on communications, transportation, and municipal government. Extensive materials were created for this course. Although it increased their work load appreciably, five faculty members jointly offered the course. Fifteen students volunteered to take it; six of them were left after the first semester to do second semester work.

Evaluation

The original proposal for the LOCI project described the procedures that would be necessary to evaluate the course on transportation. To judge the outcomes of his project, the project director expected to compare: (a) basic knowledge of learners in the pilot project and learners in the traditional engineering curriculum; (b) problem-solving skills of learners in the two groups; (c) ability to learn new skills in the future by members of the two groups.

The course in transportation was not offered; the appropriate measuring instruments were not devised or selected; and so the relevant measurements of course outcomes were never made. Nor were measurements of the sort described made in the course on the modern hospital. Only six students stayed with that course for the whole year, and the number seemed too few to justify rigorous comparative evaluation.

The faculty member who directed the CAUSE project at its completion instead arranged for self-evaluation of the course on the modern hospital. The five faculty members who team taught this course made observations about its teaching and noted student reactions to the course on a daily basis. One of these faculty members kept notes on observations and reactions. In general, the faculty team thought that this course was successful for those students who completed it. Although these students said that the course required a lot of work, they also said that it was worth the effort. But since initial enrollment was low and only 40% of those initially enrolled survived the first semester, the course was dropped from the curriculum.

The current chairman of the science department at the college points to several positive outcomes of the project. First, the NSF project caused the department to try new teaching methods. Team teaching, which had not been used in the science departments before the college received the LOCI and CAUSE awards, is now being used successfully at the college. After working together in the course on modern hospitals, a biologist and a physicist began team teaching a new natural science course. The interdisciplinary flavor of the course is a direct outgrowth of work on the LOCI and CAUSE projects.

The LOCI and CAUSE projects also made the institution more aware of factors to consider in mounting new programs. Today, the college is committed to undertaking "market analyses" before making commitments of its own funds to major new programs or seeking outside funds for such programs. The chairman of the department of natural sciences anticipates better results with more extensive assessment of needs for new programs. He points with some satisfaction to a project supported by the Fund for the Improvement of Postsecondary Education to develop an industrial laboratory for the college. The project was consistent with the objectives of the college, and the outcomes of the project have been positive for the school. He hopes that future projects supported with outside funding will also contribute to major institutional objectives.

Reactions to NSF

Both the original director of the LOCI and CAUSE projects and the faculty member who succeeded him as director of the CAUSE project commented about NSF programs. Both project directors said that the LOCI and CAUSE projects would not have been possible without NSF support. They reported that program guidelines and reviewer comments were clear and helpful. They thought that visits by NSF staff members to the projects were useful, and saw NSF personnel as responsive and helpful in providing funding extensions.

In the eyes of the original project director, however, evaluation guidelines were not strict enough. In his opinion, NSF should demand an account of results from LOCI and CAUSE projects. This project director also suggested modifications in LOCI policy guidelines. He recommended that institutions providing matching support for LOCI projects be screened more carefully. He also recommended making LOCI awards larger and to fewer project directors to improve the impact of projects. The individual who completed LOCI and CAUSE activities at the college said that more on-site visitation would be helpful at institutions that are not experienced in carrying out instructional and curricular development with federal funding.

Development of a Microprocessor Laboratory

The site for the final project was a state university located in a small Midwestern town. Chartered in 1868, the university has two campuses and a total enrollment of 30,000 making it the eighteenth largest university in the country. Although the institution is not a major research university, it offers doctoral degrees along with master's, baccalaureate, and associate degrees.

The university had a recent enrollment of about 19,000 undergraduate students and 11,000 graduate students. The majority of the students were residents of the state. Tuition and fees were approximately $750 for residents and approximately $1800 for nonresidents; total expenses were estimated at $3200 for residents and $4300 for nonresidents. Admissions were competitive. Recently the university received over 8000 applications, and it accepted about 75% of them. The average score for the entering freshmen on the American College Testing Program tests was 19. About 30% of freshmen graduate with their class, and 25% of the men and 15% of the women pursue graduate study.

The faculty consists of more than 2300 members. Salaries for these faculty members are at the national average, and these faculty members can turn to a variety of sources for support for instructional improvement and professional development activities. A mini-sabbatical program provides travel grants to individual faculty for attendance at conferences and workshops. Summer teaching improvement awards provide one to two months of summer salary for course and professional development. A total of $50,000 per year is budgeted for these awards. Released time is also occasionally available, although awarded informally through individual departments. The Learning Resource Center at the university provides consultant services to faculty members with instructional problems. This Center also provides technical assistance to faculty members interested in developing instructional aids.

Background of the Project

The director and co-director of the LOCI project were both faculty members in the computer science department. The project director received her doctorate in computer science from a research university in the Midwest in 1975 and came directly to the department of computer science as assistant professor. Her teaching and research interests included design and implementation of software systems and programming languages. At the completion of the LOCI project in 1978, she left her teaching position to pursue research at a major research laboratory. The co-director got his Ph.D. in mathematics at a research university in the Midwest in 1969. He also came directly to the department of computer science as an assistant professor. He was promoted to associate professor in 1975, and became department chairperson in 1977. His teaching and research interests include design of hardware systems, theory of computation, and analysis of algorithms.

The department of computer science is a relatively new department at the university. First established as an independent academic department in 1970, it began to offer an undergraduate major in 1974. Like the field of computer science the department of computer science has grown rapidly in recent years. In 1974 the department had 25 undergraduate majors; in 1977 there were 200; in 1980 undergraduate majors totaled 400. There are currently 10 faculty members in the computer science department.

Two developments in computing stimulated the project co-directors to develop their proposal. The first was the arrival of microprocessors on the computer market. Soon after the first microprocessor appeared in 1971, it became apparent to the project directors that microcomputers would revolutionize computing. New methods of operation would replace the old; "central processing" would give way to "distributed intelligence"; and the use of computing would expand rapidly into more and more sectors of society. Computer science departments were not making adequate preparations for this imminent revolution, the project directors thought, and this troubled them.

A second development that concerned the project directors was a growing tendency to separate hardware and software concerns in computer curricula. One of the clearest signs of this split was the presence on college campuses of separate hardware-oriented computer engineering departments and software-oriented computer science departments. With hardware and software taught separately, students found it difficult to appreciate total computer systems. Their lack of a broad perspective was not too serious a problem as long as large machines dominated the computing field. Such machines needed specialists for support. But with the rise of smaller computers, generalists familiar with all aspects of computer systems would be needed. Students would have to know both hardware and software and how the two were related.

In 1976 the project directors' department was already beginning to integrate instruction on hardware and software. A new course, Fundamentals of Computing Systems, offered for the first time in the fall of 1976, used the department's new mini-computer laboratory to give students hands-on experience with both hardware and software. But with an enrollment of 48 in the new course, the laboratory could not provide time for exclusive use of the mini-computer by each student. Laboratory projects had to be limited to those which could be carried out on a shared machine.

The project directors thought that they could solve both their problems by revising Fundamentals of Computing Systems to include a microprocessor laboratory. This revised course would bring the latest computer technology into the computer science curriculum, and it would at the same time give students a chance to develop their own small computing systems in an unlimited hands-on environment. The project director's 1977 LOCI proposal asked NSF for approximately $25,000 for this project. Institutional contribution was listed as $26,000. The project was scheduled to start in June 1977 and was expected to be completed in one year. The bulk of the NSF funds were to be used for summer salaries for the co-project directors. Just over $3000 of NSF funds were to go for computing equipment.

Project Objectives and Activities

The major objectives of the project were two:

a) to imbed microprocessor technology into the curriculum;

b) to give students the opportunity to study the relationship between computer hardware and software through hands-on design of a microprocessor-based computer system.

The project directors intended to devise a new type of course that would provide each student with a microcomputer as a personal and portable laboratory. The microcomputers were to be both an object of study and a pedagogical tool.

The new course was to consist of four modules that would show students how to build a total computing system. Starting with a simple piece of hardware, students would develop their own loaders, text editors, and assemblers. The four modules were to cover:

a) Design of the microcomputer--a module to introduce students to digital logic circuitry.

b) Interfacing--a module on the techniques necessary to enable microcomputers to communicate with other devices.

c) Applications of microcomputers--a module on a simple application of microcomputers, such as simulation of a digital watch.

d) Building a computing system--a module on writing a self-assembler for the microprocessor.

To create the course, the project directors needed to accomplish at least two tasks. First, they had to write material for students since a completely suitable text was unavailable. Second, they had to prepare computer hardware and software support. They intended to initially purchase eight microcomputers along with supporting manuals and equipment, and enlarge the lab only after using it for a semester in teaching. A graduate student was to assist in readying the laboratory for the revised course.

Project activities moved along on schedule for the most part. Only small adjustments were made to the original plans for the project. One of the proposed modules--on applications of microcomputers--was not developed. Another module was written in its place. One of the programming tasks originally expected to be completed in one year in the end required the part-time efforts of one faculty member and four graduate students over a period of two years.

The project directors first offered Fundamentals of Computing Systems with a microcomputer laboratory on a trial basis during the 1977-78 academic year. The first offering of the course provided opportunities for discovering unexpected problems and for refining materials and procedures. When the course was first offered, one of the project directors noted, only two out of eight students were able to complete a difficult assembler programming problem at the end of the course. When the course was offered for the fourth time recently, 65 out of 80 students completed this assignment. The project director was pleased that the revisions have apparently added to course effectiveness.

Today the microprocessor is an established part of Fundamentals of Computing Systems, a course required of all undergraduate computer science majors. The laboratory has grown in size to 30 microprocessors--half are Motorola 6800's and the remainder are Intel 8085's. Ten of these microprocessors are set up as permanent "base stations" in the laboratory; the remaining computers are available for checkout by students. The laboratory easily supports 60 to 80 students in Fundamentals of Computing Systems, and can probably support more students. Maintenance of equipment in the microprocessor laboratory has not been a problem. The microprocessors are highly reliable, and costs for maintenance are less than $1000 per year. Departmental funds budgeted for purchase and maintenance of equipment easily cover this item, and a part of these funds go toward augmenting equipment in the laboratory.

Faculty members and graduate students in computer science are currently making extensive use of the microcomputer laboratory. Five faculty members in the department use the laboratory in their own teaching. In addition, two graduate students and five faculty members are conducting research projects utilizing laboratory microcomputers. Four master's theses have already been completed utilizing equipment. Overall, the department chair pointed out, the laboratory seems to have contributed to a reduction in anxiety about computer hardware in the department.

Faculty members outside of the institution have also learned about the project, and are making some use of the projects results. The lecture notes that the project co-directors originally wrote for the course became the basis for a computer science textbook that will be published this fall. Both project directors have also presented papers and written articles on the project. Findings have been presented at a regional workshop, a national conference, and an international conference. One of the reports on project findings is available in a set of published conference proceedings; another is available in a journal on computer science.

Evaluation

The project directors planned to evaluate the course in two major ways. First, they intended to ask students and faculty members about their reactions to the initial course. The second approach to evaluation was to be more formal. A controlled evaluation seemed possible since Fundamentals of Computing Science was to be offered in 1977-78 both with and without the microcomputer laboratory. The project directors planned to use common testing devices with the two groups of students, and they also planned to compare performance of the two groups in later upper division courses.

Reactions to the course and the microprocessor laboratory were favorable from both students and faculty. Students seemed more stimulated and productive when creating software for real as opposed to simulated machines. Faculty members noticed the impact of the laboratory on student attitudes, and began using the laboratory in their own teaching. The feedback to the project directors about the course and laboratory has therefore been very positive and gratifying.

The project directors have not yet carried out any formal evaluation of project effects. As the project developed, the project directors began to see a controlled evaluation as both more difficult and less important to do. The project directors thought that the number of students taking the revised course when it was first offered was too small for a formal evaluation. They also thought that it would be hard to interpret any difference in achievement of students from the revised and old versions of the course since the difference in content covered in the two versions was so great. Finally, the project directors were not sure a formal evaluation of the course was necessary. Its effectiveness was clear enough to the faculty, and the new course and microlaboratory soon became institutionalized at the college.

Reactions to NSF

Overall, both project directors considered the LOCI program satisfactory for their needs. In their opinion, reviewer comments about their proposal were helpful. They reported, however, that the comments must be read critically since reviewers do not always accurately assess strengths and weaknesses of proposals. The project directors also said that NSF could improve some aspects of the administration of the LOCI program. Tardiness in announcing awards and a lack of clarity about deadlines created some problems for the project directors. In addition, project directors thought that they would have benefited from opportunities to discuss personally their project results with NSF personnel.

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Summary and Conclusions

One of the curricular projects clearly benefited the department where it took place. In the years since the LOCI project began, the microcomputer laboratory has grown in size and importance in its department, and the project director--now department chairperson--has written about the project for national and international audiences. The other two projects were less successful. The directors of both of the projects resigned from their institutions in disappointment before the revised courses were offered. Others took up their work, but the final results of the projects were less than expected. After one tryout, each of the revised courses was dropped. Evaluation of the projects was informal. In each case, students in the revised courses were too few to warrant formal evaluation.

Is there anything that these two projects had in common that distinguished them from the more successful project? The directors of the two less successful projects were both new to their institutions. Prior to taking teaching positions, both had worked at major research centers. For their projects to succeed, both teachers had to win the cooperation of their new colleagues. Both of the less successful projects involved several courses.

It is possible that such factors influenced project outcomes:

a) Experience of project director--A project director who has just arrived at an institution may not be in the best position to assess needs at the institution or to develop realistic plans for meeting these needs.

b) Scope of projects--Projects involving several courses require more cooperation among faculty members. New faculty members may find it especially hard to win such cooperation from their colleagues.

Chapter 7

Overall Summary and Conclusions

The case studies described in this volume complement the quantitative studies of Volume II in two ways. They provide a check on the data from questionnaires and reports, and they bring up some issues not raised by the quantitative analyses. In both ways the case studies round out the picture of the LOCI program that emerged from the studies reported in Volume II.

The site visits gave us an impression about project outcomes that was less positive than the impression conveyed by questionnaire results from LOCI project directors (reported in Volume II, Chapter 5), but more positive than the impression left by final reports on LOCI projects (reported in Volume II, Chapter 6). In our judgment, six out of ten projects achieved their major goals. One of the remaining four projects produced some positive effects, and three of the projects seemed to accomplish little of a positive nature. Three of the ten project directors documented their project results with quantitative data in final reports. The other project directors either did not submit final reports or submitted final reports that were descriptive and impressionistic.

We could not reach firm conclusions about factors that contributed to successful project outcomes because the sample of institutions that we visited was so small. The site visits, however, suggested that several factors may be related to successful project outcomes:

a) Projects involving "low" technology may have been more successful than projects involving more complex technologies. With more complex hardware, project directors seemed to run into more snags.

b) Projects that involved adaptation of existing approaches seemed to have more positive outcomes than projects involving development of new approaches. Project directors who had clear models to imitate--especially models that they had learned about in workshops--seemed to have an easier time than project directors who tried to construct new approaches by themselves.

c) Project directors with career commitments to instructional research and development seemed more likely to complete their projects successfully.

d) Projects directed by faculty members who had "settled in" at an institution seemed more successful than projects of faculty members in their first year at an institution.

e) Projects involving a single course taught by a LOCI project director seemed more successful than multi-course projects. Resources provided by LOCI may be spread too thin on multi-course projects.

The site visits thus suggested several areas where program guidelines might be improved:

a) Project directors--NSF program managers may wish to consider restricting awards to teachers who have been at institutions for at least a year. Just as institutions require faculty members to teach for several years before they apply for sabbatical leaves for further study, LOCI might require faculty members to serve at institutions for a year or two before submitting applications for updating courses or programs at the institutions. This requirement might be most appropriate when a project involves several courses or a whole program. Faculty members who have "settled in" for a year or two might assess better than newcomers the difficulties they will meet in trying to change a sequence or group of courses at an institution.

b) Evaluation--Most LOCI proposals did not commit the project directors to careful and controlled evaluation of project outcomes, and project directors sometimes "cut back" on evaluation activities during their projects. Without better local evaluation of projects, conclusions about results of projects will always be open to question. This is surely an area where better guidelines can be written for faculty members writing proposals and for reviewers reading them.

c) Final reports--Guidelines for final reports are also in need of improvement. Some of the project directors we visited were uncertain about expectations for final reports. One project director was dismayed to have a final report returned with a notation that it was submitted too early. Two others learned that final reports they submitted did not reach the proper division of NSF. More clarity in guidelines for submitting final reports is therefore necessary. The guidelines should also encourage project directors to submit reports with results that can be synthesized effectively by program managers. In recent years educational researchers have developed tools for objectively synthesizing applied findings in education and other areas, and these tools can yield objective generalizations about the effectiveness of large groups of projects. In principle, these tools can be applied to results from funding programs such as LOCI, but in reality the results reported by LOCI project directors are far too impressionistic to be of use in objective synthesis. In our opinion, this area, more than any other, needs careful attention from NSF personnel.