THE OPEN PHYSICS LABORATORY AND CHARACTERISTICS OF EFFECTIVE TEACHING ASSISTANTS: A CASE STUDY

DISSERTATION

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The purposes of this study were (1) to chronicle the development of an open physics instructional laboratory, the Physics Instructional Center (PIC) at the University of North Texas; (2) to determine student, faculty, and staff perceptions about the characteristics of effective teaching assistants in an open physics instructional laboratory; and (3) to identify representative teaching assistants who were perceived by students as being most helpful and to determine their perceptions about the characteristics of effective teaching assistants. The literature which provided the developmental base for the open laboratory includes Sam Postlethwait's audio tutorial laboratories, modular curriculum development, individualized and personalized instruction, Keller plan instruction, student self-pacing, and the introduction of media to enhance existing curriculum efforts. This literature, the Physics Instructional Center, and its evolution over a decade are described. Instructional staff, teaching assistants, and students were interviewed, and students were surveyed to determine the

most effective characteristics of teaching assistants in an open physics laboratory environment.

The attributes which were deemed most important to an effective teaching assistant by students include the following, in order of importance: (1) was willing to help when asked; (2) was adequately prepared; (3) clearly understood the equipment and procedures; and (4) displayed a lack of rude, patronizing or condescending behavior toward students. The teaching assistant attributes which were deemed most effective by teaching assistants and faculty and staff directly correspond to the attributes described by students. The following conclusions were drawn from this study: (1) student input appears to be important in identifying the characteristics of an effective teaching assistant in an open laboratory environment; (2) students and instructional staff substantially agree on effective teaching assistant characteristics; and (3) the most important teaching assistant characteristics appear to include those that are personal in nature, those that involve knowledge of the discipline, and those that involve organization of the laboratory for students' learning.

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CHAPTER I

INTRODUCTION

Science is not only a body of knowledge but also a process by which problems or questions may be approached, studied, and sometimes solved (Sund and Trowbridge 1967). To help students participate in and learn about this process of science, the instructional science laboratory has been integrated into most science curricula; the instructional laboratory is considered an integral part of any college or university science course and represents one of the fundamental differences between science education and other disciplines. In physics the instructional laboratory, usually shortened to the term laboratory, is a relatively recent development in higher education which originated in the United States of America at the Massachusetts Institute of Technology in 1869.

> The MIT lab was organized to be ready for full operation in the fall of 1869 "to instruct the third year class by laboratory work; and if an experience of one year shall be favorable, as I feel it must be, we can gradually enlarge our facilities and take in the lower classes. I am convinced that in time we shall revolutionize the instruction in physics as has been done in chemistry" (Phillips 1985, 522).

Much current science education research focuses on developments in the physics instructional laboratory, and many exemplary grants are made in this area annually

(National Science Foundation 1987). A prominent example of these major research programs is the PIC at the University of North Texas. This is a unique learning facility which combines five major educational research areas in science education: (1) individualized instruction; (2) open hours or student-directed scheduling; (3) media-based, primarily videotape, laboratory preparation; (4) Keller plan testing and student tutorial; and (5) student grades based upon mastery learning objectives which do not produce normalized grade distributions. The laboratory instruction in the PIC is quite different from that in a traditional physics laboratory; the two major differences being that the teaching style is primarily interactive rather than directive, and that the performance of the learning objectives is the direct responsibility of the student and not under the scrutiny of a single instructor (Physics Instructional Center 1987).

The teaching assistant plays a critical role in most science laboratory instruction, and, indeed, often has complete responsibility for curriculum choices, student direction or supervision, and student evaluation in a traditional closed instructional laboratory (American Association of Physics Teachers 1988; Berdie et al. 1976; Muhlestein 1974; Spears 1984). A review of semester schedules of classes for several major colleges and universities revealed that it is unusual to find a senior faculty member teaching in an instructional laboratory.

In the PIC at the University of North Texas teaching assistants play several different roles. Few of these roles are familiar to new teaching assistants in the sense that traditional physics graduate students presumably have little or no experience in open, individualized, or media-based instructional programs. Therefore, successful instructional-behavior models in this unique setting should be developed (Bozack 1983), and teaching assistants should be oriented and trained in these model techniques before being expected to teach and to have their teaching evaluated in the open laboratory. The methodology for developing these teaching-learning models should include all of the constituents of the PIC, students, teaching faculty and staff, operational staff, and teaching assistants. These models should include physics curriculum development methods, communication skills, interpersonal relations skills, and a variety of teaching methods.

Statement of the Problem

The problem of this study involves identifying and ranking in importance the characteristics of effective teaching assistants in the learning environment of an open physics instructional laboratory.

Purposes of the Study

The purposes for this study were (1) to chronicle the development of an open physics instructional laboratory and associated teaching techniques; (2) to determine student, faculty, and staff perceptions about the attributes of an effective teaching assistant in an open physics instructional laboratory; and (3) to identify representative teaching assistants who are perceived by students as most helpful and determine their perceptions about the attributes of an effective teaching assistant.

Research Questions

The following questions were formulated in order to achieve the purposes of this study:

1. What are the attributes of a helpful teaching assistant as perceived by students in an open physics laboratory?

2. Which of these attributes can be consistently ranked as helpful by students?

3. What are the characteristics of an effective teaching assistant as perceived by teaching faculty and operational staff in an open laboratory?

4. What are the characteristics of an effective teaching assistant as perceived by teaching assistants who have been identified as most helpful by students, and

teaching assistants who have not been identified as most helpful by students?

Definition of Terms

The terms helpful and well-prepared, as applied to teaching assistants, were frequently found to be used by students in interviews, in general comments, or in open-ended questions as being synonymous with the term effective teaching assistants. The term effective often appeared on early PIC survey instruments, developed from student responses, directly associated with the terms helpful or well-prepared. In this study the terms effective and helpful in describing teaching assistants are equivalent. The term physics laboratory refers to the instructional laboratory available to students, or student laboratory, and not the physics research laboratory. The term open laboratory specifies a laboratory in which students choose to participate in laboratory exercises at times of their own choosing and for differentiated lengths of time, rather than having specifically arranged meeting hours which are the same during each week of a semester. In an open laboratory a student interacts with many teaching assistants in a semester; in a closed laboratory a student is generally associated with a single teaching assistant. Almost all of the research literature dealing with teaching assistants involves the environment associated with a closed laboratory.

Background

A review of the research objectives announced and grants made in science and engineering education by the principal funding agency in the United States, the National Science Foundation (NSF), from 1975 to 1985 clearly indicates three major areas of research interest and research funding: (1) innovative methods in the science teaching laboratory and laboratory equipment; (2) characterization of the students entering studies in science and engineering and ways to encourage more student diversity, particularly more participation among minorities and women; and (3) the introduction of state-of-the-art technologies into science education. These emphases led to the selection of one part of a major NSF grant which produced the PIC at the University of North Texas as the unit to be studied in this research.

Since the instructional laboratory is such an integral part of science education, and particularly physics education, the components of laboratory instruction should be carefully defined and examined, and new educational methodologies should be investigated (Pestel 1983). These methodologies are often highly site specific and cannot be readily duplicated at other institutions because of cost of laboratory space and equipment and the introduction of teaching-learning models which are unfamiliar to many traditional faculty members and teaching assistants. General principles or teaching-learning models which appear successful in many of the research grants involving various institutions and personnel should be shared as often, and in as many types of literature, as possible. The NSF refers to this process as dissemination and encourages it widely among research participants.

The PIC in the Department of Physics at the University of North Texas is a unique educational research effort and laboratory learning facility. No other media-based student science laboratory program reported in the literature has the programmatic size, research design base, curriculum production record, and length of uninterrupted operation and growth over a decade. The PIC was designed and constructed in 1976 and 1977 under a NSF Comprehensive Assistance to Undergraduate Science Education (CAUSE) grant (Cause Grant No. SER76-15912).

The PIC was established in order to create an environment of positive student contact with the sciences, and physics in particular, via a clearly individualized learning program with flexible, open, hours, providing many different learning resources, and allowing students to use the resources in a manner deemed most useful to them. The term individualized indicates that students are personally, and individually, responsible for their own learning, following a clearly defined set of objectives which lead to a grade based on mastery performance (Postlethwait and Hurst 1972).

The curriculum consists of written materials and media materials. The principal media is videotape with lesser numbers of programs in slide-tape, model manipulation, and audiotape formats. More than 90 percent of the media used directly in the curriculum materials was produced in-house.

The primary objective of the PIC is to provide laboratory instruction in physics to support a very traditional major university lecture mode of instruction with large multiple section courses. Each investigation in the PIC consists of an audiovisual tutorial presentation to complement laboratory written materials, a structured laboratory experience under the supervision of several teaching assistants, and an exit evaluation which involves a test and a Keller plan tutorial session with a teaching assistant (Keller 1968). The curriculum is designed as mastery based, and grades are not expected to fit any normal distribution. Each student is allowed equal access to the facilities during approximately thirty-six to forty hours per week on a first-come-first-served basis. Each student is informed that performance is based upon completion of specific goals within scheduled time frames; several resources are available to students to help fulfill those goals. The available resources include lecture notes, course text materials, laboratory written materials, media materials, teaching assistants, teaching faculty members, PIC staff, and others. Students are encouraged to develop various learning paths that best serve their individual needs. The size of the effort necessitates a clerical staff of students who manage student movement, keep records, and assist students in resource location (Postlethwait and Hurst 1972; Physics Instructional Center 1988). The PIC began serving students in 1977 and has functioned continuously since that time. The PIC has served more than 15,500 students with more than 350,000 student media uses and more than 2,000,000 contact interactions between students and individual teaching assistants. More than 200 programs are available to students, faculty, staff, and the university community.

The curriculum development and administrative operational decisions of the facility are based upon information gathered by research directed at the needs of individual students. In that regard, each semester that the facility has been open, a student opinion survey instrument has been administered. The survey instrument was designed to solicit student demographic information, specific times of use, amount of time necessary to complete a laboratory investigation, adequacy of and student attitude toward curricular materials available, and attitude toward instructional personnel and their helpfulness and preparedness, or effectiveness. Almost all curriculum development and operational decisions, within budgetary limits, are based upon student responses to these surveys. Students have developed a high confidence in their ability to influence the decision making process through these surveys; and although the surveys are voluntary, high return rates (consistently above 50%) have been routine for over a decade. The statistical validity and consistency of the surveys have been extremely high. The overall student opinion of the effectiveness of the teaching assistants was very consistent from 1978 until 1984, when it turned downward from 1984 until 1987. During 1987 preliminary survey techniques were used to identify what students considered to be effective teaching models. An orientation program for teaching assistants was provided in an attempt to increase students' opinions of teaching assistants as reported in the survey results and to increase the effectiveness of the PIC. The refinement of students' perceptions of successful teaching assistants was established as a primary goal for the PIC in 1988. As the work began on this goal the effort was expanded to compare and contrast the perceptions of students, instructional staff, and teaching assistants on successful teaching models in the PIC.

Several faculty members and the PIC staff felt that a need existed to produce a written document stating the educational principles which have been examined within the framework of the PIC and to expand the research into successful teaching models. The effort to produce an expanded description of an effective teaching assistant and the perceived need to chronicle the development of the PIC were the primary motivations leading to this study.

Significance of the Study

This study is concerned with the identification of characteristics exhibited by teaching assistants in an open physics laboratory environment which prove to be most beneficial to students who are learning physics and developing positive attitudes about science in general. The profile does not exist in a coherent form in the literature. The institutional facility in the study is extremely unique; and open learning facilities themselves are rare, many having existed in the 1960s and 1970s but few having survived into the 1980s and 1990s.

The background studies conducted at the University of North Texas, which formulated much of the information cited in this study, have been reported only in conference proceedings and reports to granting agencies. Therefore, although site specific in the nature of the study and the uniqueness of the site, this study represents a significant contribution to the formal literature of higher education research dealing with a topic of genuine concern to science departments throughout most traditional institutions of higher education.

Organization of the Study

This chapter states the problem, purposes, research questions, definitions of terms, background, and significance of the study. Chapter II chronicles the development of the PIC, the primary background literature used in developing the philosophy, goals, procedures, and curricula of the PIC, and lists several of the educational principles found to be effective in the PIC's first decade of service. Chapter III describes the methods of data collection for the teaching assistant effectiveness surveys and the treatment of data. Chapter IV presents the analyses of data and some of the findings of the research. Chapter V presents a summary of the major findings, discussion, conclusions, and recommendations for further study.

CHAPTER II

BACKGROUND LITERATURE AND THE EVOLUTION OF THE PHYSICS INSTRUCTIONAL CENTER: EFFECTIVE TEACHING TECHNIQUES

Introduction

This chapter reviews the primary literature upon which the educational principles of the Physics Instructional Center (PIC) were founded, documents the early development of the PIC, and presents some of the educational principles which were tested over a period of one decade and judged by the faculty and instructional staff to be effective open laboratory teaching techniques. The uniqueness of the PIC as a facility must again be emphasized. It was neither intended to be a model facility to influence other institutions nor to export curriculum materials, but rather was designed as an educational research facility and, primarily, a working instructional laboratory handling a large number of service course students with minimal cost and maximal positive influence on these students' attitude toward science. However, the PIC exported more than forty physics curriculum programs and was used as a model facility in more than eighty National Science Foundation (NSF), National Education Agency (NEA), Eisenhower, and National Endowment for the Humanities (NEH) educational grants. Many members of the PIC staff served as consultants and trainers on other grants. The PIC annual visitors' log included, in general, more than 100 visitors per year in the first six years of operation. The faculty and staff of the PIC in the years 1976-1989 presented more than 145 scholarly papers; were the topic of sixteen articles written about the PIC in the popular press; developed and directed more than thirty workshops in curriculum development, media production, large scale student information systems, student staff development and management, and teaching assistant training techniques; and they served as consultants to numerous other science laboratory projects and teacher training institutes.

Review of Developmental Literature

The background literature for the development of the open physics laboratory and effective laboratory teaching techniques was concentrated on three major topics: (1) the science education research environment from 1970 until 1978, as reflected primarily by funded projects from the NSF; (2) the individualized instruction models implemented successfully in science curricula; and (3) the instructional models which might be directly related to orienting and training teaching assistants in effective laboratory teaching techniques.

Science Education Research

The NSF convened two topical conferences at Airlie House, in Virginia, February 10-12, 1974 and January 11-13, 1976, entitled "Project Directors' Meeting" and "Critical Issues Affecting Science Education Research and Development Projects." In November of 1989 the head of the Science and Engineering Education Directorate of NSF, Bassam Shakhashirie, stated :

> The issues and opinions of the Airlie Conferences were the most dramatically centralized preview of all science education research in the last decade and a half (American Association of Physics Teachers 1989, 3).

Much of the discussion at the Airlie Conferences involved grant administration and evaluation, peer and panel review processes, and curriculum development and dissemination. The principle concerns of both conferences were extremely well summarized in the remarks of Arnold A. Strassenburg (Appendix A). The topics addressed by Strassenburg included (1) fundamental resistance to change from faculty and institutions; (2) the range of quality of new curriculum developed; (3) the need for better dissemination systems; (4) the need for unit or modular development; (5) the need for skilled personnel to integrate new technologies into curriculum; (6) the problem of coordination and the lessening of political conflict between academic institutions, professional societies, and industry; (7) the need for meaningful evaluation; and (8) the proliferation of unevaluated materials.

The principal topics of educational research considered at both conferences included (1) systematization of modular development of curricula, (2) individualized instruction, (3) the diffusion of innovations and technology transfer (i.e., media and computer development in curricula), (4) impediments to developing multidisciplinary or inter-disciplinary programs, and (5) alternatives to higher education degree programs (National Science Foundation 1974).

At the 1976 Airlie conference some of the largest and most exemplary research projects in the United States were described, and some were demonstrated. Projects included (1) a computer based modular course in chemistry at the University of Texas; (2) major developments in computer graphics developed by Alfred Bork at the University of California, Berkley; (3) a modular course in biology developed by the American Institute of Biological Sciences; (4) Sam Postlethwait and W. V. Mayer's "Minicourse Development Project" at Purdue; (5) a Keller-plan course in physics at the University of Nebraska; and (6) the development of a modular Nuclear Physics Laboratory course at North Texas State University. The abstracts of several of these projects are exhibited in Appendix B.

Also on display at the second Airlie Conference were some of the first interactive curricula materials available for the PLATO network; this represented the first truly interactive video computer terminal with graphic capabilities (PLATO 1977). The staff of the Biological Sciences Curriculum Study (BSCS) displayed procedures developed in large scale publishing techniques and curriculum standardization and control when using modular development with many authors.

Clearly the emphases of funded research involved individualization of instruction; modularization of curricula, primarily to provide students more control over their own pace and interest levels in science; wider utilization of technology in an educationally experimental setting where meaningful evaluation could be done and the outcomes disseminated; and the implementation of innovative reward structures for the constituents, faculty, staff, and students, of highly non-traditional experimental programs. Each of these emphases was addressed in a meaningful way in the North Texas State University Comprehensive Assistance to Undergraduate Education (CAUSE) grant of 1976, which developed the PIC and redeveloped the undergraduate instructional program in the Department of Physics.

Individualized Instruction

Sam N. Postlethwait of Purdue University has significantly influenced modern models of science education with his ideas about individualized instruction.

> A student can select four variations of coffee from an ordinary vending machine, but when he enters the classroom he may receive instruction identical to that of several hundred other students. It is an obvious fact of life that people exhibit great diversity in background, interests and capacities, yet our educational system is made up of large blocks of content (courses) with little or no provision to break the lockstep of time, content or instructional procedure.
> Many people can trace their excitement about a specific subject to the special way the subject was presented by a great teacher (Postlethwait and Hurst 1972, 1).

So many of these premier teachers are involved with relatively few students.

> Hopkins says the best learning situation takes place with the "teacher on one end of the log and the student on the other" (Postlethwait and Hurst 1972, 2).

Postlethwait developed a system referred to as the audio tutorial (AT) system. The first AT lab was introduced in a botany course at Purdue University in 1961. The AT system soon expanded to have the following elements: (1) tangible objects (specimens, experimental equipment, models); (2) printed materials (texts, study guides, journal articles); and (3) projected images (slides and movies) (Postlethwait 1972, 2). The diversity of materials and flexibility of learning opportunities were key points to this new model.

The AT system was expanded in the middle 1970s to include minicourses, each made up of several elements: (1) independent study sessions (ISS) in a learning center with appropriate materials and media; (2) general assembly sessions (GAS) which were basic weekly lectures to large audiences; and (3) an integrated quiz session (IQS) which involved less than ten students and one instructor and was scheduled weekly for one-half hour. In the IQS each student was asked to perform tasks with the entire session which, according to Postlethwait, provided

> (1) direct feedback on the effectiveness of the components of the AT program, (2) an opportunity for each student to know at least one instructor very well, (3) each student to be well known by at least one instructor, and (4) an opportunity to take care of certain administrative details (Postlethwait 1972, 4).

The key to the AT program is the quality of the programs developed by individual instructors and presented to students. The programs can be placed under the direction of the best instructors. The rate and emphasis of study is directly controlled by the students (Postlethwait 1976). The system is based upon clear objectives with clearly marked intervals of success. Individual units of instruction are developed, and are called minicourses. Any student can succeed at any minicourse. The smaller units are less intimidating, and students build a history of successful completion of small steps. The minicourses provide much more individualization than conventional curricula, thus meeting the needs, interests, capacities, backgrounds, and specific goals of each student. The transfer of materials between courses and between institutions can be accomplished more readily because each minicourse is essentially an independent learning system and can be easily combined with others to adapt to the local situation (Postlethwait, Novak, and Murray 1969).

A typical unit is designed around a single concept and integrates a rationale, a primary idea, a secondary idea, an instructional objective, instructional activities, in-depth studies, and optional reading and a bibliography. Postlethwait suggests the following steps for developing a lesson: (1) list all the objectives, (2) list all available media and teaching aids, (3) select media suitable to the subject, (4) list activities in proper sequence, (5) assemble materials into a program, (6) transcribe and edit, and (7) make the final tape (Postlethwait 1976; Postlethwait, Novak, and Murray 1969).

The media should preserve the personality of the instructor and the environment, such as background noise; however, the environment should not be distracting to the overall program. Postlethwait observes that the most straight-forward presentation is probably the most effective and efficient. Interruptions should be planned to break up the monotony of the performance of experiments, observations, demonstrations, reading of the text or laboratory manual, and other study activities (Postlethwait 1976). Many of these ideas were directly incorporated into the structure of the PIC, and many are addressed in the section devoted to discussing the evolution of the PIC.

Teaching Models and Techniques in Individualized Instruction for Teaching Assistants

In statistical terms, the difference between ideal individualized instruction and classroom instruction is expressed by John Carroll:

> If students are normally distributed with respect to aptitude for some subject and all students are given exactly the same instruction (the same in terms of amount and quality of instruction and learning time allowed), then achievement measured at the completion of the subject will be normally distributed. Under such conditions the correlation between aptitude measured at the beginning of the instruction and achievement measured at the end of the instruction will be relatively high (typically about +.70). Conversely, if students are normally distributed with respect to aptitude, but the kind and quality of instruction and learning time allowed are made appropriate to the characteristics and needs of each learner, the majority of students will achieve mastery of the subject. And, the correlation between aptitude measured at the beginning of instruction and achievement measured at the end of the instruction should approach zero (Carroll 1963, 723).

There are several essential elements of individualized instruction. Individualized instruction must be self-paced or at least lockstep self-paced. Deadlines must exist, but each student must be given sufficient opportunity to learn and assimilate at his or her own pace. There must be frequent feedback for the students and instructor. There must be explicit way points, usually stated as learning objectives which state what is to be learned, through what procedures the learning will happen, and through what means the objective completion will be evaluated. Learning units should be broken into small enough portions that students can achieve mastery in short periods of time, maintaining a process of several successful experiences; however, units must manage some unity and sense of progression toward an end. Students should have paths prescribed so that some units depend on the completion of others and other units stand alone. The instruction must center on the students' needs and be directed by students and not by the instructor. Only students can comprehend the best learning path available for their individual purposes. Students must be active participants, directly involved, and self-directed and self-paced. Evaluation should be criterion-referenced, especially if test elements are involved. Provision should be made for students to surpass expectation for recognition or personal reward; objectives should be comprehensive and not limiting to the best students (Novak 1977).

The role of the teaching assistant is usually critical to an individualized instruction program in higher education. Faculty members prepare the curricula and evaluation instruments. Teaching assistants interpret the subject discipline and provide learning resources, translate course and evaluation procedures, and usually direct student evaluation. The teaching assistant observes and records what students are doing and is regularly available to students. The teaching assistant must be well prepared in the discipline and the procedures, and be able to relate well to students. Often unit mastery is examined orally by teaching assistants in an attempt to solicit student behavior and examples based in the students' own language, actions, and metaphors. This highly personalizes the interaction between the instructor, the teaching assistant, and the students (O'Connor 1976).

There are many methods for individualizing instruction. Some of the methods include modular instruction, personalized systems of instruction, audio tutorial, grade contracts, computer assisted instruction, computer based instructional management systems, programmed instruction, individually prescribed instruction, learning centers, learning resource centers, mastery learning, and various media presentation methods. Each of these methods is exhibited in some form in the NSF grant programs abstracted in Appendix B.

Modular Instruction

Modular instruction has taken a prominent role in personalized instruction. Modular instruction depends heavily upon providing students with a rationale of direct relevance for the material being learned. Developing a modular course format usually involves a conceptual framework provided by the discipline. From the conceptual framework a series of learning activities are designed. These activities must be evaluated and student mastery must be established or students must be redirected along another path to mastery (Goldschmid and Goldschmid 1972; Saunders 1976).

The module itself typically has a set of elements:

1. Statement of purpose;

2. Description of prerequisite skills;

3. Instructional objectives (behavioral);

4. Diagnostic pretests;

5. Implementers: lists of equipment and supplies, whereabouts of necessary information, and helpful procedures;

6. The modular program;

7. Related experiences: lectures, reading assignments, group discussions, field trips, opportunities for independent study;

8. Evaluation post-test: suggests student success or whether to recycle students through remedial modeling, repetition, or another learning module;

9. Assessment of the module: (a) population of students, (b) average completion time, (c) degree of competency obtained by students, and (d) other relevant data from field experiences (Creager and Murray 1971).

Modular instruction leads to clearly articulated goals or objectives for students. The lack of specific goals for studying is a primary problem for students in introductory science courses.

Keller Plan

A particular personalized system of instruction is the Keller PSI system (Keller 1968). Its primary features are (1) self-pacing, commensurate with the student's ability and other demands upon the student's time; (2) unit perfection required for advancement; (3) the use of lectures and demonstrations as motivational techniques; and (4) the use of proctors and teaching assistants, which permits repeated testing, immediate scoring, almost unavoidable tutoring, and a marked enhancement of the personal-social aspect of the educational process. A faculty member's role in a Keller plan course is curriculum development and test construction. Proctors evaluate students individually for mastery on a test. The test may be multiple choice, essay questions, oral examination, or a performance test. Final grades in the Keller plan courses are determined by the number of units mastered with no regard to examination marks other than pass or fail. Students must master a unit to continue to the next. The biggest problem with the course may lie with the number of students who do not complete the course in a given amount of time, such as a semester. Some of the problems of Keller plan lie in (1) low ability students, (2) not enough time during a semester, and (3) lack of motivation.

Instructors must be sure that (1) teaching materials are technically good enough so that the subject is learnable with normal motivation; (2) materials are relevant, humorous, and have intrinsic interest to students; (3) units are short enough to be completed in no more than a few days, better one evening; and (4) enough proctors or tutors are provided so that students can get quick service when they want a test or reasonable question answered.

The Keller plan method developed a large following during the 1970s. However, the nontraditional nature of the programs and insufficient reward structure for innovative faculty and staff led to the demise of most of the courses.

Reviews of materials and programs in individualized instruction are compiled and chronicled at many institutions such as the Center for the Improvement of Undergraduate Education at Cornell University; the Center for Research and Development in Higher Education at the University of California, Berkley; and the Center for Personalized Instruction at Georgetown University. A newsletter is published monthly from the Center for Personalized Instruction, Georgetown University, Washington, DC (Center for Personalized Instruction 1975)

Summary of Background Literature

The bibliography involved in creating the original plans for the PIC had approximately 358 entries. The major topics of interest were (1) individualized instruction with student self-pacing, as envisioned primarily by Postlethwait; (2) modularized instruction programs as exemplified by several NSF grants and institutional and departmental programs described at the American Association of Physics Teachers (AAPT) annual meetings and through NSF Project Directors' meetings; (3) physics networks and repositories including the Physics Modules Network (PHYSMOD), the Physics Media Courseware Project (PHYSWARE), the development of the American Institute of Physics (AIP) research classification index, the AAPT film repository, the AAPT topical course sessions, and others (None of the networks came into wide use or recognition.); (4) Keller plan testing-tutoring directly involving teaching assistants; and (5) the introduction of media, principally videotape, technology into the laboratory teaching program.

Development of the PIC and Effective Educational Principles in the Open Laboratory

Early Background

The PIC was founded in July 1976 under the name Individualized Audio Tutorial Investigation (IAI) Center as a part of a NSF Comprehensive Assistance to Undergraduate Science Education (CAUSE) grant of approximately $300,000 which was designated to redevelop and modernize the entire undergraduate physics instructional effort at North Texas State University. The PIC, in 1990, provides laboratory instruction for many of the service courses (nonmajor courses) in the Department of Physics. It has produced more than 200 media programs in physics and science education. It has trained and developed more than 300 individuals, within and outside the University of North Texas, physicists and scholars, in mediated science education and media production and development. It has served as a model facility in at least eighteen other NSF grants for similar programs. It consistently is graded, on a scale from one to five points (five being excellent and one being poor), by its constituents (faculty, staff, teaching assistants, and students) as having an overall rating of approximately four, with media programs rated slightly higher.

Initial Stages of Development

The years 1968 through 1975 represented an unprecedented era of expansion in programs of the Department of Physics at North Texas State University. This growth rate was considerably larger than the growth rate of the university. Between 1967 and 1975 the faculty expanded rapidly, the research budget more than quadrupled, and the number of undergraduate and graduate semester credit hours taken by students more than doubled. The undergraduate semester credit hours in Physics grew from approximately 6,000 hours in 1967-1968 to more than 10,000 hours in 1974-1975, while the total undergraduate semester credit hours in the university underwent a slight decline (Sybert et al. 1976, 3). The portion of those hours which represented service course hours, not physics majors courses, grew from 75.3 percent to 88.1 percent (Sybert et al. 1976, Appendix 10).

> The service-course clientele ranges from those students taking survey courses which satisfy distribution requirements to those desiring some particular skill or body of information pertinent to their specific discipline (Sybert et al. 1976, 4).

The service courses included Descriptive Astronomy; Electricity and Magnetism; Wave Motion and Acoustics; Physical Science; Musical Acoustics; General Physics (Non-Technical); General Physics (without Calculus); Energy and Our Physical Environment; Contemporary Geophysics/Geochemistry; Contemporary Astronomy/Astrophysics; Light, Color, and Holography; Elements of Atomic and Nuclear Physics; and Procedures and Materials for Teaching Secondary School Science.

This was an unusually large number of service course offerings for a major university, compared to an average of six service courses for a research university (American Association of Physics Teachers 1988). Each of these courses was served by a lecture (with demonstrations) and a laboratory that meet weekly. To support the addition of so many service courses the undergraduate laboratory program underwent rapid and relatively unplanned expansion. The growth of service course hours was not paralleled by an expansion in laboratory equipment or facilities. The laboratories were generally taught by teaching assistants, many nonnative English speakers, who had little training in teaching skills and limited communication and interpersonal relationship skills. No orientation or training of teaching assistants was in place. The department chairman and the Undergraduate Affairs Committee (UAC) received numerous complaints about the laboratories, leading to, the following comment:

> The laboratory ideally is the most meaningful and educationally valuable part of a physics course, providing as it does the indispensable hands-on experience which the student needs. . . . However, our experience has been that the laboratory is typically the portion which is least effective and about which student attitudes are least positive. . . . Students have also expressed the desire for an instructional format which would better accommodate their various individual needs and interests (Sybert et al. 1976, 5).

The department leadership then determined that something should be done to improve the undergraduate laboratories.

A working group formed in the fall of 1975 by the UAC began preparing a program to address the needs of the undergraduate laboratory. This project became a grant application in January 1976 to the NSF under the CAUSE program. The CAUSE was designed to provide very large block grants to produce significant change and to improve existing programs based upon currently successful science education research models.

The internal redevelopment program was later broadened. It included a general departmental review including a distinguished review panel and a second large NSF block grant application for Research Initiation and Support (RIAS) for the Atomic Physics Research Group and the newly emerging Quantum Optics Program (later the Center for Applied Quantum Optics, CAQE).

The opinions of the faculty were solicited in two open faculty meetings and several individual faculty interviews. A blue ribbon Departmental Advisory Committee of distinguished physicists and educators was convened in Denton, Texas, in the spring of 1976 to review the Department of Physics and the two NSF grant proposals. The committee consisted of: Marlan O. Scully, University of Arizona, Professor of Optical Sciences; Lewis Cochran, University of Kentucky, Vice President of Academic Affairs; Melba Phillips, SUNY at Stony Brook, Executive Officer of the American Association of Physics Teachers; and Norman Einspruch, Texas Instruments, Vice-President Corporate Development. This panel offered numerous constructive suggestions about departmental development and policy, and positively reviewed the grant proposals.

The CAUSE proposal planning and writing group consisted of J. R. Sybert, Chairman of the Department of Physics and Project Director; Virginia Rawlins and Rogers Redding, Physics faculty members; and Jack Hehn, Assistant to the Chairman, Director of Undergraduate Laboratories, and Supervisor of Teaching Assistants. A comprehensive review of the literature in undergraduate laboratory teaching resulted in the following suggestions:

> Science education has undergone a change in both content and emphasis. Methods other than the traditional lecture-recitation-laboratory (LRL) are now being used by science instructors in kindergarten through graduate school. A search of the literature reveals many uses of the Personalized System of Instruction (PSI) format based upon the Keller Method, Computer Assisted Instruction (CAI), Audiovisual Tutorial instruction (AVT), programmed material, modular studies, open laboratories, learning centers, and Piagetian-based instruction (Sybert et al. 1976, 6-7).

A set of goals and objectives was developed to meet the needs of the laboratory program. The goals included in the grant proposal were (1) an increase in the student's understanding of the basic natural laws central to the study of physics, and (2) an improvement in the attitude of the student toward the study of science in general and physics in particular (Sybert et al. 1976, 7). These goals lead to the following set of objectives: (1) to provide individualization of instruction, (2) to offer self-paced modules, (3) to provide efficient and high quality learning experiences, (4) to achieve greater coherence among instructional activities, (5) to interface with the national network of physics modules, and (6) to provide on-going criterion-referenced evaluation designs (Sybert et al. 1976, 8).

The proposal was submitted in February 1976 and the CAUSE grant for $298,300 was awarded to North Texas State University on June 15, 1976 (letter to C. C. Nolen, President of North Texas State University). The RIAS proposal was denied June 23, 1976 (letter to C. C. Nolen, President of North Texas State University). Plans began immediately to implement the grant.

The block grant had a large matching funds compliment and one of the first NSF formal agreements of future continuance. These were enthusiastically supported by the administration of the university, as evidenced by a strongly worded letter of local support from University President C. C. Nolen. The letter stated:

> It is imperative that new attention be focused on the teaching-learning process. No greater task faces this university . . . than the task of relating its overall educational goals to the teaching of individuals (Sybert et al. 1976, iii).

A group of nationally recognized consultants was organized to help plan and implement the program and provide training for faculty and staff; these consultants included:

S. N. Postlethwait, Purdue University; M. R. Mayfield, Austin Peay State University; N. F. Six, Western Kentucky University; C. G. Shugart, Northeast Louisiana University; A. A. Bartlett, University of Colorado; and Rod O'Connor, Texas A. & M. University.

A Physics Faculty Retreat was held September 24-25, 1976, with four of the consultants making presentations. The entire physics faculty (28), all teaching assistants (44), and several staff members, including the University President, Academic Vice-president, and Dean and Associate Deans of the College of Arts and Sciences participated in the retreat. Those at the retreat showed a general optimism about the outcome of the project.

Following this conference the initial plan to redevelop the undergraduate program and PIC began to take shape. The UAC and the chairman began redevelopment of departmental lines of authority to plan and implement the changes in the undergraduate program. Coincidentally a major new research group in quantum optics, laser physics, was being organized and faculty were being recruited to expand the effort. This entailed a reorganization of the graduate studies and research efforts. Large influxes of departmental extramural research income and university matching funds dramatically changed the entire department.

The undergraduate program was systematized into three phases: undergraduate majors and technical courses, undergraduate astronomy courses, and other undergraduate service courses. The astronomy courses encompassed more than 50 percent of the undergraduate service course hours in the Department of Physics. Within one year approximately $170,000 in equipment was added to the undergraduate laboratory program. The undergraduate physics majors courses underwent little immediate change, with primary emphasis on new laboratory equipment. Approximately $95,000 of the money was used for astronomy laboratory equipment, and approximately $75,000 was used for undergraduate physics service course laboratory equipment. These figures represent ten times a typical single annual budget allocation.

The astronomy laboratory facilities at an observational site several miles north of the campus were dramatically updated and enlarged and an indoor astronomy laboratory was begun. The number of laboratories each student was required to complete and the number of observing hours was very low compared to other courses, primarily due to the large number of students, nontraditional hours (night hours), and difficulty in obtaining qualified astronomy laboratory instructors. The laboratories had operated for many years on arranged schedules. Using the arranged schedules, each student requested specific observation sessions and individual students were not assigned to fixed times or fixed dates during the semester. Because the astronomical calendar often did not coordinate well with the standard academic calendar, a great deal of flexibility was often necessary.

The other undergraduate service courses were brought under an umbrella administrative organization which later became known as the PIC. The PIC organization and facilities evolved continuously after 1976, with the responsible administrators upholding the principles laid out in the CAUSE grant as closely as possible. Decisions were based upon student outcomes and student opinions whenever possible within resource restraints.

Original planning was based upon a review of current research literature, the recommendations of the consultation staff, the review of papers delivered at state and national AAPT, AIP, NSTA meetings, and various media organization meetings, including the International Science Film Congress, Texas Association of Educational Technology, the Film Institute of America, and others. The principals in the CAUSE development and planning, Jim Sybert, Virginia Rawlins, and Jack Hehn, began to visit mediated learning or production centers and associated media vendors; more than thirty five facilities were visited including several media vendors, several junior colleges, several medical schools, two veterinary schools, several Montessori schools, several private high schools, three advertizing production studios, two professional broadcasting facilities, and many other universities and colleges, especially media libraries and media collections. Local expertise was solicited; the members of the media staff of the Texas College of Osteopathic Medicine, especially Bob Combs, were extremely helpful in planning and implementing the physics media facilities. The site visits and discussions of problems with operating staff members of the existing facilities visited proved to be the most important and reliable data used to plan the PIC. The operational advice about types and durability of equipment proved extremely valuable. Detailed information about the life expectancy and durability of equipment is not often published, and vendors claims made in bids are not always fulfilled. Written policies and vendor bidding procedures from the various institutions were also reviewed and analyzed.

The physics laboratory development program was organized into three phases: (1) planning, constructing, and equipping the learning center; (2) production, implementation, and evaluation of the investigation modules; and (3) training laboratory personnel and obtaining necessary equipment for performing specific experiments in each course. The remodeling of the physics building was begun in the spring of 1977. The first students were introduced into the PIC in an experimental program in the summer of 1977.

Facilities

As the initial mission of the PIC was concluded remodeling of the physics building was begun in order to produce a small television production studio (approximately 500 square feet), a mediated learning center (approximately 2,000 square feet), and teaching laboratories (originally, approximately 800 square feet). More laboratories were added over the years, as the PIC expanded in course load and student load, to a total of approximately 2,500 square feet.

The media center was developed to maximize flexibility. Areas were arranged for media circulation, student record-keeping, and crowd control and security; student testing and evaluation; media viewing and curriculum exercises; offices for staff personnel; and curriculum and media production areas. The student access area was a large central room which could be modularized with media carrels or movable partitions. The offices and production area were placed at the rear of the facility and the student record keeping area and ingress corridor were placed near the doors. The one central facility was made by opening nine existing offices and student laboratories into one room and incorporating an under-utilized hallway. Walls were removed between existing closed laboratory rooms to form large open laboratories which could maximize supervision with minimum personnel.
A media carrel was designed for the media center which incorporated features from models observed at other centers

for maximum flexibility. The carrel was designed to handle from one to three students. It could be adapted for various media modes:

1. The working surface of the carrels was large, forty-eight inches by forty-eight inches, roughly twice as large as most commercially available carrels.

2. Each carrel would hold one fourteen inch color television and a three-fourths inch videotape playback unit to be viewed at approximately thirty inches.

3. Each carrel could accommodate two slide projectors placed on shelves which extended from below the front of the carrel, with projection on a white Formica surface which formed the back of the carrel.

4. A shelf was provided which extended twelve inches from the back of the carrel and was adjustable to any height to hold curriculum materials, specimen equipment, books, or other equipment. A light was attached to the bottom of the shelf to illuminate the working surface.

5. Large removable panels (twenty-four inches by twenty-four inches) were attached to each side of the carrel wall which could hold cork covered boards to post materials or pegboards to hold specimens and laboratory or other equipment.

6. A large covered shelf was positioned directly below the surface to hold student books, notebooks, and other materials which students brought to the media center.

A grid of electrical outlets was extended from the ceiling at sixteen-square-foot intervals so that four carrels could be serviced. This allowed the carrels to be placed in any arrangement in the room and still be supplied with electrical power. The wall areas of the media center were outfitted as standard physics laboratory benches with gas, water, and electrical facilities so that laboratory experiments and measurements could be duplicated in the media center.

A large area in the center of the media facility was set aside for the Keller plan testing and tutoring. This area was outfitted with student desks for testing, and utilized the laboratory benches on the side walls for duplication of student laboratory measurements.

A main circulation desk was provided for checking out media materials. A computer system at the circulation desk was also used to keep records of student grades and attendance.

The computer record keeping system, developed over a six-year period, evolved from a time-shared remote HP2000 system to a multi-PC-based, on-site system. The system was written and maintained in BASIC, primarily, by the Operations Manager. The record keeping system allowed survey and student evaluation instruments to be analyzed and reports to be generated on a weekly and semesterly basis. These reports contained information about student uses of the laboratory and student success levels, reported grades directly to faculty members, and provided analyses of various student survey and opinion instruments given regularly. The usage reports were posted weekly and sent to the teaching faculty. Students quickly learned to use the reports to examine their grades on an on-going basis and to determine times that the PIC was least utilized so that they could receive maximum attention from teaching assistants.

Future project goals included expansion of the number of courses and laboratories serviced by the PIC. Other goals included the expansion of the computer services to include student-directed tutoring and testing and access management.

Administration and Personnel

The PIC was originally organized into three administrative areas: media and modular instructional material production, laboratory operation and faculty liaison, and instructional personnel, primarily teaching assistants. The administrator of each of the three areas initially reported to the Project Director, and later to the Chairman of the Department of Physics. This administration has evolved through many different models in the decade the PIC has been in operation. As with any large facility, individual talents and personalities formed many of the working relations and caused definitive roles. A strong central administrator who could represent the interests and articulate the goals of the facility to the departmental executive committee and the physics faculty as a whole evolved as a critically important position. The administrator was a direct appointee of the Department Chairman and worked closely with the departmental administration. Under the direction of the central administrator four distinct areas of responsibility were identified and a supervisor was made responsible for each area: (1) the daily operation of the learning center including student information systems (eventually kept on various personal computers), maintenance of media programs, supervision of clerical staff, and preparation, reproduction, and coordination of sales of laboratory written materials; (2) the production of new material and the review and remediation of existing programs, and curriculum development, maintaining proper liaison with the faculty member developing the material; (3) the daily maintenance of the laboratory equipment and supervision of the laboratory facilities; and (4) the supervision, training, and evaluation of the instructional personnel.

A typical staff for a semester consisted of thirty-five to forty instructional personnel, including teaching assistants, undergraduate instructional assistants, and faculty and staff. A clerical staff of five to seven undergraduate students provided record keeping services, student access and media circulation supervision, and clerical support services. A production staff of three to five provided graphic support, media production and duplication services, and curriculum development support services.

In the mid-1980s a very comprehensive training and development effort was provided for the student clerical personnel. The program involved the development of detailed job descriptions, a job sharing program, evaluation methods leading to promotion and pay raises, training in interpersonal skills and direct public service, and training in resume writing and career selection. This program became a model program which was cited often by the university student personnel office and lead to a significant increase in the tenure of the student clerical personnel, dramatically reducing training and turnover costs.

Curriculum Production and Review

Curriculum was developed around the theory of modular instruction, a modified minicourse curriculum. A physics service course typically consisted of twelve modules of laboratory instruction, or laboratory investigations. The course instructor selected from twenty to thirty possible modules which could be used in a particular course. The curriculum was intended to be carefully integrated with individual elements including: (1) text material from the lecture course; (2) lectures delivered by an instructor; (3) a written laboratory module; (4) a videotape or another media program; (5) a set of laboratory exercises performed by individual students or by laboratory pairs; and (6) an individual exit behavior, typically a written or practical laboratory test administered and tutored in Keller plan format by a teaching assistant. Students were reminded that in the interactive mode, a principal resource was always the instructional personnel with whom they interacted, and that these personnel were waiting for students to solicit help rather than directing them.

Curriculum development was the responsibility of the physics faculty and was coordinated by staff members of the PIC. Typically a faculty committee designated the need for a new module and appointed a faculty member, or course coordinator, to prepare the material. The module began with the development of objectives and a written module of instruction which supported a topic in a lecture course. The module was designed around a laboratory exercise or experience. A laboratory experiment with equipment, space considerations, and supervision and instructor training was developed from the modular materials. Next a media program was designed in a coordinated effort between the physics faculty member, the PIC producer, and the PIC staff. The producer scheduled production efforts and completed a product which could be reviewed and approved by the faculty curriculum committee and PIC staff. A test, or other exit behavior, was designed with teaching assistant training procedures and typical student outcomes. Finally the entire module was be included in a semester schedule for the course.

Most of the media presentations were developed on videotape. A partial mediography is exhibited in Appendix D. The programs were developed around six specific areas. The initial section of the presentation was an attempt to place the particular physical phenomenon to be studied in various applications which students could readily recognize in their everyday lives. In the second part of the program the physical principles were delineated and a presentation of the physical theory was treated much like a normal lecture mode; however, much emphasis was placed on visual models and direct applications of the principles as descriptive phenomenon. The curriculum developer was encouraged to place much emphasis on developmental behavioral objectives being clearly stated and justified to the students. The third part of the program outlined experimental procedures for the investigation with emphasis on data taking techniques and any safety or other laboratory procedures of special importance. This generally included a description of the equipment and useful techniques in how to optimize the use the equipment. The fourth part of the program described data analyses techniques and demonstration of principles exemplified by the data structures. Finally the program was concluded with summary remarks and an attempt was made to tie the experiment and physical principles directly into the world in which students live daily. The format was evaluated as very effective by students in early structured interviews and in the evaluation instruments. The programs were developed with graphic and visual aspect ratios adjusted for near viewing and were not well adapted to classroom demonstrations.

The programs were set for approximately twelve minutes of viewing time, a time interval corresponding to commercial television script development. With the use of multiple visual images to reenforce principles described orally, most presenters found that twenty-five to thirty minutes of traditional lecture could easily be condensed into the ten to twelve minute format. The information density, therefore, was approximately three times that of normal lectures. Students had complete control of the videotape and could stop and review at leisure; however, documentation of student uses in the learning center showed that this technique was seldom used. Students seemed to approve of the higher information density and often commented on the pacing of the tapes as maintaining interest and "not being boring." Instructors often commented on how well students adapted to the higher information density and seemed to maintain higher retention levels.

Each module had a concrete exit behavior with a pass or fail criterion. These exit instruments included multiple choice tests, practical laboratory examinations where students repeat measurements and demonstrate laboratory techniques, computer simulations which lead to testing, and a few essay tests. Each of these exit behaviors was graded by teaching assistants in a Keller plan format where immediate feedback and tutoring took place in a face-to-face meeting with each student. Teaching assistants were trained to challenge students to demonstrate principles and were empowered to change questions and accept answers based on student oral or graphic responses in addition to written materials submitted. A pilot program was developed in 1988 to expand the multiple choice tests to a computer delivery system, allowing students with exceptionally high test scores to bypass time consuming interviews with teaching assistants. This would optimize the use of the tutor's limited time with students who most needed the help.

Students could repeat the exit behavior instrument as many times as possible within the length of time that the laboratory was available, usually one week. A single passing behavior was the grade criterion; the total laboratory grade was based on the number of modules passed in a semester. This grade criterion was competency based and did not produce Gaussian grade distributions. Most lecture instructors recognized this and adjusted lecture grades and course grades to anticipate excellent laboratory grades. The high grades in the laboratory clearly increased students' confidence in their ability to succeed in a science course, as demonstrated in every evaluation completed over the entire life of the facility.

The first generation of videotapes was made in a very short time and under intense pressure for the developers. Forty-five complete laboratory programs were produced in the first year. The electronic curriculum underwent one complete generation of formal review by faculty, students, and staff. Approximately 90 percent of the curriculum was rewritten, and the video tapes were reproduced in the years 1980-1986. The facility is currently ready to perform more sophisticated evaluation of the second generation of curriculum.

Initial Project Evaluation

A central tenant of the PIC was the principle that student opinion and student outcomes would drive the decision making processes as much as possible within sound curricular and budgetary constraints. The original grant period was monitored under a contract with the Center for Research and Evaluation of the College of Education of North Texas State University. The conclusions in the final report to the NSF dealt with several topics. The direct measures about the goals of the grant produced positive results.

> In summary, the Physics 121 and 131 courses appeared to produce some positive cognitive and no observable negative impact upon student cognitive scores. Some indicators appear to substantiate higher retention among physics 121 students during year III. Physics 131 students' cognitive scores seemed generally parallel for each implementation year (Center for Research and Evaluation 1979, 37).
>
> The goal concerning attitudinal improvement did not appear to be attained. While some changes were present it was felt that they were minimal (Center for Research and Evaluation 1979, 45).

Several comments were made about the need for students to adjust to the open laboratory and learn what was expected of them.

> The first problem area was encountered by staff and students during the initial implementation of the IIA [sic]. A problem was centered around a number of student adjustment factors regarding their responsibility to initiate their own laboratory investigations. Many students were accustomed to the traditionally scheduled instructor initiated didactic laboratory sequence. . . . It was also noted that as new students entered the PIC courses during year III this problem substantially reduced at the outset. The latter improvement in student adjustment to the open PIC schedule was perhaps attributable to the time constraints and better student entering expectations which resulted from their own informal communications (Center for Research and Evaluation 1979, 58-59).

Many aspects of the evaluation could not be directly controlled by PIC personnel and indicated the need for departmental integration of the laboratory program into the overall instructional program. Also, there were direct indications of a need for more teaching assistant training.

> Some students also voiced concern over laboratory/lecture/test and even laboratory/test coordination stating that tests were not always related to labs. A project staff member stated that the function of the grader/tutor is essential to their program. While many perceived the teaching assistants and grader/tutors as helpful others felt that they should offer "more" assistance and be "eager" to give aid. Some areas of future explorations should include ways of providing flexibility of requirement related to the independent laboratory on subsequent examinations (Center for Research and Evaluation 1979, 61).
>
> The original plan called for complete implementation of the individualized laboratory materials to be available in all four service courses by the end of the first year. This was not possible (Center for Research and Evaluation 1979, 62).

There were unexpected benefits from the open laboratory.

> An unanticipated finding was that improved cognition may have been related in part to process evaluation along more rigid laboratory standards. One grader/tutor stated that grading was "stiffer" now so there may be no improvement in course grades but comprehension is up (Center for research and Evaluation 1979, 63).

Overall, students compared the PIC favorably to other science laboratories in which they had participated.

> A number of students favorably compared the project CAUSE physics labs to labs taken in other science and education programs. . . . Students liked lab much better when they could go at their own pace. One student stated: "I really like the availability of tapes and the PIC." Another student mentioned, "The videotapes are good. I can stop the tape and go over any point I find confusing until I understand it. The best thing is that I can do my lab when I feel like it" (Center for Research and Evaluation 1979, 65-66).

The Center for Research and Evaluation report concluded that,

> with the proper adjustments based on student input and evaluation recommendations the PIC should establish itself as a model facility and the IIA [sic] continue as a viable scientific instructional format (Center for Research and Evaluation 1979, 66).

Continued Evaluation Within the PIC

Following the first three years, when the NSF grant was completed, the evaluation process was continued by the PIC staff. The Operations Manager was explicitly responsible for semesterly evaluation and reports to the instructional staff. The early surveys were subject to frequent change, had no consistent administration procedure, and provided little statistical validity; however, after 1982 a more reliable, comprehensive student survey has been administered according to consistent procedures near midterm and near the end of the semester. The survey (Appendix C) was designed as a long base line information gathering tool. A review of student responses shows very definite student opinion trends in various areas. The instrument was designed to solicit student opinion about (1) exit behavior in the testing program (testing), (2) teaching assistant effectiveness and helpfulness (teaching assistants), (3) electronic curriculum quality (media), and (4) operational problems (operations). Two questions are open-ended and ask for the best and worst features of the facility. A review of the results from these instruments presents a statistically uniform long base line data bank so that changes in student opinions can be readily discerned with even small numbers of student responses or small changes in answer frequencies. The survey results showed little or no change from course to course, semester to semester, and day of the week. The results of the survey were consistently used to make operational decisions such as hours of operations, quantity and quality of curriculum materials offered, clerical procedures learned from orientation and training processes, and physical and equipment arrangements.

The student results for the areas testing, media, and operations changed very little over the years from 1982 to 1987. Students maintained a survey value of four for the Keller plan aspect (testing) of the PIC. Students maintained a survey value of slightly greater than four for electronic curriculum (when the scale is inverted to comply with other scales). Students maintained a survey value of slightly less than four for operational considerations.

Concentrating on the questions in the survey concerning helpful and well-prepared teaching assistants, a review of the data from 1984 to 1987 revealed student opinion moving in a negative direction. Faculty, staff, and teaching assistants were interviewed, and basic agreement that teaching assistant performance was less satisfactory than in the past was evident.

In order to improve this situation in the laboratory several actions were taken involving teaching assistants. An orientation program was undertaken to discuss certain teaching methods and communication skills in an effort to transfer some of these skills to teaching in the laboratory.

An orientation and training workshop for teaching assistants was held at the beginning of each semester and lasted two days, or approximately 15 hours. The following topics were chosen as the major emphases to be covered in the workshop (Hammond 1972; Hendershot 1971; Hildbrand and Wilson 1970; McKeachie 1969; Munce 1962; Shulman 1971):

1. The role and scope of the teaching assistant in the department and as a representative of the department and the university;

2. The students' perceptions of teaching assistants and teaching assistants' perceptions of students;

3. The goal recognition of different constituents and how to merge these goals (Simpson 1971): (a) goals of students, (b) goals of graduate students as teaching assistants, (c) goals of the Departmental of Physics, and goals of teaching faculty;

4. A representative profile of a typical laboratory student (the physics major, or the non-major, service course

student) concentrating on differing mathematical and conceptional recognition skills;

5. Communication skills including barriers to communication and specific hierarchial communication models within physics instruction;

6. Evaluation techniques based upon objectives and distinguished as mastery evaluation or graded evaluation (Mager 1968);

7. Specific questioning techniques useful in an inquiry laboratory teaching model (emphasizing open versus closed questions and leading or looped questions);

8. Specific laboratory skills including observation techniques, appropriate levels of error analysis, levels of mathematical analysis, and scientific epistemology at various levels influencing laboratory techniques of instructors and students;

9. Demonstration of preparedness through organization and competency of presentation; and

10. The need to present an impression of being sincerely enthusiastic about physics and about teaching and learning.

The teaching assistants' response to the training was overwhelmingly positive.

Following the new orientation process, the PIC was in a position to gather more specific information about student, faculty, and staff perceptions of teaching assistant attributes which are most helpful to the laboratory students.

Summary

A brief chronicle of the establishment of the PIC from 1976 and 1977 until the present has been presented in this chapter. The background literature upon which the PIC was developed provided the following major topics of interest: (1) individualized instruction with student self-pacing, as envisioned primarily by Postlethwait; (2) modularized instruction programs; (3) physics networks; (4) Keller plan testing-tutoring directly involving teaching assistants; and (5) the introduction of media, principally videotape, technology into the laboratory teaching program. This chapter has also listed some of the techniques which have been tested over a decade and found to be effective in teaching very large numbers of students in an open laboratory program. Administrative responsiveness and planning and development based on the perceived needs of students have played a central role in the success of the facility.

CHAPTER III

RESEARCH METHODS AND PROCEDURES

Introduction

The development of the open physics laboratory, described in Chapter II of this study, produced a need to ascertain clearly the characteristics of an effective teaching assistant in an open, individualized laboratory as perceived by students, other teaching assistants, and instructional staff. In order to accomplish this data were gathered using a written survey, a pictorial recognition survey, and both structured and unstructured interviews. This chapter describes (1) the development and administration of the survey instruments; (2) the development and implementation of the pictorial recognition survey; (3) the development of interview protocols and processes; and (4) the methods used in the analyses of data.

Environment

This is a case study involving the Physics Instructional Center (PIC) at the University of North Texas in Denton, Texas (Cates 1985; Good, Barr, and Scates 1941). The population studied consists of the persons associated with the PIC during one long semester and two summer semesters.

Research instruments were administered to typical enrollments in a spring semester, a summer I semester, and a summer II semester. The group in the spring semester consisted of 530 students, 35 teaching assistants, and 15 individuals from the faculty and instructional staff. The Summer I enrollment was 67 students; the Summer II enrollment was 64 students. The summer staff consisted of 14 teaching assistants, and 11 individuals from the faculty and instructional staff. The students surveyed were not physics majors; they were taking service courses in a science to satisfy their degree requirements. Summer enrollment each semester is much smaller, usually less than 15 per cent of the long term; however, summer school students typically spend considerably more time on task, and produce appreciably better work. Many are transient students who are enrolled in other colleges, thus providing a great diversity of opinion.

Data

The data in this study consist of (1) PIC students' responses to a survey instrument describing the attributes of the most helpful teaching assistant in the open laboratory, (2) comments from structured interviews with teaching faculty members and operations staff of the PIC, (3) comments from structured interviews with teaching assistants identified by students as being most and least helpful, and (4) comments from interviews with randomly selected teaching assistants and students.

Data Collection Techniques

A survey instrument was developed to measure student perceptions about teaching assistants (Appendix E). The instrument consists of twenty attribute statements concerning the most helpful teaching assistant. The twenty attributes were consistently prevalent in the comments section of the long base line institutional survey instrument analyzed over the past twenty semesters and among interviews with the various constituents of the PIC. The survey instrument was reviewed and considered valid by all of the members of the PIC instructional faculty and staff (Forcese and Richer 1973; Nickens, Pruga, and Noriega 1980; Wiseman and Aron 1970).

Students were asked to rank each attribute on the survey instrument on a five point interval scale of strongly agree to strongly disagree in reference to the most helpful teaching assistant in the open laboratory. The attributes were listed, then randomly assigned a position on the survey. A random number table was used to select two from as many as possibly five questions to be written in the negative format expecting low mean scores representing noneffective attributes; these two attributes were written in negative form and were analyzed for consistency in the expected reversal of student opinion. Two open-form, or commentary questions, asked about general behavior of teaching assistants that was most helpful and least helpful. The survey continued with a solicitation of comments and open, general expression. The demographics collected involved only the physics course in which the student was enrolled. Surveys were numbered for distribution control; however, no attempt was made to match individual respondents with data (Grosof and Sardy 1985; Jones 1973; Kerlinger 1973).

The survey instrument was distributed to each student who viewed media during the week of midterm in the long semester and during the second and fourth weeks of each of the summer sessions. The instrument was distributed and collected by clerical personnel in the PIC. Each student was encouraged to respond; however, response was not mandatory. Two announcements of the survey with a solicitation of participation by students were read aloud in each lecture classroom, and several copies of the announcements were posted in prominent positions in the PIC (Borg and Gall 1979).

Structured interviews were conducted with teaching faculty members and operational staff members. The interviews concentrated on the attributes of an effective teaching assistant, and student and teaching assistant interactions which were judged most beneficial to the students (Budd and Kelly 1970; Flanders 1970).

Each student interacts with many teaching assistants during a typical laboratory experience, which may extend over a week. No single teaching assistant is in a directive role with respect to the student's laboratory experience. Teaching assistants wear name tags when on duty; however, few students learn the names of the teaching assistants. To help students recognize teaching assistants, a bulletin board was posted at the exit door of the PIC with the picture and name of each instructional assistant working in the PIC during the semester. Below each picture and name a white index card which could be removed daily was attached. When the survey instrument was returned, each student was given a self-adhesive dot and asked to attach it to the card below the picture and name of the instructional assistant who was most helpful to him or her during the semester. A sign advising students in written form of all survey procedures was posted at the PIC clerical desk. Students were informed in writing that a second dot, differing in color, was available upon request (Slavin 1984).

Structured interviews involving the teaching assistants' perceptions of an effective teaching assistant were conducted with the five teaching assistants who received the most dots and with five randomly-chosen teaching assistants who received the least dots in the bulletin board exercise. The interview structure was similar to the interview structure for faculty members and operational staff (Rossi, Wright, and Anderson 1983).

Student interviews were conducted in an attempt to validate and confirm the opinions expressed on the survey instrument. Ten one-hour time intervals were randomly selected from the normal hours of operation during a midterm laboratory week. The first student to enter the facility after the beginning of each time interval was interviewed briefly.

Structured interviews were conducted according to a formal interview protocol. This protocol was pilot tested with five teaching assistants and three instructional staff members before use in the study. Emphasis was placed on open-ended questions about most and least helpful behaviors, and on structured questions using the twenty items on the survey form. In addition questions involving the ability to transfer information gained through this process were asked. Teaching assistants were also asked whether their performance was influenced by data taken during the semester. The interview protocol is exhibited in Appendix F (Good, Barr, and Scates 1941).

Treatment of the Data

The number of students responding to the survey are exhibited in tabular form. Data from the survey instrument are summarized and are exhibited in tables showing the mean student response to each attribute and the standard deviation. The mean and standard deviation for each attribute from each semester are also exhibited. The attributes were ranked according to mean scores and divided into three groups which are designated more effective, effective, and less effective. The responses from each semester were statistically tested to compare the semesters for consistency or difference. The responses from each course level, physical science, general physics, and technical physics were statistically tested to compare the course levels for consistency or difference. The responses from each day of the long semester were statistically tested to compare the daily responses with the overall responses (Naiman, Rosenfeld, and Zirkel 1983; Nie 1975).

The open-format questions were summarized by listing recurrent comments and the approximate frequency of recurrence. The open-format questions were grouped by each course level to determine if any differences were exhibited between groups of students.

Teaching assistants were grouped by seniority and country or language of national origin. These factors were compared to the teaching assistants' number of student votes as most helpful from the bulletin board exercise. Initials rather than names were used in the data analyses to provide anonymity for teaching assistants.

Interviews with the teaching faculty, teaching assistants, operational staff, and students were described narratively. Recurrent themes were analyzed in terms of frequencies of recurrence.

Summary

This chapter delineates the research methods for this study. The students of the PIC were given written surveys and groups of students, instructional staff, and teaching assistants were interviewed. The survey instruments and interviews were used to produce profiles of the characteristics of effective teaching assistants. The data were analyzed by statistical methods. Data analyses and summaries of anecdotal remarks from interviews are provided in Chapter V.

Chapter IV

PRESENTATION OF DATA RELATED TO CHARACTERISTICS OF EFFECTIVE TEACHING ASSISTANTS IN AN OPEN PHYSICS LABORATORY

Introduction

The data for this study of the characteristics of effective teaching assistants in an open physics laboratory consist of (1) student responses to teaching assistant attribute questionnaires, (2) interviews with students, (3) interviews with teaching assistants, and (4) interviews with instructional faculty and staff. The student responses to the questionnaire are compared by semesters and by day of the week, for temporal continuity, and by course levels; statistical agreement and differences are inferred. Anecdotal records from the interviews are displayed in order to compare and contrast to the data from the questionnaires.

Teaching Assistant Attributes as Reported by Students

The instrument and methodology of the survey involving questionnaires which list the attributes of teaching assistants are described in this chapter. The instrument is exhibited in Appendix E. Table 1 contains the response rates of students to the survey instrument as well as the enrollment for each semester and each course for the spring semester, the number of questionnaires returned, and percentage of returned questionnaires. Not all returned questionnaires were marked with identifiable course numbers; therefore, the total of the respondents represents all questionnaires returned and may not be equal to the sum of the course respondents.

Table 1. -- Student Response Rates to Questionnaires

Semester (Course)	Enrolled	Questionnaires Returned	Percentage of Response
Spring Semester			
Physical Science	255	109	42.7
General Physics	96	49	51.0
Technical Physics	152	75	49.3
Total	503	265	52.7
Summer I Semester			
Total	67	35	52.2
Summer II Semester			
Total	64	34	53.1

These totals represent a large sample size and should provide reliable statistical representation. The number of responses in the summer semesters was too small to segregate the sample into courses. The assumption was made, and verification was later statistically inferred, that the summer semesters represented results which were extremely similar to those of the long semester.

In order to facilitate the identification of each attribute by idea rather than question number in reporting the data, key words were used to replace the phrase used in the questionnaire. These key words shown in Table 2, specify either teaching assistant behavior or outcome of a teaching assistant behavior toward a student. The question numbers, complete question phrase, and shortened descriptive version, or key word or words, which are used in reporting the data are provided in Table 2.

Teaching assistant attributes might be divided into three categories. The three categories include: (1) those that are personal techniques of individual teaching assistants, (2) those that are directly related to the physics discipline, and (3) those that involve teaching and learning models in the open laboratory environment. Students seemed to respond to each of these categories in discussing the attributes on the survey in later interviews. In the interview format the same key phrases displayed on Table 2 were used with students.

Table 2. -- Key Words Associated with Each Teaching Assistant Attribute on the Questionnaires

Question	Questionnaire Phrase	Key Word
1	was adequately prepared	prepared
2	was willing to help when asked	willing
3	gave me confusing information	confusing
4	used different examples to help me understand concepts	examples
5	did not overestimate my mathematical ability	mathematics
6	expresses a sense of humor	humor
7	did not give undue attention to one student	attention
8	gave information in simple and concise terms	concise
9	treated each student equally and fairly	fair
10	could identify and understand my needs	needs
11	moved around the laboratory often	moved
12	was not rude, patronizing, or condescending	not rude
13	was enthusiastic about his/her work	enthusiastic
14	was concerned about my achieving my goals	goals

Table 2. -- Continued

Question	Questionnaire Phrase	Key Word
15	clearly understood the equipment and procedures	equipment
16	asked several questions that helped me to understand	questions
17	treated me as an individual	individual
18	was argumentative	argumentative
19	willingly helped with physics coursework other than lab	coursework
20	was patient and willing to repeat information	patient

Data from the questionnaires are divided into two temporal groups, each semester and each day of the week within a long semester. Data from the questionnaires are divided into course levels; these course levels represent student groups with significantly different science backgrounds and mathematical abilities.

Data from the questionnaires are first organized by semester. The student ratings, mean, and standard deviation for each attribute are presented in Table 3 for the spring semester, Table 4 for the summer I semester, and Table 5 for the summer II semester.

Table 3. -- Student Ratings for Each Attribute for the Spring Semester

Question	Key Word	Mean	Standard Deviation
1	Prepared	4.39	0.726
2	Willing	4.53	0.685
3	Confusing	2.52	1.08
4	Examples	3.66	0.990
5	Mathematics	3.77	0.987
6	Humor	3.68	1.13
7	Attention	3.73	1.03
8	Concise	3.86	0.896
9	Fair	4.03	0.848
10	Needs	3.90	0.873
11	Moved	4.06	0.925
12	Rude	4.22	0.883
13	Enthusiastic	3.95	0.849
14	Goals	4.00	0.805
15	Equipment	4.35	0.751
16	Questions	3.78	0.894
17	Individual	4.04	0.808
18	Argumentative	2.28	1.00
19	Coursework	3.19	0.837
20	Patient	4.18	0.761

Table 4. -- Student Ratings for Each Attribute for the Summer I Semester

Question	Key Word	Mean	Standard Deviation
1	Prepared	4.41	0.704
2	Willing	4.56	0.746
3	Confusing	2.35	1.13
4	Examples	3.74	0.898
5	Mathematics	3.79	1.15
6	Humor	3.71	1.03
7	Attention	3.91	1.03
8	Concise	4.11	0.723
9	Fair	4.35	0.597
10	Needs	4.00	0.853
11	Moved	4.41	0.660
12	Rude	4.29	0.799
13	Enthusiastic	4.27	0.666
14	Goals	4.06	0.720
15	Equipment	4.47	0.706
16	Questions	3.85	0.972
17	Individual	4.32	0.638
18	Argumentative	2.18	0.936
19	Coursework	3.21	0.808
20	Patient	4.15	0.734

Table 5. -- Student Ratings for Each Attribute for the Summer II Semester

Question	Key Word	Mean	Standard Deviation
1	Prepared	4.31	0.900
2	Willing	4.59	0.355
3	Confusing	2.29	1.20
4	Examples	3.97	0.891
5	Mathematics	3.89	0.884
6	Humor	4.43	0.903
7	Attention	4.26	0.852
8	Concise	4.11	0.932
9	Fair	4.43	0.558
10	Needs	4.29	0.926
11	Moved	4.40	0.553
12	Rude	4.57	0.698
13	Enthusiastic	4.28	0.750
14	Goals	4.40	0.694
15	Equipment	4.43	0.778
16	Questions	4.20	0.933
17	Individual	4.43	0.608
18	Argumentative	2.28	1.20
19	Coursework	3.86	1.07
20	Patient	4.40	0.553

The number of student responses was 265 in the spring semester, 35 in the summer I semester, and 34 in the summer II semester. The number of students responding each summer semester represented less than 15 percent of the number of students responding in the spring semester. Thus, the results of the spring semester represent a much larger number of students. However, summer students are generally more independent, spend more time on task, make better grades overall, and are often described by faculty as "much more serious students." The student responses were quite similar for the questionnaire for all three semesters.

The student ratings of each attribute are displayed as ranked by relative effectiveness in subsequent tables. Attributes with a mean of greater than 4.2 are designated as more effective attributes. Attributes with a mean of less than 4.2 but greater than 3.9 are designated as effective attributes. Attributes with a mean of less than 3.9 are designated as less effective attributes. Attributes with the highest means, generally, have the smallest standard deviation, indicating the greatest agreement among individual students regarding the importance of the attribute.

The student ratings for each attribute, ranked by mean scores, exhibited with standard deviation, and divided into categories by degree of effectiveness are presented in Table 6 for the spring semester.

Table 6. -- Student Ratings for Each Attribute for the Spring Semester Ranked by Effectiveness

Question	Key Word	Mean	Standard Deviation
	More Effective Attributes		
2	Willing	4.53	0.685
1	Prepared	4.39	0.726
15	Equipment	4.35	0.751
12	Rude	4.22	0.883
	Effective Attributes		
20	Patient	4.18	0.761
11	Moved	4.06	0.925
17	Individual	4.04	0.808
9	Fair	4.03	0.848
14	Goals	4.00	0.805
13	Enthusiastic	3.95	0.849
10	Needs	3.90	0.873
	Less Effective Attributes		
8	Concise	3.86	0.896
16	Questions	3.78	0.894

Table 6. -- Continued

Question	Key Word	Mean	Standard Deviation
5	Mathematics	3.77	0.987
7	Attention	3.73	1.03
6	Humor	3.68	1.13
4	Examples	3.66	0.990
19	Coursework	3.19	0.837
3	Confusing	2.52	1.08
18	Argumentative	2.28	1.00

There are four attributes rated by students in the spring semester as more effective, referred to by the key words as willing, prepared, equipment, and rude. The standard deviations of the ratings for the more effective attributes are smaller than the standard deviations for the eight attributes rated as less effective. This indicates that the students are in greater agreement about the attributes rated more effective than those rated less effective.

The student ratings for each attribute, ranked by mean scores, exhibited with standard deviation, and divided into categories by degree of effectiveness are presented in Table 7 for the summer I semester.

Table 7. -- Student Ratings for Each Attribute for the Summer I Semester Ranked by Effectiveness

Question	Key Word	Mean	Standard Deviation
	More Effective Attributes		
2	Willing	4.56	0.746
15	Equipment	4.47	0.706
1	Prepared	4.41	0.704
11	Moved	4.41	0.660
9	Fair	4.35	0.597
17	Individual	4.32	0.638
12	Rude	4.29	0.799
13	Enthusiastic	4.27	0.666
	Effective Attributes		
20	Patient	4.15	0.734
8	Concise	4.11	0.723
10	Needs	4.00	0.853
14	Goals	4.06	0.720
7	Attention	3.91	1.03
	Less Effective Attributes		
16	Questions	3.85	0.972

Table 7. -- Continued

Question	Key Word	Mean	Standard Deviation
5	Mathematics	3.79	1.15
4	Examples	3.74	0.898
6	Humor	3.71	1.03
19	Coursework	3.21	0.808
3	Confusing	2.35	1.13
18	Argumentative	2.18	0.936

There are eight attributes rated by students in the summer I semester as being more effective, referred to by key words as willing, equipment, prepared, moved, fair, individual, rude, and enthusiastic. The first three attributes directly correspond to the ratings of the students in the spring semester. The standard deviations of the ratings for the more effective attributes are smaller than the standard deviations for the less effective attributes indicating greater student agreement on the more effective attributes.

The student ratings for each attribute, ranked by mean scores, exhibited with standard deviation, and divided into categories by degree of effectiveness are presented in Table 8 for the summer II semester.

Table 8. -- Student Ratings for Each Attribute for the Summer II Semester Ranked by Effectiveness

Question	Key Word	Mean	Standard Deviation
	More Effective Attributes		
2	Willing	4.59	0.355
12	Rude	4.57	0.698
15	Equipment	4.43	0.778
9	Fair	4.43	0.558
17	Individual	4.43	0.608
6	Humor	4.43	0.903
11	Moved	4.40	0.553
20	Patient	4.40	0.553
14	Goals	4.40	0.694
1	Prepared	4.31	0.900
10	Needs	4.29	0.926
13	Enthusiastic	4.28	0.750
7	Attention	4.26	0.852
16	Questions	4.20	0.933
	Effective Attributes		
8	Concise	4.11	0.932
4	Examples	3.97	0.891

Table 8. -- Continued

Question	Key Word	Mean	Standard Deviation
	Less Effective Attributes		
5	Mathematics	3.89	0.884
19	Coursework	3.86	1.07
3	Confusing	2.29	1.20
18	Argumentative	2.28	1.20

There are fourteen attributes rated by students in the summer II semester as more effective. The first three attributes directly correspond to the ratings of the students in the spring semester. The student ratings for most of the attributes are higher in the summer II semester, but the standard deviations correspond to the previous semesters. The two attributes designed to solicit negative responses were clearly recognized by the students in the summer II semester as being less effective attributes.

The rankings for the attributes are very similar for the three semesters; indeed, there is little statistical difference in the highest rankings. Table 9 displays the student ratings for each attribute for the three semesters ranked by effectiveness in the spring semester.

Table 9. -- Student Ratings for Each Attribute for the Spring, Summer I, and Summer II Semesters Ranked by Effectiveness in the Spring Semester

		Mean		
Question	Key Word	Spring	Summer I	Summer II
		More Effective Attributes		
2	Willing	4.53	4.56	4.59
1	Prepared	4.39	4.44	4.31
15	Equipment	4.35	4.47	4.43
12	Rude	4.22	4.29	4.57
		Effective Attributes		
20	Patient	4.18	4.15	4.40
11	Moved	4.06	4.41	4.40
17	Individual	4.04	4.32	4.43
9	Fair	4.03	4.35	4.43
14	Goals	4.00	4.06	4.40
13	Enthusiastic	3.95	4.27	4.29
10	Needs	3.90	4.00	4.29
		Less Effective Attributes		
8	Concise	3.86	4.12	4.11
16	Questions	3.78	3.84	4.20

Table 9. -- Continued

Question	Key Word	Mean		
		Spring	Summer I	Summer II
5	Mathematics	3.77	3.79	3.88
7	Attention	3.73	3.91	4.26
6	Humor	3.68	3.71	4.43
4	Examples	3.66	3.74	3.97
19	Coursework	3.19	3.21	3.86
3	Confusing	2.52	2.35	2.29
18	Argumentative	2.28	2.18	2.29

Student ratings of each attribute for the summer semesters were tested to compare the population means for each attribute with the null hypothesis that the population means from the spring semester are the same as the population means for the summer I and summer II semesters. Calculating a two-tailed _Z_ test with a confidence interval of .01, alpha equal 0.01, values of less than 2.575 were used to infer that the means for an attribute were indeed statistically indistinguishable. In Table 10, each attribute is listed in a row and the semesters, in columns, with a zero in the matrix indicating no difference in the means and a >1 indicating a statistical difference with a confidence interval of greater than 1 percent (REFLEX 1990).

Table 10. -- Statistical Agreement Between Student Ratings for Each Attribute for the Spring, Summer I, and Summer II Semesters Ranked by Effectiveness in the Spring Semester

Question	Key Word	Mean Spring	Agree Mean Summer I	Agree Mean Summer II
		More Effective Attributes		
2	Willing	4.53	0	0
1	Prepared	4.39	0	0
15	Equipment	4.35	0	0
12	Rude	4.22	0	>1
		Effective Attributes		
20	Patient	4.18	0	0
11	Moved	4.06	>1	>1
17	Individual	4.04	0	>1
9	Fair	4.03	>1	>1
14	Goals	4.00	0	>1
13	Enthusiastic	3.95	0	0
10	Needs	3.90	0	0
		Less Effective Attributes		
8	Concise	3.86	0	0
16	Questions	3.78	0	>1

Table 10. -- Continued

Question	Key Word	Mean Spring	Agree Mean Summer I	Agree Mean Summer II
5	Mathematics	3.77	0	0
7	Attention	3.73	0	>1
6	Humor	3.68	0	>1
4	Examples	3.66	0	0
19	Coursework	3.19	0	>1
3	Confusing	2.52	0	0
18	Argumentative	2.28	0	0

To test whether there was temporal or cyclic agreement in student ratings of each attribute during the spring, data were divided by day collected and statistically compared to the overall data means using the same test described for the comparison between data means from individual semesters. From the total sample of 265 students, 22.3 percent was collected on Monday, 23.0 percent was collected on Tuesday, 27.9 percent was collected on Wednesday, and 26.8 percent was collected on Friday. Each day represented different students and different teaching assistants and clerical personnel. Table 11 represents the student ratings of attributes for each day compared with the overall attribute means.

Table 11. -- Student Ratings for Each Attribute for the Spring Semester and for Each Day Ranked by the Effectiveness in the Spring Semester

Key Word	Spring Semester Mean	Monday Mean	Tuesday Mean	Wednesday Mean	Thursday Mean
		More Effective			
Willing	4.53	4.49	4.61	4.50	4.52
Prepared	4.39	4.37	4.43	4.35	4.14
Equipment	4.35	4.32	4.38	4.30	4.41
Not Rude	4.22	4.05	4.18	4.28	4.33
		Effective			
Patient	4.18	4.16	4.30	4.07	4.24
Moved	4.06	3.93	4.13	4.00	4.19
Individual	4.04	3.90	4.06	4.07	4.10
Fair	4.03	3.98	4.18	3.88	4.09
Goals	4.00	3.97	3.95	3.88	4.17
Enthusiastic	3.95	3.90	3.93	3.91	4.06
Needs	3.90	3.73	3.85	3.91	4.07
		Less Effective			
Concise	3.86	3.76	3.77	3.88	4.00

Table 11. -- Continued

Key Word	Spring Semester Mean	Monday Mean	Tuesday Mean	Wednesday Mean	Thursday Mean
Questions	3.78	3.70	3.66	3.77	3.96
Mathematics	3.77	3.66	3.66	3.71	4.00
Attention	3.73	3.66	3.67	3.66	3.93
Humor	3.68	3.54	3.36	3.66	4.09
Examples	3.66	3.54	3.51	3.74	3.80
Coursework	3.19	2.93	3.25	3.19	3.37
Confusing	2.52	2.51	2.64	2.58	2.39
Argumentative	2.18	2.27	2.20	2.38	2.29

To test for a daily difference in student ratings of attributes, data were divided by day collected and statistically compared to the overall data means using the same test described for the comparison between data means from individual semesters. In Table 12, the student ratings of each attribute are listed in rows (with the attributes ranked by the means of the spring data) and the days are listed in columns with a zero in the matrix indicating no difference in the mean and a >1 indicating a statistical difference with a confidence interval of greater than 1 percent.

Table 12. -- Statistical Agreement Between Student Ratings for Each Attribute for the Spring Semester and for Each Day Ranked Effectiveness in the Spring Semester

Key Word	Mean Spring	Agree Mean Monday	Agree Mean Tuesday	Agree Mean Wednesday	Agree Mean Thursday
		More Effective			
Willing	4.53	0	0	0	0
Prepared	4.39	0	0	0	>1
Equipment	4.35	0	0	0	0
Not Rude	4.22	0	0	0	0
		Effective			
Patient	4.18	0	0	0	0
Moved	4.06	0	0	0	0
Individual	4.04	0	0	0	0
Fair	4.03	0	0	0	0
Goals	4.00	0	0	0	0
Enthusiastic	3.95	0	0	0	0
Needs	3.90	0	0	0	0
		Less Effective			
Concise	3.86	0	0	0	0
Questions	3.78	0	0	0	0

Table 12. -- Continued

Key Word	Mean Spring	Agree Mean Monday	Agree Mean Tuesday	Agree Mean Wednesday	Agree Mean Thursday
Mathematics	3.77	0	0	0	0
Attention	3.73	0	0	0	0
Humor	3.68	0	0	0	0
Examples	3.66	0	0	0	0
Coursework	3.19	0	0	0	0
Confusing	2.52	0	0	0	0
Argumentative	2.28	0	0	0	0

To test for agreement between student ratings of each attribute between individual physics courses, or course level, and the overall spring semester, data were divided by course in which collected and statistically compared to the overall data means using the same test described for the comparison between data means from individual semesters. From the total sample of 265 students, more than 41 percent of the data were collected from Physical Science students, more than 18 percent were collected from General Physics students, more than 28 percent were collected from Technical Physics students. Table 13 displays student ratings of attributes for the spring semester and for each physics course, ranked by effectiveness in the spring semester.

Table 13. -- Student Ratings for Each Attribute for the Spring Semester and for Each Physics Course Ranked by Effectiveness in the Spring Semester

Key Word	Spring Semester Mean	Physical Science Mean	General Physics Mean	Technical Physics Mean
		More Effective		
Willing	4.53	4.57	4.47	4.51
Prepared	4.39	4.57	4.29	4.32
Equipment	4.35	4.47	4.25	4.35
Not Rude	4.22	4.19	4.25	4.31
		Effective		
Patient	4.18	4.29	4.08	4.09
Moved	4.06	4.16	4.06	3.97
Individual	4.04	4.14	4.10	3.91
Fair	4.03	3.95	4.00	4.11
Goals	4.00	4.15	3.94	3.88
Enthusiastic	3.95	4.03	4.07	3.79
Needs	3.90	4.04	3.82	3.77
		Less Effective		
Concise	3.86	3.96	3.92	3.80

Table 13. -- Continued

Key Word	Spring Semester Mean	Physical Science Mean	General Physics Mean	Technical Physics Mean
Questions	3.78	4.10	3.88	3.32
Mathematics	3.77	3.83	3.82	3.71
Attention	3.73	3.66	3.71	3.91
Humor	3.68	3.99	3.55	3.45
Examples	3.66	4.04	3.61	3.17
Coursework	3.19	3.19	3.29	3.23
Confusing	2.52	2.47	2.31	2.61
Argumentative	2.18	2.35	2.37	2.09

To test for a course level difference in attribute ranking, data were divided by course in which collected and statistically compared to the overall data means using the same test described for the comparison between data from individual semesters. In Table 14 each attribute is listed in rows, with the attributes ranked by the overall means of the spring data, and course levels are listed in columns with a zero in the matrix indicating no difference in the mean and a >1 indicating a statistical difference with a confidence interval of greater than 1 percent.

Table 14. -- Statistical Agreement Between Student Ratings for Each Attribute for the Spring Semester and for Each Physics Course Ranked by Effectiveness in the Spring Semester

Key Word	Spring Semester Mean	Physical Science Mean	General Physics Mean	Technical Physics Mean
		More Effective		
Willing	4.53	0	0	0
Prepared	4.39	0	0	0
Equipment	4.35	0	0	0
Not Rude	4.22	0	0	0
		Effective		
Patient	4.18	0	0	0
Moved	4.06	0	0	0
Individual	4.04	0	0	0
Fair	4.03	0	0	0
Goals	4.00	0	0	0
Enthusiastic	3.95	0	0	0
Needs	3.90	0	0	0
		Less Effective		
Concise	3.86	0	0	0

Table 14. -- Continued

Key Word	Spring Semester Mean	Physical Science Mean	General Physics Mean	Technical Physics Mean
Questions	3.78	0	0	>1
Mathematics	3.77	0	0	0
Attention	3.73	0	0	0
Humor	3.68	0	0	0
Examples	3.66	0	0	>1
Coursework	3.19	0	0	0
Confusing	2.52	0	0	0
Argumentative	2.18	0	0	0

Three open-ended questions on the survey were asked for commentary responses. The response rate for the open-ended questions was 237 out of 334, approximately 71 percent. Question 1 asked: What did the teaching assistant do that was most helpful? Question 2 asked: What did the teaching assistant do that was least helpful to you? Question 3 asked for general comments. Based on all of the combined data for the spring, summer I, and summer II semesters, several comments can be made in broad categories. However, the categories are represented by one actual comment in a student's own words. Table 15 lists these comments.

Table 15. -- Tabulation of Open-Ended Comments by Students About the Attributes of a Most Helpful Teaching Assistant

Category	Approximate Number of Responses
What did the teaching assistant do that was most helpful?	
Was patient	121
Helped set up equipment	106
Helped until I understood	54
Was available very quickly	36
Appreciated my level of understanding	42
Repeated information several times	31
Used several real world examples	20
Explained why things were done	15
Went beyond my question to explain the process	15
What did the teaching assistant do that was least helpful?	
could not understand his/her English	172
wrong answers to question	161
different T. A.'s give different answers to same question	131
too much mathematics for me	66

Table 15. -- Continued

category	approximate number of responses
gave me the answer instead of helped me to get answer	54
did it for me instead of helping me	52
did not know the lab	42
did not want to help me	31
went way beyond the materials	23
did not explain concepts	22
go frustrated with me	17
only helped the pretty girls	17
going off on tangents	16
general comments	
individuality of this lab is great	164
This is the best laboratory I have ever seen.	68
labs were too far in front of the lecture	55
need more help with questions at end of lab	31
The T. A. did an excellent job.	27
lab is understaffed and does not operate enough hours each week	16

One student wrote, "I am very pleased with the way the PIC is run. It seems to be very efficient in achieving its goals (1) to help students to understand Physics and (2) to help students enjoy Physics. I never dread coming to lab!"

Interviews with Faculty and Staff

Interviews were conducted with faculty and instructional staff, teaching assistants and students. The interview protocol used is exhibited in Appendix F.

The faculty and instructional staff members interviewed had from five to twenty-four years of experience in teaching physics at the university level. All were comfortable with the PIC philosophy, felt competent to interact in the environment, and enjoyed the experience. The five most effective attributes of an effective teaching assistant (as phrased on the student survey instrument) identified by the faculty and instructional staff were the following:

1 was adequately prepared,

2 was willing to help when asked,

15 clearly understood the equipment and procedures,

20 was patient and willing to repeat information, and

6 expresses a sense of humor.

The first four attributes were identified by students as being more effective and the last attribute was rated as relatively unimportant. The faculty and instructional staff identified the least effective attributes as the following:

19 willingly helped with physic other coursework,

14 was concerned about my achieving my goals,

18 was argumentative,

3 gave me confusing information, and

7 did not give undue attention to one student.

There was not clear agreement with students except in the points that were negatively stated on the survey. The faculty expressed an interest in achieving more individual bonds between teaching assistants and students. The faculty was most concerned about the English language proficiency of teaching assistants and the need for more teaching assistant preparation for the laboratory assignments. They uniformly considered the most detrimental behavior of a teaching assistant to be arrogance or condescension toward students.

Interviews with Teaching Assistants

The five teaching assistants identified by the students in the pictorial survey as being most helpful were interviewed at length using the protocol in Appendix F. These teaching assistants identified by the students as most helpful each had at least two years of experience in the PIC. Three of the five teaching assistants were non-native English speakers. This contradicts the common faculty and student assumption that language is often the principal barrier to teaching assistant performance.

The five teaching assistants identified the most effective attributes of an effective teaching assistant as being the following:

2 was willing to help when asked,

1 was adequately prepared, and

15 clearly understood the equipment and procedures.

The attributes identified directly correspond to the attributes chosen by students of the PIC. The comments made by the teaching assistants include: (1) a need for direct student empathy and appreciation of the level of sophistication of the student with respect to the physics and mathematics, (2) being very patient in order to answer the same question many times during a work shift, and (3) questioning the students to illicit responds from them in their own words and concepts and using these words to develop the physical principles. The teaching assistants described as most helpful seemed to assume that any teaching assistant should be well-prepared and should clearly understand the equipment.

The teaching assistants described by students as most helpful identified the least effective attributes as the following:

18 was argumentative, and

3 gave me confusing information.

These results directly agree with student ratings of the attributes and are the only negative attributes on the survey.

The most helpful teaching assistants seemed to be soft spoken and mild mannered but appeared to exhibit a definite teaching personality and a clear interest and enthusiasm for physics. These teaching assistants were prepared to discuss the PIC at length, and stated that they were genuinely committed to the concept that an open laboratory was the best way to teach physics laboratories and presented many more opportunities for individual contact between the teaching assistants and students.

From the many teaching assistants receiving very few votes as being most helpful in the pictorial survey, five were selected at random. These teaching assistants identified the most important attributes of a helpful teaching assistant as the following:

7 did not give undue attention to one student,

12 was not rude, patronizing, or condescending, and

6 expresses a sense of humor.

These attributes were ranked in the middle of the student ratings on the survey. These teaching assistants chose the least effective attributes as the following:

18 was argumentative, and

3 gave me confusing information.

These results agreed with student ratings of the attributes and were the only negative attributes on the survey.

Three of these teaching assistants had poor English language skills and did not have well-defined goals in their own physics education. The faculty found these teaching assistants to be in need of more teacher training and student sensitivity training. The interviews were, generally, not very informative or productive.

Following the interviews with all of the teaching assistants, a videotape of a round table discussion among the "best teaching assistants" was produced as an instrument to be used in future teaching assistant training courses. The teaching assistants identified essentially the same important behaviors on the videotape that are described in this study.

Interviews with Students

Student interviews were conducted to validate and confirm the opinions expressed on the survey instrument. Ten one-hour time intervals were randomly selected from the normal hours of operation during a midterm laboratory week. The first student to enter the facility after the beginning of each time interval was interviewed briefly. Comments from student interviews clearly supported the data represented by the survey forms. The students identified the more effective attributes as the following:

2 was willing to help when asked,

1 was adequately prepared,

15 clearly understood the equipment and procedures, and

12 was not rude, patronizing, or condescending.

These attributes directly correspond to the survey results. The students stated that language could be a barrier; however, many teaching assistants have overcome language barriers with teaching techniques and a clearly expressed willingness to help students with specific problems. Students were most concerned with their own perceptions that the teaching assistant clearly wanted to be of help and understood the physical concepts and measuring techniques of the laboratory. Most students were sympathetic to the difficulties that teaching assistants face in an open laboratory, including lack of direct control and unwillingness of students to prepare properly for work in the laboratory. Students also recognized the apprehension and frustration with which most students approach a physics course and the disadvantage that presents to a teaching assistant or physics instructor.

Summary of Major Findings

The following is a summary of the major findings of this study corresponding to the research questions developed in Chapter I:

1. The attributes which were deemed most important to an effective teaching assistant by students included the following, in order of importance: (1) was willing to help when asked, (2) was adequately prepared, (3) clearly understood the equipment and procedures, and (4) displayed a lack of rude, patronizing or condescending behavior toward students.

2. The attributes which were deemed least important to an effective teaching assistant by students were (1) being argumentative, (2) giving confusing information, (3) helping with physics coursework other than the laboratory, and (4) using a variety of examples to help students understand concepts.

3. The attributes which were deemed most important to an effective teaching assistant by most helpful teaching assistants as chosen by students correspond to the attributes described by students as being effective.

4. The attributes which were deemed most important to an effective teaching assistant by faculty, staff, and other teaching assistants correspond to the attributes described by students as being helpful. Two additional attributes were patience and willingness to repeat information and a sense of humor.

CHAPTER V

SUMMARY OF MAJOR FINDINGS, DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS FOR FUTURE STUDY

Introduction

The purposes of this study were (1) to chronicle the development of the Physics Instructional Center (PIC) at the University of North Texas, an open physics instructional laboratory; (2) to determine student, faculty, and staff perceptions about the attributes of effective teaching assistants in an open physics instructional laboratory; and (3) to identify representative teaching assistants who were perceived by students as being most helpful and to determine their perceptions about the attributes of effective teaching assistants. The information gathered to address these purposes included results from a questionnaire that dealt with teaching assistant attributes, interviews with students, faculty, staff and teaching assistants, interviews with teaching assistants characterized by students as being most helpful, and others. Data from the questionnaire were displayed and were treated statistically to determine constituent agreement and to examine homogeneity of responses. The interviews were described narratively and compared to the responses to the survey instrument.

Summary of Major Findings

The following are of the major findings of this study corresponding to the research questions developed in Chapter I:

1. The attributes which were deemed most important to an effective teaching assistant by students include the following, in order of importance: (1) was willing to help when asked, (2) was adequately prepared, (3) clearly understood the equipment and procedures, and (4) displayed a lack of rude, patronizing or condescending behavior toward students.

2. The attributes which were deemed least important to an effective teaching assistant by students were (1) being argumentative, (2) giving confusing information, (3) helping with physics coursework other than the laboratory, and (4) using a variety of examples to help students understand concepts.

3. The attributes which were deemed most important to an effective teaching assistant by most helpful teaching assistants as chosen by students correspond to the attributes described by students as being effective.

4. The attributes which were deemed most important to an effective teaching assistant by faculty, staff, and other

teaching assistants correspond to the attributes described by students as being helpful. Two additional attributes were patience and willingness to repeat information and a sense of humor.

Discussion

The students, teaching assistants, faculty, and staff surveyed basically agreed upon the attributes of effective teaching assistants. Teaching assistants and faculty members indicate that attributes should be clearly delineated and instructors trained in the importance of these behaviors. The attributes seem unduly simple; however, there was clear agreement among the constituents. The most effective teaching assistants assumed that these qualities were shared by all teaching assistants and were somewhat surprised to learn the need to state them clearly in a teaching assistant training program. More complex teaching methods involving multiple examples and interrelated questioning techniques seem to go unnoticed by students.

Teaching assistants with limited native English language skills were perceived as effective teaching assistants if they possessed the willingness to help, were well prepared in concept and laboratory techniques, and possessed good personal interaction skills. Several of the teaching assistants chosen by students as being effective were not native English speakers. However, in other studies students often report language barriers first when discussing teaching assistant problems (Shana 1978).

All of the attributes on the survey have been identified over several years as being important to students. The distinction of this study was to rank the priority of these attributes. Students did not indicate that any of the positive attributes were detrimental to their learning environment; therefore, all of these attributes should be encouraged.

Student goals are so ill-defined that trying to match teaching assistant perceptions with student goals is almost meaningless. Empathy and appreciation of student cognitive levels in mathematics and concepts of physical science better serve the teaching assistant than goal models.

Conclusions

The following conclusions are inferred from this study:

1. Student input appears to be important in identifying characteristics of effective teaching assistants in an open laboratory environment.

2. Students and instructional staff seem to agree on the characteristics of effective teaching assistants in an open laboratory environment.

3. The most important characteristics of effective teaching assistants appear to include those that are personal in nature, those that involve knowledge of the

discipline, and those that involve organization of the laboratory for students' learning.

Recommendations for Future Study

The following recommendations are proposed for further study:

1. The effort to survey student perceptions of effective teaching assistant attributes should be continued in order to build a data base that exhibits uniformity or changes over a long base line period.

2. The survey data should be differentiated by sex to determine whether there is a difference between male and female attitudes about the attributes of effective teaching assistants.

3. The results of a continuing study should be directly incorporated into teaching assistant orientation and training programs and should be shared with instructional faculty and staff.

4. Operational changes in the PIC should be examined and implemented which encourage and compliment the teaching assistant attributes deemed effective by students.

5. A study should be made to compare the perceptions of students in closed laboratories with those expressed by students in the open laboratory about the attributes of effective teaching assistants.

6. Programs at other institutions which exhibit many of the open laboratory characteristics should be surveyed to obtain student perceptions toward helpful teaching assistant attributes.

7. A survey instrument should be developed to measure and characterize communications between students, teaching assistants, and instructional faculty and staff. The information from this instrument should then be incorporated into the teaching assistant training and development program.

8. A study should be undertaken to examine and develop the role of the physics faculty in training teaching assistants.

APPENDIX A

REMARKS OF A. A. STRASSENBURG SUMMARIZING THE NATIONAL SCIENCE FOUNDATION AIRLIE HOUSE CONFERENCE TOPICS

There have been some oft-repeated, or at least loudly voiced themes. Here are some that I have heard:

1. Academic institutions resist change. We need more effective methods of calling their attention to the possibilities offered by new degree programs, new materials, and new technologies.

2. Individual faculty members resist change. The barriers to the adoption of innovative instructional systems are numerous and high. Among the most significant are a lack of incentives in existing academic reward structure, lack of a felt need for change, the inferior quality of some new products, and the lack of both adequate information about suitable models and new instructional systems.

3. We need more effective dissemination systems for exiting materials such as workshops, regional dissemination centers and information retrieval systems, and we need more information about existing mechanisms such as ERIC and the Science Information Exchange. Professional societies could also help, but hey need financial support.

4. There should be continuing encouragement for the development of smaller units of instructional materials and systems. By this technique we can increase diversity in a cost-effective manner.

5. To increase the influence of instructional innovation, we must solve problems of a political nature, as well as the usual problems concerning content and methodology.

6. The wider use of educational technology awaits the generation of more software, the training of more skilled technical personnel, the modularization of system and the standardization of systems components, and the reduction in cost of hardware.

7. Continuing education will not thrive unless incentives for students and faculty are increased, opportunities are better advertised, and the efforts of industry, academia, and the professional societies are coordinated.

8. Meaningful evaluation of instruction requires careful planning and better funding, but developers must identify what and why they are evaluating, when to evaluate, what kind of evaluation serves their proposes, and how much evaluation is useful.

9. Developers themselves disagree on the major problems as well on the solutions. This suggests that support for research on the effectiveness of instructional systems is at least as important as support for materials development.

10. the proliferation of largely unevaluated materials and programs, greater expectation, higher instructional costs, a decline of educational productivity, and decreases in institutional and federal support for education have created a crisis for educators. We need the continuing financial support of NSF for promising research and development in education, and we need their moral support in our efforts to justify to a skeptical public and a cost-conscious administration quality education for all who seek it (National Science Foundation 1974, 10-12).

APPENDIX B

PROJECT ABSTRACTS FOR EXEMPLARY NATIONAL SCIENCE FOUNDATION SCIENCE EDUCATION GRANTS

1) Project C-BE, University of Texas, John Allan, and J. J. Lagowski, ($1.63 million), (SED74-21031)

Computer-based instructional techniques assist the instructor in teaching to large classes material which is more and more sophisticated. Computer power was developed to provide interactive terminals, interactive graphics, laboratory data acquisition and process control, mark-sense grading, real-time video projection and terminal-controlled movies and slide. (National Science Foundation 1976, 1).

2) Computer Graphics in Learning, University of California Berkley, Alfred A. Bork, Richard Ballard, and Joseph Marasco, ($660,000), (SED 74-2089-A02)

The project explores the use of interactive computer graphics as an aid in learning. The three phases concern (1) the restructuring of a beginning physics course to allow student choice of content as well as pacing; (2) development of more effective ways of employing computers in education, including improved authoring systems; and (3) dissemination of programs and information about the best utilizations of the computer in learning environment.

The project seeks to develop compelling examples of effective use of the computer in learning, particularly with regard to graphical facilities, hoping to provide new and exciting individualized learning resources for students which can be employed in both standard and PSI environments.

An important aspect of our work is to develop an authoring system which allows faculty with no direct knowledge of computer programming to prepare student-computer dialogues. The chances of success, particularly for the long-range point of view, are considerable. (National Science Foundation 1977, 105).

3) <u>BIOTECH</u>, American Institute of Biological Sciences, Richard A. Dodge, ($1.34 million) 71-04400

> The purpose was to produce individualized teaching modules which demonstrate a wide range of biologically related technical skills. The modules are task oriented and do not consider conceptual or philosophical questions and may be used in virtually any teaching situation requiring the learning of a biological skill or technique. Each module stands alone and demonstrates "how to do" a task. BIOTECH modules may be inserted into any teaching plan when and where students need to see how a task is done.
>
> The modules are skill-oriented, self-contained, independent units which may be incorporated singly or in groups within exiting courses, programs, or training regimes (National Science Foundation 1976, 63).

4) <u>Minicourse Development Project</u>, W. V. Mayer and S. N. Postlethwait

> The Minicourse Development Project engaged in the design, preparation, organization, and development of a series of minicourses that constitute the major content core of a generalized introductory collegiate biology course. The project was a joint effort of the BSCS and Purdue University.
>
> The term "minicourse" is intended to mean "small course." By dividing large units of content (i.e., biology, into smaller units), the elements of the instructional program can be grouped in a variety of ways to accommodate diverse requirement of both students and teachers.
>
> The Minicourse Development Project affords even greater potential for flexible use and individualization by presenting the self-instructional materials in an audio-tutorial (A-T) format. the A-T system of individualized instruction, as developed at Purdue University, has been a successful instructional strategy in the freshman botany and zoology course at Purdue (National Science Foundation 1977, 32).

5) Human Sciences Program, Biological Sciences Curriculum Study, William V. Mayer,

> Choice and flexibility are important characteristics of the program. Development and learning are specific to individuals. Students differ in learning style, process bias, cognitive and affective maturity, perception and motivation, as well as in many other ways. To accommodate these diversities, the Human Sciences curriculum provides a variety and abundance of learning activities related to a topic. Students are free to choose among the alternatives. Instructional activities are designed to serve as a stimulus to learning rather than as a prescription for what is to be learned (National Science Foundation 1977, 127).

6) Close-Range Photogrammetry, Miami Dade Community College, Joel Kobelin, ($54,000), (SED 75-18976)

> The long range goal of the project is the development of a model two year program leading to an associate degree for training photogrammetry technicians to (1) work in museum or archives settings, or (2) transfer into bachelor's degree programs for continuing their education.
>
> The interdisciplinary aspects of combining the scientific and technical with the social science and humanities area suggest new relationships among curricula and the faculty that teach them.
>
> Finally, the concept of minimizing additional proliferation of courses, through new combinations of exiting courses to develop a new program suggest an economically realistic approach (National Science Foundation 1976, 121).

7) Modular Short Courses in Chemistry, Colorado State University, Robert Osteryoung, (SED 73-10325 A02), ($99,500)

> To remedy a problem existing at the graduate level in area outside of chemistry which have a "high content" of chemistry, we are developing a series of "short courses" in a number of area of chemistry. These courses with high audiovisual content, are designed to meet, primarily, the needs of non-chemistry graduate students or technicians who must make use of the principles, practices and instruments associated with chemistry as a core discipline. The course modules last two weeks, with an hour of lecture or a laboratory period scheduled each day.
>
> In general, chemistry departments do not make an effort to provide "service" courses for non-chemistry graduate students whose interest in chemistry may be very narrow (National Science Foundation 1976, 187).

8) Keller Plan Calculus-Based Physics Modules, CBP Workshop, University of Nebraska-Lincoln, Robert G. Fuller, ($57,320), (SED75-11210-A01)

> The project began as a college faculty workshop during which time fifteen experienced Keller Plan instructors wrote a complete set of modules for a calculus-based, general physics course. Each module includes learning objectives, references to assignments in each of five leading textbooks . . ., problems with solutions, a practice test, and three forms of mastery tests with grading keys. The workshop completed forty-three modules for physics plus three calculus background modules, an orientation module, review tests and an appendix on how to use the Keller Plan (National Science Foundation 1977, 211).

9) <u>The Development of Nuclear Experiments and Senior Research Projects for Undergraduates</u>, North Texas State University, J. L. Duggan, (Coauthors, F. D. McDaniel, and J. G. Hehn), ($70,900), (SED 74-20286)

In this project a series of nuclear science modules are being developed. The modules are being developed for the following academic disciplines: physics, chemistry, biology, geology and environmental sciences. In each area the modules are rather self contained and center around some piece of experimental nuclear instrumentation.

Each of these modules is designed around some "state of the art" piece of nuclear instrumentation (National Science Foundation 1977, 111)

APPENDIX C

PHYSICS INSTRUCTIONAL CENTER
SEMESTER SURVEY INSTRUMENT

PHYSICS INSTRUCTIONAL CENTER DEPARTMENT OF PHYSICS NORTH TEXAS STATE UNIVERSITY

We are attempting to evaluate PIC services. Please respond to service related questions soley upon your experience with the PIC. Please return the completed form to the PIC front desk. THANK YOU for your assistance.

DEMOGRAPHIC DATA: please circle the appropriate response

A. CLASS Freshman Sophomore Junior Senior Graduate

B. COURSE 1210 1220 1310 1430 1440 Special Student

C. I most often come to the PIC labs on MONDAY TUESDAY WEDNESDAY THURSDAY

D. I most often use the PIC and LABS during the following hours, (circle appropriate HOURS
MORNINGS 8-10, 10-12 AFTERNOONS 12-2, 2-4 EVENINGS 4-6, 6-8

Midterm Evaluation

Please answer the following questions about the PIC. Use the scale below:

5	4	3	2	1
strongly agree	agree	no opinion	disagree	strongly disagree

( ) 1. Having to take an exam over each investigation helped to insure that I studied and better understood the objectives and results of the experiment.

( ) 2. PIC hours were adequate.

( ) 3. The exams were fair and covered the laboratory investigation.

( ) 4. The teaching assistants in the laboratory were helpful when I needed assistance to complete the experiment.

( ) 5. I feel the teaching assistants were adequately prepared to help me in the lab.

( ) 6. The average grade on the videotapes that I have seen is 1) A, 2) B, 3) C, 4) D, 5) F

( ) 7. Did you experience delays or frustration due to the laboratory equipment? 1) Yes 2) No If yes, how?

8. What did you like best about the PIC?

9. What did you like least about the PIC?

Please feel free to make any comments relevant to the PIC.

APPENDIX D

PHYSICS INSTRUCTIONAL CENTER

PARTIAL MEDIOGRAPHY

PHYSICS INSTRUCTIONAL CENTER
North Texas State University

No.	Videotape Programs
156	Accelerated Motion & Angle of Lean (Neie) 9.0 min. 1980
136	Acids, Bases and Salts (Escue) 10.4 min. 1978
146	Analysis of Light by a Spectroscope (Sybert) 18.0 min. 1979
101	Archimedes' Principle (Sybert) 17.0 min. 1977
152	Atwood Machine (Redding) 12.0 min. 1977
140	Ballistic Pendulum (Redding) 9.0 min. 1978
103	Boyle's Law (Stephens) 13.0 min. 1977
139	Centripetal Force (Rawlins) 13.0 min. 1979
133	Change of Phase (Brown) 4.5 min. 1978
127	Chemical Changes (Escue) 8.9 min. 1978
162	Chemical Laboratory Techniques (Wood) 1980
148	Circular Motion (McCurdy) 9.0 min. 1979
125	Collision on Two Dimensions (Dowdy) 10.5 min. 1978
149	Electric Circuits (McCurdy) 13.0 min. 1979
104	Electric Fields (Mackey) 8.5 min. 1977
105	Electrolysis of Water (Escue) 9.0 min. 1977
117	Expansion of Solids (Stephens) 9.0 min. 1977
106	Free Falling Body (Stephens) 12.0 min. 1977
119	Harmonic Motion (McCurdy) 9.5 min. 1977
159	Harmonic Motion, 2nd Edition (McCurdy) 11.5 min. 1980
150	Heating Effect of an Electric Current (McCurdy) 9.0 min. 1979
107	Inclined Plane (Rawlins) 12.9 min. 1977
121	Interference/Diffraction (Smirl) 11.0 min. 1977
124	Introduction to the Oscilloscope (Marsh) 20.0 min. 1978
137	Lenses (Krishnan) 10.0 min. 1978
108	Magnetic Fields (Deaton) 8.5 min. 1977
165	Magnetic Forces on Electric Currents (Windham) 9.5 min. 1981
109	Measurement (Rothwell) 11.5 min. 1977
161	Measurement, 2nd Edition (Rothwell) 12.5 min. 1980
132	Mechanical Equivalent of Heat (McCurdy) 11.0 min. 1978
141	Night Sky: Spring (Harrison) 37.0 min. 1979
131	Night Sky: Summer (Harrison) 30.0 min. 1978
134	Night Sky: Autumn (Harrison) 41.0 min. 1978
119	Ohm's Law (Resistivity of Wire) (Windham) 9.0 min. 1977

138 Oxidation and Reduction
(Escue) 6.5 min. 1979

135 Photoelectric Effect
(Sears) 19.0 min. 1978

144 Radioactivity
(Stephens) 8.5 min. 1979

111 Radioactivity: Half Life
(Basbas) 7.0 min. 1977

157 Reflection/Refraction
(Redding) 14.0 min. 1977

164 Resonating Air Columns and The Speed of Sound
(Redding) 1981

142 Rotational Motion
(Neie) 10.0 min. 1979

122 Series and Parallel Circuits
(Toten) 15.0 min. 1978

113 Specific Heat
(Rawlins) 13.0 min. 1977

118 Spectroscopy
(Roberts) 11.0 min. 1977

114 Speed of Sound (Air Column)
(Marsh) 12.0 min. 1977

143 Spherical Mirrors
(Krishnan) 12.0 min. 1979

115 Standing Waves
(Marsh) 9.0 min. 1977

147 Torque and Center of Gravity
(Neie) 14.0 min. 1979

116 Vector Addition
(Hehn) 10.5 min. 1977

151 Vector Addition, 2nd Edition
(Hehn) 19.0 min. 1980

166 The Wheatstone Bridge
(Windham) 9 min. 1981

<u>No.</u> <u>Slide-tape Programs</u>

18 Minerals
27.0 min. 1978

19 Rocks
7.0 min. 1978

20 Soil Tests
12.0 min. 1978

17 Weather Elements
14.0 min. 1978

APPENDIX E

STUDENT SURVEY OF OPEN LABORATORY TEACHING ASSISTANTS QUESTIONNAIRE

BEHAVIORS OF THE MOST HELPFUL T.A.

DEPARTMENT OF PHYSICS
PHYSICS INSTRUCTIONAL CENTER

NORTH TEXAS STATE UNIVERSITY

STUDENT SURVEY OF OPEN LABORATORY TEACHING ASSISTANTS

PLEASE USE THE FOLLOWING SCALE TO INDICATE YOUR ATTITUDE TOWARD THE T.A. BEHAVIORS WHICH WERE HELPFUL TO YOU IN THE OPEN LABORATORY.

STRONGLY AGREE	AGREE	NO OPINION	DISAGREE	STRONGLY DISAGREE
5	4	3	2	1

PHYSICS COURSE (PLEASE CIRCLE ONE):

1210 1220 1310 1320 1430 1440

IN THE OPEN LABORATORY THE MOST HELPFUL TEACHING ASSISTANT:

01.	WAS ADEQUATELY PREPARED.	5	4	3	2	1
02.	WAS WILLING TO HELP WHEN ASKED.	5	4	3	2	1
03.	GAVE ME CONFUSING INFORMATION.	5	4	3	2	1
04.	USED DIFFERENT EXAMPLES TO HELP ME UNDERSTAND CONCEPTS.	5	4	3	2	1
05.	DID NOT OVERESTIMATE MY MATHEMATICAL ABILITY.	5	4	3	2	1
06.	EXPRESSED A SENSE OF HUMOR.	5	4	3	2	1
07.	DID NOT GIVE UNDUE ATTENTION TO ONE STUDENT.	5	4	3	2	1
08.	GAVE INFORMATION IN SIMPLE AND CONSICE TERMS.	5	4	3	2	1
09.	TREATED EACH STUDENT EQUALLY AND FAIRLY.	5	4	3	2	1
10.	COULD IDENTIFY AND UNDERSTAND MY NEEDS.	5	4	3	2	1
11.	MOVED AROUND THE LABORATORY OFTEN.	5	4	3	2	1
12.	WAS NOT RUDE, PATRONIZING, OR CONDESCEDNING.	5	4	3	2	1
13.	WAS ENTHUSIATIC ABOUT HIS/HER WORK.	5	4	3	2	1
14.	WAS CONCERNED ABOUT MY ACHIEVING MY GOALS.	5	4	3	2	1
15.	CLEARLY UNDERSTOOD THE EQUIPMENT AND PROCEDURES.	5	4	3	2	1
16.	ASKED SEVERAL QUESTIONS THAT HELPED ME TO UNDERSTAND.	5	4	3	2	1
17.	TREATED ME AS AN INDIVIDUAL.	5	4	3	2	1
18.	WAS ARGUMENTATIVE.	5	4	3	2	1
19.	WILLINGLY HELPED WITH PHYSICS COURSEWORK OTHER THAN LAB.	5	4	3	2	1
20.	WAS PATIENT AND WILLING TO REPEAT INFORMATION.	5	4	3	2	1

WHAT DID THE T.A. DO THAT WAS MOST HELPFUL?

WHAT DID THE T.A. DO THAT WAS LEAST HELPFUL?

PLEASE FEEL FREE TO EXPRESS ANY OTHER COMMENTS ON THE BACK OF THIS PAGE.

APPENDIX F

INTERVIEW PROTOCOL

INTERVIEW PROTOCOL

Demographics:

How many semesters have you held a TA?;
taught this course?

How long have you taught in the PIC laboratory?;
been a student in the PIC?

What is your TA classification?;
student classification?

(Teaching Assistants only)

Have you passed the Ph. D. qualifier?

Do you intend to include teaching as a career goal?

With regard to interactions with students/TA's do you feel
- comfortable?
- competent?
- enjoy the interactions?

What is your normal preparation cycle for each week's laboratory?

Looking at the survey instrument given to the students what would you rank as the five
- most important TA attributes?
- least important TA attributes?

(Teaching Assistants only)

Do you feel like you make an effort to exhibit any of these attributes in the laboratory? If so which ones? Why?

What is the most important thing that a TA can do in the laboratory to help students to perform?

What is the most detrimental behavior that a TA can exhibit?

What behaviors have you seen in other TAs/students
that you have tried to emulate?
have expressly tired to avoid?
(follow: Have you discussed this with other TAs/students and what were the outcomes?)

DO YOU HAVE ANY OTHER COMMENTS ABOUT THE PIC OR TEACHING ASSISTANT ACTIVITIES?

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