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FACTORS INFLUENCING THE EXTENT OF USE OF INSTRUCTIONAL COMPUTING IN INTRODUCTORY PHYSICS AT FOUR TERTIARY INSTITUTIONS

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ABSTRACT

FACTORS INFLUENCING THE EXTENT OF USE OF INSTRUCTIONAL COMPUTING IN INTRODUCTORY PHYSICS AT FOUR TERTIARY INSTITUTIONS

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The two main objectives of this research were: (1) to examine current usage of instructional computing in introductory physics courses at four different tertiary institutions in a midwestern state; and (2) to examine primary factors influencing the extent of use of instructional computing in the physics courses at these institutions.

Ethnographic methods were used in this research to acquire data at four institutions including two leading research universities, one community college, and a state-supported university that focuses more on instruction than research. Data were collected using formal and informal interviews, classroom observations, and analysis of pertinent documents. Interviews with faculty members emerged as the main source of data. During the fieldwork, the researcher used triangulation to cross-check the validity of data collected.

The results of the study showed that faculty members at these four settings mainly used computers mainly as a tool for laboratory work in the introductory physics courses. Computers were used to gather and analyze data in

the laboratory. However, these uses of computers were rather limited, except at Beta Community College which used computers more than the other three settings in the laboratory.

Six factors related to individual faculty members influenced the limited use of instructional computing at these settings: (1) faculty members' perceptions of instructional computing; (2) faculty members' concerns about students' difficulty in learning physics; (3) faculty members' perceptions of their main roles; (4) constraints on faculty members' time; (5) "territorial" conflicts with other departments ; and (6) faculty members' observations of students' attitudes toward instructional computing. Equally important were three factors that were related to both the faculty members and administrators : (1) emphasis of research instead of teaching; (2) inadequate incentives for faculty members involved in instructional computing; and (3) limited funds for instructional computing.

All nine factors emerged as critical in determining faculty members' involvement in instructional computing. The combined effect of these nine factors suggests that the faculty members have greater influence than the administrators on the application of instructional computing. Also, these factors suggest that both the faculty members and administrators must be supportive in instructional computing to ensure its success.

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CHAPTER I

INTRODUCTION

The first part of this chapter provides rationale and objectives of the research, including the background for the research, its purposes and significance, initial research questions, and final research questions. The second part of this chapter deals primarily with research method. There are sections discussing the research method, selection of research sites, data collection, data sources, and data analysis. The third and final part of this chapter discusses three different topics including theoretical framework, definition of terms, and overview of the dissertation.

Introduction

The computer is perhaps the single most important technological phenomenon affecting our society today. In many scientific areas, computers have shown themselves to be one of the most powerful tools for research yet derived (Koshland Jr., 1985). However, in the educational system, the impact of this powerful technology is only beginning to be felt. It has a great potential in helping educators to provide a better learning environment for students (Bonner, 1984; Bork, 1984).

A computer revolution is alleged to be sweeping through higher education (Johnson, 1980; Osgood, 1984). No one has made an accurate count of all the Apple II's, IBM Personal Computers, Macintoshes, and other such machines that have appeared on American campuses during the last few years (Gilbert and Green, 1986). These machines are revolutionizing our society in business, science, and government. The speed, power, low cost, and small size of these computers make them attractive and essential at these organizations.

In education, there is much excitement that this is the threshold of genuine educational innovation. However, there is also much confusion on how to successfully implement this innovation (Gilbert and Green, 1986). Earlier technical innovations, such as slide projectors or audio tape recorders, are not only different in format, but also in content and most importantly process. Phrase such as "computer cultures" suggest the difference in the magnitude of the change involved (Papert, 1981).

Some uses of computers in higher education parallel those in industry and business. These include facilitation of registration, maintenance of student records, storage of information for catalogs, scheduling rooms for classes, and for usual business routines such as accounting, payroll, and personnel records. Computers have also been used extensively in data processing and research.

In addition, there are many instructional applications of computing in higher education as discussed in Kearsley, Hunter, and Seidel (1983). Students in science, engineering, business, and other disciplines use the computer as a tool to solve complex problems and for data analysis (Chambers and Sprecher, 1980). Students can use computer graphic capabilities to plot relationships which might otherwise take hours to do by hand or might be impossible to visualize in other means. Physics students may process experimental data or use the computer for solving problems.

Computer software for use in the classrooms has changed during the last decade. Students can use drill and practice software that provide a large number of practice problems on the materials that have been taught. In tutorial programs, the computer takes the role of providing information on the materials and may include practice problems on the material as the tutorial lessons proceed. Testing is another area that computers have been used in the classrooms and they are commonly use in self-paced individualized courses. Teachers can assign students to do homework and have computers check the homework assignments and provide feedback to students. Computers are also used to do numerical calculations that are time consuming if done manually. Using simulation programs, students can participate in "real-life" situations. Students are using computers to write their own programs in BASIC or PASCAL to solve complex problems in various subjects.

In the teaching of physics, computers have been used for more than a decade. Computer software has been written to teach concepts, facts, and problem solving. Initially programs were written for large, time-sharing computer systems like PLATO at the University of Illinois (Kearsley, Hunter, and Seidel, 1983). However, in the late 1970's, development of computer software has spread to include microcomputers. This is mainly due to the affordable price of microcomputers in the market (Balkovich, Lerman and Parmelee, 1985). There are programs available to simulate laboratory experiments, to draw graphs, to collect and analyze data as well as others mentioned in the preceding paragraph. In short, computers are currently being used for a variety of purposes in the teaching of physics. Nevertheless, there is evidence that computers are not widely used in the teaching of physics perhaps due to the financial constraint faced by most tertiary institutions, or resistance to change by physics instructors. Certainly, the potential exists to use computers in teaching physics, but little is known about the degree to which it has been realized or about the reasons that influence its utilization in tertiary institutions.

Purpose of Research

The research has two main objectives. The first objective is to examine current usage of instructional computing in teaching introductory physics courses (general physics courses) at the tertiary level. The second objective is to find out principal factors or conditions that influence the extent of using instructional computing in these courses.

Initial Research Questions

In order to meet the purpose of the study as mentioned earlier, specific research questions were initially formulated as follows:

1. What are current practices of instructional computing in the introductory physics courses at four tertiary settings?
2. What are the salient characteristics of instructional computing in the introductory physics courses from the point of view of physics faculty?
3. How, in the perception of physics faculty, may the traditional notion of teaching physics in introductory physics courses change as a result of instructional computing?
4. What factors are primarily affecting or influencing the extent of using instructional computing in introductory physics courses?

Final Research Questions

The initial research questions stated earlier were used as a point of departure at the outset of this study and were mainly based on the researcher's preconceptions of the sites and issues involved. As this research progressed, the researcher found that it was necessary to reformulate the questions and to add some new questions. Erickson (1986) supported this by stating:

> When we consider fieldwork as a process of deliberate inquiry...the participant observer's conduct of sampling, hypothesis generation, and hypothesis testing go hand in hand. The fieldworker's daily presence in the setting is guided by deliberate decisions about sampling and by intuitive reactions as well. When and where the observer goes, who she talks to and watches...all these involve strategic decisions about the nature of the key research questions and working hypotheses of the study (p. 97).

After the researcher was in the field for a few months, he found that there was a need to shift the focus of this study towards more specific issues. Therefore, the researcher reformulated the questions and added some new questions to the initial list of questions. Thus, the final set of research questions were as follows:

1. To what extent is instructional computing being used in the introductory physics courses at the four tertiary settings?

1a. Are there different levels of use of instructional computing at the four settings? If so, how do they differ?

1b. What are the types of computers being used and how are they used at these four institutions? What are the problems related to the types of computers used?

2. How may the traditional notion of teaching physics in introductory physics courses change as a result of instructional computing? Is instructional computing compatible with the traditional notion of teaching physics?
3. What are the perspectives of physics department faculty members regarding the teaching and learning of physics and the place of instructional computing in introductory physics courses?

3a. How do the faculty members perceive their main role or duty as a faculty member in the Physics Departments?

4. What are the policies of instructional computing at the Physics Departments?

4a. What are predominant factors used to determine promotion of faculty members?

5. How do students who have experienced instructional computing in the introductory physics courses perceive it?

Research Methods

Traditionally, educational research has relied heavily on quantitative methods to provide answers to its questions. Usage of instructional computing has been numerically counted and statistically analyzed in a number of studies. As useful as this information may be, it does not present the essence of physics faculty members' experience with instructional computing nor does it provide insight into the interrelationships found in the academic, social, and cultural environment in which the faculty operates. Bogdan and Biklen (1982) contend that:

> Educational research is changing. A field once dominated by measurement, operationalized definitions, variables, and empirical fact has had to make room for a research approach gaining in popularity, one that emphasizes inductive analysis, description, and the study of people's perceptions.

Ethnographic research also known as naturalistic, qualitative, and field research was the method used for this study (Bogdan and Biklen, 1982). The ethnographic research design is based on theoretical assumptions that meaning and process are crucial in understanding human behavior, that descriptive data are important to collect, and that analysis is best done inductively; and data are collected through participant observation, interviews, and document analysis.

Thus, this study was carried out using an ethnographic research approach that: (1) emphasized descriptions of activities, based on observations of faculty members and students in classrooms as well as written documents; (2) study of people's perceptions, using interviews and casual conversation with faculty members, key administrators, and students; and (3) inductive analysis of these data. Classroom observations of faculty members and students using instructional computing in introductory physics courses were made. Faculty members who were using instructional computing in their teaching of physics and those who were interested in using it were interviewed. A few key administrators in these institutions were interviewed to find out the departments' policies and practices of instructional computing. Several students in courses that utilized instructional computing were interviewed to find out their views of instructional computing. This decision was based on the assumption that observing classroom instruction and interviewing physics faculty members, administrators, and students would elicit information about the utilization of instructional computing and the factors that influence the use of computers for instruction.

Data were supplemented by documents in the physics departments and other secondary sources, including course materials, annual research reports of physics departments, bylaws of the departments, faculty members' salary lists, papers on instructional computing delivered at professional meetings by faculty members, campus newspapers, and catalogs of the institutions.

Fetterman (1980) said that "triangulation is a basic tool used in ethnographic research --- testing one source of information against another from various perspectives, to arrive at a balanced interpretation of reality."

Although this procedure for verifying or triangulating the classroom observations with interview data and document analysis might be considered intimidating, this did not seem to be the case with the participants. Faculty members in the physics departments, administrators at these institutions, and students were given the right to waive tape recording of interviews and were informed that they were at liberty to answer or not answer questions as they wish. In addition, they were informed that all recorded data would only be reported anonymously.

Selection of Research Sites

The selection of samples or sites in ethnographic research is different from statistically-based deductive research where a random sample is generally used. Ethnographic research often uses the guidelines of what Glaser and Strauss (1967) called "theoritical sampling." That is, comparisons groups (in this case, institutions) were selected based on their relevance to the research questions. In terms of this study, this means only institutions that had implemented instructional computing in teaching introductory physics qualified for the sample or site. In order to obtain a more representative sample and restrict the extraneous variables for this research, consideration for inclusion in this sample was limited to institutions of higher education in one midwestern state. While any state could have been selected as the area in which to conduct the research, accessibility had to be considered as a factor in conducting the research. Because the researcher lived in a midwestern state of the United States, that became an important factor in selection.

Selecting the sites for the research was a process of trying to obtain a number of various elements to be represented by the site. Ideally, the institutions should be of different types because, according to the Office of Technology Assessment (1982), community colleges exhibit the greatest ability to be innovative and adopt new approaches to education as compared to other types of institutions of higher education. Also, institutions selected were expected to range from a rather small institution, which would have a small number of faculty and administrators, to larger institutions with more complex organizational patterns. Equally important, institutions chosen were expected to range from leading research universities in the country at one end, to a community college emphasizing teaching at the other extreme. This ensured that the institutions selected would provide a cross-section of institutions in the state. Since the ethnographic methodology requires an intensive and detailed analysis of the subject, it was impossible in relation to the time and financial resources that were available to select a large number of institutions in which to conduct this study. Therefore, the researcher decided that four sites would provide the information needed to conduct an analysis that would meet the criteria discussed earlier. The four institutions that were selected for the sample were Alpha University, Beta Community College, Sigma University, and Theta University, all pseudonyms. These institutions are described in Chapter III.

Data Collection

An important aspect in conducting ethnographic research was determining the method for collecting data. In this study, basis for data collection were interviewing, observing classrooms and labwork, and reviewing pertinent documents to the research.

The first step in data collection was contacting an individual at the institution under study who was involved in instructional computing. This individual was asked for information about other individuals who were directly and indirectly involved with the usage of computers in teaching physics. From this information, a list of individuals was compiled. Through this procedure, the researcher has some degree of confidence that all individuals involved with instructional computing were identified and interviewed.

The second step in data collection was to schedule an on-site visit to each institution. The purpose of these on-site visits was to conduct interviews with individuals from the list generated in the first step.

The third and final step was the actual data collection. First, interviews conducted during on-site visits to the institutions provided some information.

Follow-up visits were conducted to interview individuals and also observe classrooms using computers. In the meantime, pertinent documents were analyzed. This process of data collection continued throughout the seven months at Alpha University and Beta Community College (i.e. from November 1986 to May 1987). This helped the researcher to have a complete picture of instructional computing and factors that shaped instructional computing at these two institutions. However, for Sigma University and Theta University less intensive study was done. The researcher spent about two weeks at each of these institutions in the months of March and April 1987. The data obtained were useful to compare what was going on at the two former institutions. The data collection process at Sigma University and Theta University was done after the researcher had gathered nearly all the data from Alpha University and Beta Community College. With most of the data collected at both institutions, the researcher had fewer problems focusing his data collection at Sigma University and Theta University. In short, the researcher knew what to seek, and as a result, data were gathered more efficently. Nevertheless, as indicated earlier, data gathered at both Sigma University and Theta University were less extensive than those at Alpha University and Beta Community College, while data gathered at Alpha University and Beta Community College were more detailed and extensive.

Data Sources

Major means of gathering data were the following:

Field notes were used in recording of data. Throughout the study, the researcher carried a spiral notebook in which he jotted down what went on at the sites. Classrooms observations, and interactions with faculty members and students were recorded in the field notes. Notetaking was done as unobstrusively as possible. As soon as possible after leaving the research site each day, rough field notes were rewritten to provide a more detailed description of events of that day's observations.

Interviewing was another means or tool for gathering data. The interviews conducted were an important means of clarifying and reinforcing the data recorded in the field notes. Because of this need to clarify data, the interview approach was used througout the study. All interviews were tape-recorded. This was done to ensure vivid recall of the interviews.

Document analysis was another valuable source of gathering data for the study. Documents collected and analyzed for this study were catologs of the four institutions, course materials that utilized instructional computing, bylaws of the departments, annual research reports of the departments, various issues of the campus newspaper, and numerous other documents shared by faculty members and students, including faculty members' papers on instructional computing delivered at professional meetings. These documents were mainly to substantiate data collected through observation and or interviews, although some contained source of new data.

Data Analysis

The next aspect of the qualitative research methodology to be discussed is the analysis of data. The analysis of data in qualitative research differs from other methodologies in that in other methodologies data analysis consists of a discrete activity. Data are first collected and then usually entered into a computer to produce a statistical analysis from which conclusions are drawn. However, ethnographers do these processes simultaneously (Glaser and Strauss, 1967). Bogdan (1972) described the process used in qualitative or ethnographic research:

> ... as the researcher is in the field and recording his notes, he begins focusing on certain recurrent themes, which are revealed in observed behavior, and verbalization. Certain understandings begin to develop and sociological concepts are drawn upon to make sense out of the situation. Working hyphotheses become refined and new concepts are developed. In many cases the analysis of the themes direct the observer in his field work and help determine the areas in which he will spend his time. (p. 58)

Thus, the data were collected and analyzed simultaneously. As this process was conducted, inferences were drawn, new questions raised, and themes and patterns developed that modified the scope and focus of the reserach. Obtaining information from different vantage points and methods confirmed or contradicted the ongoing findings, thus indicating to the researcher areas in which to narrow or expand the research. One concept that helps to understand these processes is the funnel approach. Agar (1980) described this funnel approach as:

> You begin wide-open to whatever you can learn, but within such a broad boundary, you are already bouncing between learning and checking what you have learned....As you begin to focus your interest on certain topics, the funnel narrows....As the funnel narrows, your questions may get more and more specific, but you never stop learning. (p. 136)

After all the data were collected, a more intensive analysis of the data was conducted. This analysis was done through a comprehensive review of all the data. As data were reviewed, new insights emerged. It was at these points that additional notes were made to record new patterns obtained from the data. With these new patterns, the researcher returned to the field with additional or rephrased questions to verify the information.

Theoretical Framework

This section is intended to provide a brief and concise picture of the theoretical framework used in the study. In chapter II, there will be an extensive discussion of the theoretical framework used in this research.

There was not one single theory to draw a theoretical framework for this research, instead several theories were used as a guide. Dill and Friedman (1979) cited Gamson's theory in which she identified four models of innovation and change: (1) diffusion; (2) complex organization; (3) conflict (or political); and (4) planned change. The first three frameworks helped to isolate variables associated with innovation and change, and provided the basis for investigating factors associated with the instructional computing in introductory physics courses at the four institutions. However, the variables identified in the planned change framework do not relate to this research since, as the name implies, it is more appropriate for a change process involving instructional computing that is planned systematically. In all four institutions studied, it was evident that instructional computing developed through an evolutionary process which was not systematically planned at the outset. Therefore, the planned change framework was not appropriate for this research. Instead, the organizational culture framework was used to help in interpreting the data.

The diffusion framework helped to explain the way an innovation emerges into a system until after a period of years it has been institutionalized. In this framework, the researcher must define the institutions under investigation as a number of "adoptor units" which is the unit of analysis, such as physics departments, and the four institutions. The researcher studies the manner in which the innovation is adopted or not adopted by the units. This adoption or nonadoption is related to attributes of the innovation and of the unit. These attributes include

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compatibility with current practice, perceived relative advantage, characteristics of the innovation, ability to test trial the innovation, complexity, and attitude toward the innovation.

This diffusion framework is useful to describe either how an institution has reacted to a succession of innovations, or the history of an innovation. There are many studies that try to distinguish between adopters and nonadopters, and early and late adopters of innovations. There are some studies that examine the role of an opinion leader in the implementation of an innovation. An opinion leader is a person who is usually the first to know about an innovation and causes others in the institution to adopt or not adopt the innovation. This framework is useful for the researcher in identifying either characteristics of innovations that influence the diffusion, or characteristics of potential adopters which are related with individnual innovativeness. Dill and Friedman (1979) pointed out that this framework has a problem because of the assumption that an innovation is assumed good and should be implemented by all members in the organization. Using this framework only in this research, would not provide a complete "picture" of the factors that influenced the use of computers in instruction.

In their paper, Dill and Friedman (1979) stated that the complex organization framework allows one to find a relationship between innovativeness in institutions with factors that characterize the system as a whole. Variables included in this framework are centralization, affluence, size, formalization, age, complexity, and the nature of the system's environment. The analysis of innovation in the complex organization framework is usually done by analyzing the rate at which an organization adds new and various programs. In addition to the variables associated with organizational characteristics, the nature of the innovation itself might be an important variable in the change process. Another dimension of this framework is the relationship between previous history of successful innovations and the willingness of the organization to adopt a new innovation. If an institution has previously been successful in implementing innovations, there is a likelihood for that institution to continue to implement innovations. As prerequisite for effective educational innovation, Zaltman and Duncan (1977) suggested, "There should be top-level support in the system for the proposed change or innovation or resistance will be encountered." They also stressed that the organization or system should give incentives to members of the organization who adopt the innovation. The incentive must be attractive for the members and thus, will help to reduce their resistance to the innovation. Abedor and Sachs (1978) had this to say, "It is the sum of individual faculty readiness and organizational readiness which provides the critical combination of characteristics prerequisite to the adoption of a particular innovation."

The conflict framework, sometimes referred to as the political framework, suggests that interest groups control the innovation process. These interest groups exert pressure on the institution either for or against change. The variables associated with this framework include level of satisfaction with the change, intensity of conflict, duration of conflict, job mobility, and the extensiveness of organizational change. The conflict framework usually focuses on the history of one particular innovation. According to Dill and Friedman (1979), social conditions contribute to determine the form and intensity of the conflict and the kind, speed, and depth of change. When an innovation is introduced, interest groups form and conflict is present until the innovation is rejected or implemented. For instance, the introduction of computers at institutions may cause disequilibrium and intensify claims for power, status, and scarce resources among different groups. The conflict framework is unique in that it emphasizes the formulation of policy over execution. Changes that are brought about will consequently develop into conflicts later and the institution will need to address this. Dill and Friedman (1979) suggested that this framework focuses more on circumstances that bring about change than the change itself.

The planned change framework, which is also referred to as organizational development is a model that deals with efforts to start using innovation through managed change. A change agent is doing the change, an individual who is usually from outside the organization can induce change to the system. An assumption to this model is that members within the organization will be self-motivated and, with skills provided by the change agent, the organization will be able to move through the change process. This differs from the three previous frameworks in that it emphasizes the intervention and implementation processes. This means it does not describe change as much as changing, and factors that influence the rate and direction of change. Variables in this framework depend upon the type of change, but they normally involve factors such as level of intervention and attitudinal acceptance of the change agent. Havelock (1973) stated that the change agent works through some stages which include to establish a good rapport with the members of the organization, to determine the extent and nature of the problem, to intervene, to establish and organize self-monitoring and problem solving capacity, and to help the organization maintain the innovation without outside help. The theory most often cited as a guide to stages of planned change is that of Lewin (1957) that suggested that the organization must first break loose from existing barriers to change; then it will be possible to change the organization in some way. Finally, there must be a support structure and the changes must be "refrozen" if any long-term benefit is to be felt.

Last, but not least, is the organizational culture that helps to explain how an organization maintains itself. This is best described by Ouchi (1981) who stated that organizational culture communicates beliefs and values which provide meaning to life in the organization. Thus, the culture of the organization will determine the behavior of those in the organization. In this study, the culture of the four tertiary settings will determine the faculty members' use or lack of use of instructional computing in their teaching of introductory physics. Pettigrew (1979) defined culture as "the amalgam of beliefs, ideology, language, ritual, and myth." He added that these cultural concepts explain and prescribe behavior. Thus, organizational culture is a useful framework for this study.

In this study of the innovativeness of faculty in physics departments in four higher institutions in a midwestern state in the U.S.A. in using computers for instruction, all the variables identified in the first three frameworks discussed above were used as a guide or as a point of departure. However, planned change, was not pertinent to this study. Thus, the variables identified in that framework were not used to guide this study. Moreover, there will be no extensive discussion in Chapter II on the planned change framework. As suggested earlier, the organizational culture framework will also be used to interpret data obtained in this study.

Significance of the Research

There is a need to study the actual usage of computers for instructional purposes in introductory physics courses. This research will provide the status of computer application in teaching introductory physics courses that would be of use to physics educators and perhaps help determine the future role of computers in their teaching of physics. More importantly, the research will help us understand the "forces" in tertiary institutions that enhance or diminish the use of computers for instruction in introductory physics.

The answers that are suggested by this research will provide some guidelines for helping the implementation of instructional computing in introductory physics sequences. Thus, this research will help physics educators in particular, and educators in general involved in implementing instructional computing.

Definition of Terms

Instructional Computing: refers to the teaching of subject matter by direct interaction of students with the computer and excludes use for managing instruction such as record-keeping.

Introductory Physics Courses: courses offered to provide a broad-based introduction to physical phenomena. These courses are usually required of science and engineering majors.

Overview of the Dissertation

Chapter I, the Introduction, has set the stage for what is to follow. Beginning with an explanation of the nature and purpose of the study, it discusses the problem and its significance, provides research questions, and explanation of ethnographic research as a legitimate method of inquiry for research. The chapter concludes with a discussion on the selection of sites, the procedures of data collection and analysis, the theoretical framework used for this research, and a definition of terms.

Chapter II is devoted to a review of the literature pertinent to this research. The first section provides a discussion on the development of instructional computing followed by a review of literature of prior research on instructional computing in science. The second section is a review of the theoretical frameworks which underlie this research.

Chapter III provides an in-depth description of the four settings included in this research.

Chapter IV reports the results of this study. A presentation of the data collected is related for all four settings. The chapter ends with the interpretive component of the research in which data will be related to pertinent literature to enlarge the meaning of the findings and build connections with the research of others.

Summary of the research, conclusion from the research, limitations of this research, recommendations to the four institutions which may be useful to other institutions, and recommendations for further research which might sharpen the concepts presented in this research are presented in Chapter V.

CHAPTER II

REVIEW OF LITERATURE

This chapter provides a review of the literature in three main areas that are relevant to this research. The three areas are: (1) the development of instructional computing which provides a background for this research; (2) literature on the research and development of instructional computing in science shows the findings of the usefulness and effectiveness of instructional computing in science, including drill and practice, simulation, data acquisition and analysis, and programming; and (3) literature related to innovation research and organizational culture which is the theoretical framework of this research used to provide direction and help in the interpretation of data in Chapter IV.

Development of Instructional Computing

Ronald Clark (1974) stated, "It was in the 1930's that American researchers first pointed out the similarities between the on-off states of an electric circuit and the basic twin alternatives of logic." This marked the beginning of the idea of electrical question-asking and answering which could store, retrieve and send out information in the form of "yes" or "no" answers. In many subjects, description can be replaced by a set of questions that are answered yes or no; and with a code replacing these answers with the numbers 1 and 0. Van Amerongen (1972), explained the principles of a computer for the intelligent layman:

> When the 1 and 0 answers of the binary number system are signaled through an electrical impulse, various devices can be used for recording and retrieving this information: punched card, paper tape, magnetic tape, magnetic drums, tubes and transistors. (p. 298)

One of these binary digits, 1 or 0, in computer jargon referred as a "bit", is the information contained in a decision between yes and no. Several bits, when stored in a data processing machine, are known as a "machine word." Each machine word is stored in a "register," a device for storing each word while it is being used. Data processing involves the making up of new machine words from the contents of one or more registers. Early computers were operated by sets of instructions written in this machine language by human operators. A program-controlled machine carries out instructions in the sequence in which they occur in consecutive locations of a storage device such as a punched tape (Van Amerongen, 1972).

When this binary system of data coding was combined with the operations of mathematical logic, complicated calculations could be carried out at tremendous speeds dependent only on the rapidity with which electrical signals could be transmitted.

Gottfried Wilhelm Leibniz, a German philosopher, jurist, historian and scientist first attempted to invent a mechanical calculating machine in 17th century; Charles

Babbage, an English mathematician invented a steam-driven "analytical engine" in 1834 which involved the coding principles described earlier (Evans, 1981). However, the first fully automatic electrically operated computer was not produced until 1943 (Evans, 1981).

In 1939, Howard Aiken of Harvard obtained a grant from the Computing Tabulating Recording Company which later grew into International Business Machine Corporation, to work on a machine that he called the Automatic Sequence Controlled Calculator, the first fully automatic calculating machine. This resulted in the Harvard Mark I, completed in 1943 at Harvard. The machine was a magnificient breakthrough; however, it was large, slow and awkward, in 1946 a better machine was built by Mauchly and Eckert of the Moore School of Electrical Engineering of Pennsylvania which was the first large scale electronic digital computer (Evans, 1981). In 1951, the first successful computer for commercial use, the UNIVAC I (Universal Automatic Computer), was built and sold to the Bureau of the Census by Remington Rand (Evans, 1981).

Early computers were large and were mechanically run. At present, they have decreased in size tremendously. Evans (1981) discussed the miniaturization:

> The components of the earliest computers were large and mechanical. Then came electro-magnetic relays, which were a little smaller, after which came valves which, if anything were a shade larger. The arrival of the transistor, on the other hand, produced a quite sensational reduction in size.

Scientists never stopped with the transistor, they continued to develop smaller transistors and were able to etch multiple transistors and the connections between them on single silvers of silicon. With this, the microchip had been invented and it was possible to have entire sections of a computer's memory or logic system stored in an incredibly tiny and efficient space (Evans, 1981).

By 1971, the microprocessor had been developed. On one tiny silicon chip an entire central processing unit was etched. Christopher Evans (1981) made an interesting comparison of this outstanding achievement:

> To get a rough idea of what we are talking about, suppose that one expanded these tiny units up to the size of the valves in the original ENIAC and laid them side by side on a flat surface so that they would be two inches away from each other, what size would this turn out to be? The answer is that it would be as big as a football field.

The advent of microprocessors led to the development of microcomputers which marked a new phase of the computer revolution.

Language was the foremost problem of computing in the early 1950's. Only very few scientists and engineers understood the machine language needed to communicate with the computer, leaving a communication barrier between the users and the machine. During this time, the most crucial problems facing computer users were no longer those of hardware, but language and thus software.

After several earlier attempts were unsucessful, in 1954, a computer language was developed with which a computer user who was not a trained programmer could communicate to a computer. The language called FORTRAN (Formula Translation) was developed by International Business Machine and was not patented, hoping that it would be widely used. Although it was widely used, it did not become the worldwide language of computers and by 1965 there were approximately 1700 speciliazed computer languages (Time, 1965). Many of these were developed at universities for use in educational settings, for example BASIC (Beginners All-purpose Symbolic Instruction Code).

Software for carrying out unique functions were developed. The SPSS (Statistical Package for the Social Sciences), published in 1970, incorporated data analysis programs, from computers at more than a dozen universities (Nie, Hull, Jenkins, Steinbrenner, and Bent, 1975).

In the 1950's, the field of educational psychology experienced a new theory called reinforcement theory and in 1954 B. F. Skinner, a noted proponent of this theory, published an article on the use of mechanical devices in teaching (Skinner, 1954). This idea was later used in the development of computer-assisted instruction.

The principles of this theory of psychology were outlined by McDonald (1959) in a psychology textbook of that time:

> An operation that indicates to the learner the correctness of his response is called a reinforcement. When a golfer drives a ball straight down the fairway, he tries to carry out his swing in the same way the next time

> he drives.... If the consequences of making responses also lead to need-satisfaction, the reinforcement of the response pattern is even greater....Responses that are not reinforced are usually dropped. (p. 321-322)

Furthermore, McDonald (1959) wrote the function of the promising new teaching machines in giving reinforcement:

> One solution to the problem of providing comprehensive reinforcements has been the use of mechanical devices designed to provide reinforcement for responses as they are made. Problems are arranged in a machine in such a way that a child cannot move on to the successive steps in working an arithmetic problem until he has performed each step correctly. It is argued that since each child is receiving reinforcements for correct responses as he makes them, the learning of correct responses is greatly facilitated. Devices of this kind promise to solve some of the problems associated with providing adequate reinforcements for learning, but their use is limited at present and comprehensive research is not yet available. (p. 323)

In many locations, the idea of using a computer as a teaching machine seemed to spring up simultaneously. For example, the Open University in Britain and the University of Iowa employed computer-assisted instruction. Perhaps there are many others like Carnegie Mellon University, the University of Illinois, and Florida State University began instructional computing more than two decades ago. Recently, many more educational institutions have used computers for instruction and this has been largely due to the reasonable cost of computers lately as discussed in the next paragraph. The proceedings of the 1977 Conference on Computers in the Undergraduate Curricula (Christensen, 1977) presented papers on the application of computers in teaching social science, psychology, languages, chemistry, physics, biology, mathematics, health professions, economics, business, and engineering. This is also true today and it has been used in other subjects.

There has been a remarkable reduction in the cost of computers as a result of miniaturization. The developments that happenned after World War II were extraordinary. The analogy has been made widely, between the evolution of the auto industry and the evolution of computers. For example Christopher Evans (1979) made an interesting analogy, that if the automobile industry had developed at the same rate as the computer industry over the same period of time, it would be possible to buy a Rolls Royce for $2.75 that would get three million miles to the gallon and would have enough power to drive the Queen Elizabeth II.

With these rapid developments in computers and the reduction in price, educators at all levels began using computers in their teaching. John Naisbitt (1982) in his book Megatrends discussed the wide application of computers in education:

> 1. Students in the Alaskan bush study Alaskan history and English using microcomputers hooked up to television sets. The pilot project demonstrates the ways to use computers in remote areas.
>
> 2. Harrisburg, Pennsylvania, students use computers for instruction and to learn programming. Most of the instruction materials were obtained free...

3. Neighborhood centers in Wilmington, Delaware, offer after-school tutoring on computer terminals hooked up to data bank at the University of Delaware.

4. The Houston Independent School System says its plan to have as many as 30,000 microcomputers in use by 1985.

5. Seven Arkansas high schools use a sophisticated guidance computer to help students select a career by programming likes and dislikes and strengths and weaknesses. It stores information on 875 jobs, nearly 5,000 colleges, and more than 300 scholarships.

6. Ninety-five percent of all students in Minnesota are believed to have access to instructional computing services through the Minnesota Educational Computing Consortium, which claims it is the largest time-sharing network in the world (p. 34).

Certainly, these are some of the applications of computers for teaching. Robert Taylor (1980) argued that there are essentially three roles for the computer in education. They are tutor, tool and tutee. As tutor, the computer is used to lead students through drill and practice where rote learning is necessary. In this context the computer fulfills the role of teaching machine. As a tool, the computer is used by students to collect data in a science experiment, to analyze data, or to simulate a phenomena that is difficult to see in reality. Thus, it provides the means by which a student can work more creatively and efficiently. Lastly, as tutee, the computer is programmed by the student or literally the student instructs the computer to perform a specific set of operations.

Effectivenes of Instructional Computing

As mentioned in the preceding paragraph, there are three modes of instructional computing. In this section, the author will discuss the application of computers in teaching science in all the three modes and its effectiveness in providing meaningful learning experiences for students. In the tutor mode, drill and practice will be reviewed. For the tool mode, simulation, and data collection and analysis will be discussed. Finally, programming in the tutee mode will be reviewed.

Drill and Practice

Drill and practice programs are probably the most common educational application of computers in science teaching. These programs are used for exactly the purpose implied in their name. Teachers assign students to use these programs for drill and practice in solving problems like dynamics and balancing chemical equations.

As a student starts a drill and practice program, the computer usually asks where the student would like to begin in the skills sequence. For some programs, the computer already has a record of the student's most recently achieved level of mastery, so it automatically starts on the next level. In some programs, the teacher chooses the level at which the student enters the program.

The computer then presents problems, either one at a time or a few problems. The student types in his response to the first problem. The computer checks the response and informs the student immediately if he has gotten the correct answer or not. Thus, students do not go on to the next problem practicing incorrect skills. If the answer is correct, the computer presents the next problem. On the other hand, if the answer is wrong, the computer usually directs the student to try again. For some students who repeatedly type wrong answers, the computer may instruct him to seek help. In some drill and practice programs, when a student misses a particular type of problem repeatedly, the computer may provide a brief explanation of how to do problems of that kind.

When the student has completed a problem set successfully, some program will summarize the student's performance. Generally, others simply inform the student that he has completed the set and ask if he wants to go on to the next set.

Arons (1984) pointed out:

> efficient and well-planned drill, presented on an individual basis with immediate feedback reinforcing correct responses and correcting mistakes is a powerful instructional device. It is important in helping the student build bases of vocabulary and factual knowledge that underlie subsequent thinking, reasoning, studying, and problem solving.

This observation made by Arons is crucial for the success of drill and practice, especially in providing instant feedback so that students do not practice incorrect skills.

Hansen, Dick, and Lippert (1968) conducted a physics education project in which highly individualized computer programs were used with first-year undergraduate physics students and this was compared to traditional teaching in lecture sections. The total of the midterm and final examination scores for all the students showed significantly superior performances by the students using computers. In a study using computers to supplement regular instruction with a college general chemistry class, it was found that students who used computers performed significantly better than the control groups on the portions of the final examination of the course (Castleberry, Montague, and Lagowski, 1970).

Vinsonhaler and Bass (1972) reviewed 10 independendent studies, reported that elementary school children who received computer-supported drill and practice generally showed performance gains of one to eight months over children who received only conventional instruction. Peterman (1982) in his dissertation reviewed studies done on computer-assisted instruction which include drill and practice. His findings showed computer-assisted instruction can result in students' learning. Peterman also found that the use of computer-assisted instruction can result in less time spent covering the same amount of material. Gagne, Wager and Rojas (1981) indicated that drill and practice programs can effectively provide opportunities for enhancement of skills already learned. In the literature there are other studies showing positive results obtained with the use of computers for drill and practice (Koch, 1973; and Tauro, 1980).

In chemistry, Zitzewitz (1983) found there was no significant difference in students' learning and achievements of general chemistry who used four drill and practice programs with those who did not. The students in her studies mostly indicated on questionnaires that they found the drill and practice programs to be helpful in learning chemistry and they wanted to use similar programs to learn other subjects.

Summerlin and Gardner (1973) assigned 110 high school chemistry students to two treatment groups to investigate the effectiveness of a drill and practice program. After completion of the experiment, posttests were administered. They found that the control group which did not use computers had a significantly higher mean score than the drill and practice group.

Evidently, computers can be used to conduct drill and practice efficiently and effectively, although there were some studies that revealed conflicting results. As discussed previously, drill and practice programs have proven to be effective in helping students to achieve better results in their examinations. But we must be cautious in using these findings, because of the contradictory findings that showed the achievement of students using drill and practice was not necessarily significantly better than those who did not use computers for drill and practice. Thus, there is cause for concern when drill and practice is used as a substitute for primary instruction by teachers.

Simulation

The computer is able to simulate a situation, give a student a chance to interact with the situation, and observe change resulting from the student's action. One example is an acceleration due to gravity where students could observe and find out various conditions or situations on acceleration due to gravity. A second group of simulation programs allows the student to have a lab experience on the computer that could not be done in the science laboratory because of time, dangers, or cost of equipment. One example would be on critical mass in a fission reaction. Finally, simulation programs allow the exploration of hypothetical situations not encountered in the real world. For example, it is possible to create simulated worlds that behave according to the primitive pre-scientific conceptions of novice students. Students, left free to explore such worlds, would then quickly discover in what ways their own conceptions are not adequate to explain phenomena in the real world. For example, simulation programs can sketch the resultant orbit of a planet around the sun after students have fed in a new law of gravitation in the program.

Hartley and Lovell (1977) provided the basis for using simulations in science teaching in the following way:

> In the sciences many concepts are not only difficult to illustrate but the relationships between them are represented in formal and symbolic terms. Many students find it difficult to link these theoretical terms with the conventinal language which describes every day experience. Thus to make scientific phenomena accessible to the intellect, the teacher must illustrate the concepts, build up the student's knowledge structures, and allow him to elaborate them in ways which show the nature of the underlying principles. For these reasons, providing "simulation" exercises through the microcomputer has proved a useful and popular development in science teaching. The idea is that the program provides a "working model" of the scientific system. In fact, it is the formal representation of the system, i.e., a set of equations or a quantitative data base which can be sampled, which is embodied in the program. Usually the student cannot edit or amend the program itself, but he can manipulate the input values and observe the effects on the output displays. (cited in Walker and Hess, 1984)

As suggested by Hartley and Lovell (1977) simulation programs can be useful tools for students and teachers in learning and teaching science. There have been many studies conducted to find out the effectiveness of simulation programs used in teaching science.

Choi (1984) in his dissertation found that computer simulated experiments could be used in place of traditional laboratory experiments with an expectation of equal performance levels by students. Moreover, this only takes one half the time required for the traditional laboratory experiments. In short, Choi found that computer simulations in physical science could be efficient and cost-effective. Similar findings were also found by Bobbert (1982) and Moore (1978). Bangert-Drowns, Kulik and Kulik

(1985) in their meta-analysis found that although computer-assisted instruction has proven to be an effective instructional tool in the high school, computer enrichment studies (which include computer simulations) only increased scores by a standard deviation of 0.07. Lang (1975), studying high school physics students, found no significant difference in achievement between the computer simulation group and the traditional instructional group. In contrast to these studies, however, Boblik (1972) and Lunetta (1972) both found that the computer simulation groups had significantly better achievement scores than the group receiving traditional instruction in high school physics.

The findings suggest that computer simulations are at least as effective as traditional instruction in teaching science. Moreover, students take less time to master or learn a science concept when using simulation programs. This means computer simulations programs will save time for both teachers and students and thus are cost-effective.

Data Acquisition and Analysis

One of the most exciting uses of the computer in science instruction is in data acquisition and analysis in the science laboratory. When equipped with a thermocouple the microcomputer, a student can gather actual physical data such as temperature in the cooling curve experiment of napthalene for every second if needed; store the data; operate on or graph the data, and print out the results.

Using a photocell, counter, a pH meter, or other data acquisition instruments interfaced to the microcomputer, a wide range of experiments can be conducted like the one described earlier. This area of instructional computing is still largely unexplored and thus not much research has been conducted.

With the microcomputer students can gather data over and over again in the same manner without bias and tiring. The computer can keep on gathering data when it is not possible for students to continue. Also, the data can be collected many times faster. The data obtained can be displayed instantaneously. Results obtained can be put in tabular or graphic form and can be plotted to show the relationship between the variables. Students can do further investigations which would not be possible without the computer because there would not be enough time to redo the experiment. Thus, this tool allows the student to investigate many more examples with greater speed than is now possible (Tinker, 1981).

Certainly, this will free the student from doing the same task repetitively, and it can help the student in his conceptual understanding of the concepts involved in the experiment (Hawkins, MacIntire, and Sutton, 1987). However, Arons (1984) cautioned that if the computer short circuits insight, and just makes available end results for analysis or "confirmation," it is educationally sterile or even deleterious, especially in introductory courses. Arons also warned that the computer can relieve students from tedious calculations and while its graphic display offers considerable advantages over programmable hand calculators, "where extensive numerical computation is done without directing students' attention to analysis and interpretation of methods and results, the effort is largely wasted" (Arons, 1984), and may promote rote learning.

As mentioned in preceding paragraphs, the use of the computer for data acquisition and analysis has both advantages and disadvantages. Thus, it is necessary to study both the advantages and disadvantages systematically and use the findings to further develop useful and meaningful programs in this area.

Programming

Programming requires users "teach" the computer, in contrast to being tutored or using the computer as a tool. The users must communicate with the computer in a language it understands. As a programmer, the student assumes responsibility for his learning and this according to Papert (1980), makes learning qualitatively different. Taylor (1980) noted several advantages arising from knowledge of programming.

> First, because you can't teach what you don't understand the human tutor will learn what he or she is trying to teach the computer. Second, by trying to realize broad teaching goals through software constructed from the narrow capabilities of computer logic, the human tutor of the computer will learn something both about how computers work and how his or her own thinking works. Third,

> because no expensive predesigned tutor software is necessarry, no time is lost searching for such software and no money spent acquiring it (Taylor, 1980).

The best example is the LOGO project developed at the Massachusetts Institute of Technology. DiSessa (1982) discussed how LOGO is used in learning some concepts of elementary physics. In this program, students control the movement of the "turtle" by "pushing" it with forces of specified direction and magnitude. The turtle will move according to the laws of Newtonian physics on the screen as if it were an object on a frictionless surface. DiSessa found students who undergo such experiences, develop an intuitive understanding of elementary mechanics that is difficult to achieve in traditional learning milieu. Mead (1976) studied the use of computers in an introductory physics course by teaching students in an experimental group to write programs to solve same problems assigned to a control group to solve by the traditional method. He found that students using computers did not achieve higher scores on examinations than did the control group. Mead observed these students casually during this research and found that students complained that programming the computer to solve these problems took too much time. Although, Mead's finding were not supportive to the use of programming, many recent qualitative studies have shown that programming helped students in their ability to solve problems (Clements, 1985 and Miller, 1985).

Thus, in DiSessa's (1982) study students learned control of the computer and they gained insights into their own learning processes. They acquired control over themselves and their own thinking. They learned how to learn. In this regard, programming seems to provide students an opportunity to learn and it is also cost-effective according to Taylor (1980). However, much more research and development is needed in this area to find out more about its effects and potential.

Theoretical Framework

There is no single conceptual framework that has guided most research on innovation because there are several theoretical frameworks that have been used in many studies. A typology developed by Gamson and cited by Dill and Friedman (1979), identified four frameworks in which to organize research on innovation. The framework identified by Gamson were diffusion, complex organization, conflict, and planned change. The first three frameworks will be used to organize the literature. The planned change framework will not be discussed in this chapter because it is not related to this research as indicated earlier in Chapter I. Instead, there will be a section on organizational culture. Until now, this aspect of organizational behavior has not been applied to instructional computing. But, as this disssertation demonstrates, it plays an important role if not being central to understanding the use of computers in teaching of introductory physics.

Diffusion Framework

Diffusion framework refers to the manner in which an innovation is adopted by one unit and then the innovation is diffused through the system. In other words, diffusion is the process by which an innovation spreads.

There were several diffusion studies conducted at Columbia University's Teachers College more than 40 years ago. Mort and Cornell (1938) studied public school systems to find out if there was a relationship between school innovativeness and local control of school financial decisions. The major findings of the studies conducted at Columbia University were:

1. There is approximately a 25 year lag time between the introduction of an innovation and its widespread adoption.

2. The adoption of an innovation follows a general S-shaped pattern, that is first a few schools implement the innovation, then a majority of schools adopt the innovation, and finally, the remainder schools adopt it.

3. The variable which is the best predictor of school innovativeness is educational cost per pupil (Mort, 1946).

The studies at Columbia University's Teachers College indicated the importance of the role played by financial resources in implementing innovations. This financial consideration is not lost upon administrators who must deal with the financial aspects of an institution on a daily basis; this is often overlooked by many advocates of innovation. The studies at Teachers College also showed the significance of the time element involved in the diffusion of an innovation and the predictable pattern in the implementation of innovations.

Rogers (1962) conducted a comprehensive study on the adoption of innovation to find the characteristics of innovations which encourage people to use the innovations. In this research, he reviewed a broad range of studies pertinent mainly to the diffusion of innovations in agriculture and medicine. The reviewed studies were divided into eight types of diffusion and this includes the rate at which an innovation is adopted by society. Rogers later conducted his own research with county agricultural agents who were trying to get farmers to use a new hybrid corn. The findings of his research not only illuminated the process of innovation adoption, but also identified key characteristics in the nature of the innovations that farmers accepted.

In that research, Rogers (1962) identified the desirable characteristics of an innovation or attributes associated with successful adoption of innovations. The desirable characteristics were:

1. Relative advantage of an innovation over what the individual or system is at present doing.

2. The compatibility of the innovation with the user's values and past experiences.

3. The complexity of the innovation or the degree to which an innovation can be readily understood and used.

4. The divisibility of the innovation, the ability to try the innovation on a limited basis, or to try parts of it before using it in totality.

5. The communicability of the innovation or the ease with which it can be described clearly and accurately so that the practitioner can visualize the innovation.

These five characteristics reappear in a later study by Rogers and Shoemaker (1971). Pugh (1974) conducted a study to find out what happenned to each of the 166 recommendations made by the sub-committee on Teaching at Indiana University. His findings reaffirm Rogers's (1962) findings.

One attribute identified by Rogers (1962) that enhanced the adoption of an innovation is the communicability of the innovation. Schultz and Webb (1979) conducted a research in community colleges on the adoption of a screening model for the evaluation of proposed programs and curricula. In this research, they found that successful adoption occurs when data are used to provide direction in planning new programs.

Winstead (1982) conducted a study at Wichita State University to find out the effectiveness of a Management Planning Model which emphasizes the participatory approach to organizational change through decentralized decision-making and the adoption of management by objectives. The findings of the study suggested that successful implementation of an innovation requires a strong commitment to the innovation by the higher echelons of the administrators. Besides, this study found that subunits involved in the innovation must be clear about the mission of the organization and understand the effects of the proposed innovation.

In summary, there are three common themes in this framework. First, an innovation is accepted based upon time, that is, an innovation will be adopted by one unit and later move on to another unit in the organization. This requires time. Secondly, the innovation must have a perceived usefulness or advantage over the traditional method and be compatible with the current system in the organization. Lastly, the innovation must have the ability to be tried first before it is fully implemented.

<u>Complex Organization Framework</u>

Dill and Friedman (1979) explained the complex organization framework as an "attempt to correlate innovativeness in social systems with variables which characterize the system as a whole." Normally, the organizational variables studied include characteristics such as complexity, size, age, centralization of authority, and stratification.

Katz and Kahn (1966) stated that development of an "open system" model of organization influenced much of the early research. The system describes an organization as being determined by forces and pressures from within the institution (internal) as well as from society (external). These forces and pressures act as constraints on innovation. Katz and Kahn (1966) said that organizations are influenced by external forces which compel them to reflect the demands of society. Thus, organizations and society interact in an open system.

Hefferlin (1969) conducted a well-thought research of academic change in higher education. In this research, Hefferlin identified three major sources of change in higher education. They were advocates interested in change, resources available for change, and openness of the system to change. Using a survey instrument and interviews as research tools, Hefferlin drew several conclusions from his study of 426 departments in 110 institutions. First, he identified 10 variables that correlated with academic reform. These factors include attitudes, procedures, mechanisms, and pressures. However, no one factor seemed to be indispensable in accounting for differences that exist among institutions in their willingness and ability to change their academic program. Also, most of the elements are external to the academic sphere. Next, Hefferlin concluded that an avuncular type of academic organization was most conducive to change as opposed to a patriarchal or collegium-type institution. An avuncular institution assigns high status based on expertise, shifts positions of status according to different tasks rather than in strict rotation, and does not disperse nor centralize initiative on a permanent basis. Third, Hefferlin identified the faculty and administrators as having the most direct influence in bringing about academic change. Fourth, instititional differences affect the change process. According to Hefferlin, the institutional differences are the attitudes of the most influential members of the institution, the expansion of the institution, and how influence is distributed among members of the institution. Hefferlin related that smaller religious colleges are able to institute a greater amount of change. This is perhaps an indication that smaller institutions have to contend with less bureaucratic procedures, and as a result, are more flexible than larger institutions. In conclusion, Hefferlin stated that financial resources are the key to academic innovation. A new program will be tolerated and thus implemented if it does not involve an expenditure of funds or if it brings its own financial support. If current or existing resources need to be divided to implement a new program, then it will be actively resisted and accepted only under continous threat by the other established programs.

In his study, Hefferlin (1969) found that the attitude of the most influential members of the institution is one of the key elements affecting academic reform. This was reaffirmed by Hennigar and Taylor's (1980) research of the relationship between the receptivity to change in educational management personnel with their style of management. Two key findings of this research were: (1) administrators with a high concern for productivity are more open to change than those with a low concern; and (2) administrators with a high concern for people are more open to change than those with a low concern.

Hage and Aiken (1970) presented a major contribution to the theory of change process. Their research explored several organizational relationships in sixteen health and social welfare agencies in the midwest United States. Hage and Aiken proposed a theory of innovation to examine both the different stages of the innovation process and the organizational characteristics that affect the rate of innovation. The characteristics identified by these authors as affecting the rate of change were:

1. Centralization which is the concentration of the decision making process in the hands of a proportionally few.

2. Stratification which is the different distribution of rewards.

3. Complexity which is defined by Hage and Aiken as "the number of occupational specialties in the organization and the degree of professionalism of each."

4. Formalization which is the degree of codification of jobs.

5. Job satisfaction.

6. Efficiency which is defined by them as the "relative emphasis on the cost reduction of the product or service."

7. Production which is emphasis on quantity in relation to quality.

In their research, Hage and Aiken found that increased in innovation correlates with organizations that have the characteristics of complexity, formalization, and job satisfaction. The other four characteristics correlate negatively with the rate of innovation as shown in Table 1.

Table 1: Organizational characteristics affecting the rate of innovation.

Positive Correlation	Negative Correlation
Complexity	Centralization
Formalization	Stratification
Job Satisfaction	Efficiency
	Production

Hage and Aiken's (1970) theory included four stages of the innovation process: evaluation, initiation, implementation, and routinization. They stated that the implementation stage occurs when the organization attempts to integrate the innovation. At this stage, resistance to the innovation is normally encountered, arising from unexpected problems in implementation and unwillingness of people to accept the innovation.

Their theory or model is instructive because it was among the first models to study the implementation stage as a separate stage in the innovation process. They also addressed the problem of resistance involved in the process, that emphasizes the significant of resistance as one factor for consideration by anybody attempting to implement an innovation.

Howard (1981) used Hage and Aiken's (1970) model in her study of innovation at four university libraries in the northeast United States. The findings of her study suggested that with some changes, Hage and Aiken's theory could be applied in other settings. She found a relationship between the structural variable of complexity and the rate of innovation, and a negative relationship between stratification and centralization which supported earlier findings by Hage and Aiken.

Zaltman, Duncan, and Holbek (1973) published the results of their study in which an implementation stage of innovation was studied in more detail. The purpose of their study was to isolate variables and conditions associated with the adoption of innovation in organizations. They did this through a study of organizational structure and process in an attempt to identify types of environments that are conducive to, or inhibit, the introduction and acceptance of innovation. They divided the implementation stage into two substages. First, in the "Initial Implementation Substage," the maximum potentials of conflict and disequilibrium exist, resulting from a manifesting of latent animosities and feelings of loss of power. These feelings translate into resistance which can inhibit the implementation of innovation. Resistance can be in many forms, these include active rejection, tactical manipulation in the operational sphere, passive resistance, and lack of support. The other substage of implementation is the "Continous-Sustained Implementation Substage." Zaltman, Duncan, and Holbek found that this substage is where an innovation may fail due to continued resistance, changes in personnel, or the innovation performs poorly.

They also felt that less rigid organizations provide an environment more conducive for implementing innovations. Implementations could be enhanced in organizations that are more highly centralized and less complex, because this reduces role conflict and ambiguity. The authors, however, acknowledged that resistance can be manifested at any juncture of the change process. The reasons for resistance include competition among interest groups for power, the stratification of the power structure, traditional reward systems, attempts to maintain the status quo, and hierarchical differentials.

The researchers suggested that for an innovation to become a reality, it is often dependent upon the "management-decision variables," which can be manipulated or controlled. Management has an important role to play in gaining commitment, attitudinal changes, and behavior acceptance in relation to the innovation. Moreover, the researchers found that for an innovation to be effectively implemented there needs to be in place an administration that establishes clear channels of authority and responsibility. Innovation is also enhanced by the participative approach to management which provides avenues for feedback so the innovation can be modified to gain acceptance.

The significance of the research by Zaltman and his associates (1973) is that they:

1. Examined the dynamics of the personnel involved in the implementing of innovation.

2. Found that while one type of organization provides rich ground for the initiation stage another type of organization enhances the implementation stage.

3. Provided a model that divides the change process into two stages that most people in this area now accept.

Blau (1973) applied the complex organization framework in higher education to find a correlation of institutional innovation. He found a positive correlation between the size of the institution and the amount of decentralized authority and innovation. Moreover, he also found that when other variables are controlled, institutional age correlates negatively with the rate of innovation.

There have been several studies that have attempted to find a relationship between organizational willingness to change and its size. Glover (1980) found that small liberal arts colleges are more likely to implement academic reform than larger institutions. This reaffirms Hefferlin's finding, but contradicts those of Blau. This is further complicated by Drum's (1979) study of innovations at community colleges in which he found no correlation between the variables of institutional size and complexity and innovation. Thus, these findings are not conclusive, perhaps, because of different settings.

In summary, the findings are sometimes contradictory. Nevertheless, these findings help to expand the researcher's knowledge of the complexity of institutions of higher education particularly, and social organizations in general. Thus, this framework helped the researcher to understand the very intricate nature of the institutions in the research.

Conflict Framework

The last framework to be discussed is the conflict framework, also referred to as the political framework. The framework simply means during change process, interest groups form and exert pressure on the organization either in favour or against change.

Dahrendorf (1958) suggested that disequilibrium in an organization leads to the development of groups within the organization that attempt to exert pressure upon the organization for change to cure the perceived disequilibrium. Other groups form to retain the status quo because the present system places them in a favored position. Consequently, conflict arises until the issue is settled.

Baldridge (1971) conducted a longitudinal study of decision making at a university and found that the structure and role of the university reform through internal and external pressure. The researcher used conflict theory, community power studies, and interest groups to develop a model explaining the political process of change. The internal pressures upon the university involve policy issues, while the external pressures are from such forces as increased competition from state-supported universities for low income students. Forces for reform by one group are resisted by other interest groups. Thus, intense conflict develops as interest groups try to become the dominant force. Different forces for change are successful in redirecting the mission of the university over a period of time.

Conrad (1978) conducted a study on curriculum change at four institutions. He found that there are five overlapping stages involved in the reform process. The first stage, "social structure," sets the stage for reform in establishing that conflict is a natural process that may not lead to change in higher education. If change is to occur, then dominant groups must exercise their power in favor of the change. The next stage, "conflict and interest group formation," describes the formation of interest groups in response to pressures for change. Conflict arises as different interest groups with different goals and perspectives seek influence. The third stage, "administrative intervention," occurs when the administration responds to interest group pressures and reexamines its policies. The next stage, the "policy-recommending stage," is one in which a recommendation is made to alter current policy. The final stage, the "policy-making stage," outlines the establishment of a new policy by the appropriate decision-making body. In this study, Conrad's findings were similar to Baldridge's (1971) which is when interest groups form and play an important role in the various stages of change. Administrators play a brokerage role between the two opposite interest groups. Their final decision is a compromise of the more dominant interest group.

Cooney (1976) conducted a study focusing on the decision making process in community colleges. In this study, he found that faculty in community colleges value programs that emphasize educational quality. His conclusion for the study is that to translate faculty values into policy, faculty members need to form an interest group.

/ith this interest group, the faculty can then seek to have ıccess to the decision making process. The faculty members ıust try to gain positions of authority, like becoming :hairpersons and deans. If they become one, they become lecision makers in the institution's political process.

Levine (1980) conducted a research to examine :onflict in higher education. His study focused on the :reation and eventual closing of organizational subdivisions called "colleges" at State University of New York at Buffalo. In the study, he found that organizations ıave established boundaries which are protected by interest groups. An innovation will encroach upon one or more boundaries creating disequilibrium to the organization as nany sets of boundaries compete for limited resources. The innovation will be institutionalized only if it is compatible and profitable to the organization.

Organizational Culture

Culture helps an organization maintain its unique character. Ouchi (1981) stated that organizational culture communicates belief and values that give meaning to life within the organization. Pascale and Athos (1981) described organizational culture as a "bass clef" that conveys meaning to employees, as a "compass" that provides direction, and as the "shared values and spiritual fabric" that bind the organization together. They describe how an organization's culture helps employees know how to behave and make meaning or sense out of the behavior of others. Barrett (1984) discussed the dependence of a person on his cultural milieu, and that the person must conform if he is to be approved and accepted by his fellows. Kuhn (1962) has shown how scientists, once they operate under a common paradigm (a theoretical model for research), come to share the same set of assumptions about the world. They begin to think in similar patterns and make or fail to make parallel discoveries or innovations simply because they have similar outlooks, values, and beliefs.

Perrow (1979) described the "institutional school" of organizational theory. This is associated with Selznick (1957) who differentiated institutions from organizations. The latter more clearly reflects a formal system of rules and objectives while the former are more a natural product of social needs and pressures. Perrow viewed institutions as "responsive, adaptive organisms." Administrative ideologies and values produce a distinct identity for the institution. And institutional leadership defines a clear mission or goal that guides behavior. Through the process of institutionalization, values infuse the organization and it develops a distinctive character which takes on a life of its own. The institution becomes valued for its own sake (Perrow, 1979).

Harrison (1972) wrote about organizational character, which is closely related to organizational culture. While not discussing "culture," he stated that an organization's character arises from ideological issues.

Ideologies are a central part of culture (Pettigrew, 1979). Harrison described how values and ideologies aid in the understanding of organizational behavior and conflict. He reflected the earlier concern for quantification and postulating four ideological orientations (power, role, task, and person). Harrison applied his classification to decision making, human resource utilization, and environmental interaction. His interest is in exposing organizational characteristics so that individuals can better understand the organization and potential sources of organizational conflict.

Pettigrew (1979) explicitly stated that he is interested in a family of concepts called organizational culture. He defined culture as "the amalgam of beliefs, ideology, language, ritual, and myth." Pettigrew felt that these cultural concepts explain and prescribe behavior. He stated that culture codifies meaning in a publicly and collectively accepted manner. He placed such great emphasis on culture because it is part of the longitudinal growth and development of organizations. An organization's founder imparts direction and orientation through the organizational culture. For example, the culture of a physics department in an institution is shaped by the collective beliefs of its members and the influences of other physics departments at similar universities or colleges. It is also shaped by the culture used for promotion and tenure, which at research universities is influenced by many factors including publication and judgements of quality in research.

Clark (1971, 1972) provided one of the best applications of organizational culture to colleges and universities. He focused on one aspect of organizational culture that he called saga, a "collective understanding of unique accomplishment in a formally established group." The important characteristics of saga are that it arises from the group, and it has a special meaning for them. Moreover, saga provides a foundation for the environment within the organization. The saga provides information about the culture or the institution's beliefs, ideology, and values. Saga is important because it binds individuals to the organization. It structures their beliefs about the organization. It tells them what the organization values, what has meaning, and what is of special importance. Thus explication of an institution's saga is one method of exposing the underlying values and ideologies of the organization's culture.

In his book The Academic Life, Clark found that professors at research universities perceived outstanding in academics were those who placed research up front in their agenda and let teaching trail along as a way of imparting the results of research (Clark, 1987). However, according to Clark (1987), at community colleges, the professors felt that outstanding faculty are those who are student-centered, in other words those for whom teaching takes precedence over research. He also found professors at comprehensive universities thought that to be an outstanding faculty one needs to be both an effective teacher as well as active in research. His findings illustrate the belief of professors to be considered outstanding academically at the three different types of higher institutions which are included in this research. Nevertheless, Boyer (1987) suggested, "Faculty who pursue research are acknowledging the realities of academic life and of good scholarship as well." In his national survey of college professors, Boyer found that 75 percent said that it is difficult to get tenure in their department without publishing. This has a chilling effect on classroom teaching and instructional development. Jencks and Riesman (1968) showed the price that is paid when research is rewarded and bad teaching is accepted:

> No doubt most professors prefer it when their courses are popular, their lectures applauded, and their former students appreciative. But since such successes are of no help in getting a salary increase, moving to a more prestigious campus, or winning their colleagues' admiration, they are unlikely to struggle as hard to create them as to do other things...Many potentially competent teachers do a conspicuosly bad job in the classroom because they know that bad teaching is not penalized in any formal way.

Freedman et. al. (1979) commented, "Frequently, for example, faculty members are assured that teaching effectiveness will be given as much weight as research or publication in tenure and promotion decisions, but the practice does not match the promise."

Pascale and Athos (1981) described that in situations involving conflict, decision making, or change, one can observe culture influencing behavior. This is particularly significant to this study, because the use of instructional computing is perceived as a change or innovation and thus is very much being influenced by the values and beliefs at the four higher institutions in this research.

Implications For This Research

The first section of this chapter provided the background on the historical development of instructional computing which helped the researcher to bring into perspective the current situation of instructional computing, particularly, the development of microcomputers. The next section of the literature review provided the development and research on the effectiveness of instructional computing in science. This review helped the researcher to understand the use of instructional computing in science and its effectiveness which is important in understanding the use of instructional computing in introductory physics courses. It can be concluded that the use of computers in teaching science in general, including physics, has produced mixed results, and at best only slightly better than the traditional mode of teaching. The last section of this chapter focussed on the research on innovation and organizational culture. The implications of the literature review in this section are:

1. to provide the researcher gain a better understanding of the innovation process in institutions of higher education; and 2. to help the researcher interpret the data collected in this research.

CHAPTER III

DESCRIPTION OF SETTINGS

This chapter focuses on the four research sites included in this study. It contains descriptions of the institutions and the four departments studied and an analysis of several documents primarily contributed to these descriptions. The documents used included the institution's catalog, Patterson's Guide to Four-Year Colleges and to Two-Year Colleges, and Graduate Programs in Physics, Astronomy and Related Fields published by the American Institute of Physics. Observations of classrooms using instructional computing in introductory physics courses, and interviews with faculty members both formal and informal also provided data needed for descriptions of this chapter.

Alpha University

Established in the middle of nineteenth century as a college of agriculture, Alpha University is an autonomous public institution of higher education in a state in the midwest. Less than 10 years after it was founded, it became one of the earliest land-grant institutions in the United States. It is located in a pleasant residential city with a population of about 50,0000. The city is a suburb of the capital city of a large midwestern state.

Alpha University's campus is a partially wooded area of some 1,500 acres bisected by a small winding river.

It has long benefited from skillful planning and design. Since its establishment in the middle of nineteenth century, the university has grown tremendously and it is now among the leading research universities in the nation. Many of its faculty members have received international recognition as distinguished researchers in many areas, including physics. Nonetheless, the university has retained a strong focus of concern for undergraduate education and teaching.

From its modest beginning as a college of agriculture, this university has developed to fourteen colleges, with more than 40,000 students enrolled. More than three-quarters of the students are from the state itself. Others include students from all states of the nation as well as from more than 100 foreign countries. Altogether, more than 7,000 students are enrolled in the graduate programs that are offered in 75 academic departments and schools. As a land-grant institution in the state, Alpha University is committed to provide equal educational oppurtunity to all qualified applicants. Its policies and governance reflect the educational needs of the state.

The university has all the facilities needed in all sports. It has a new indoor football facility. Its football team has attracted an average of more than 70,000 spectators for all home games. It also has remarkable records in basketball and ice hockey, attracting a capacity crowd for all home games.

The Physics Department of Alpha University has enjoyed the support from the National Science Foundation (NSF) under its University Science Development Plan for the development of "centers of excellence" in recent years. The department has recently built the world's first superconducting cyclotron with grants from the National Science Foundation. This cyclotron is housed about a quarter mile away from the Physics Department's main buiding. The department's main buiding is a three story brick structure which apparently was built after World War II and appeared to have been renovated regularly. This building houses the physics general office, offices for the faculty members and general staff, classrooms and lecture rooms, laboratories for teaching and research, and a teaching and research library for the department. This building has a new wing, which is for the High Energy Physics faculty members.

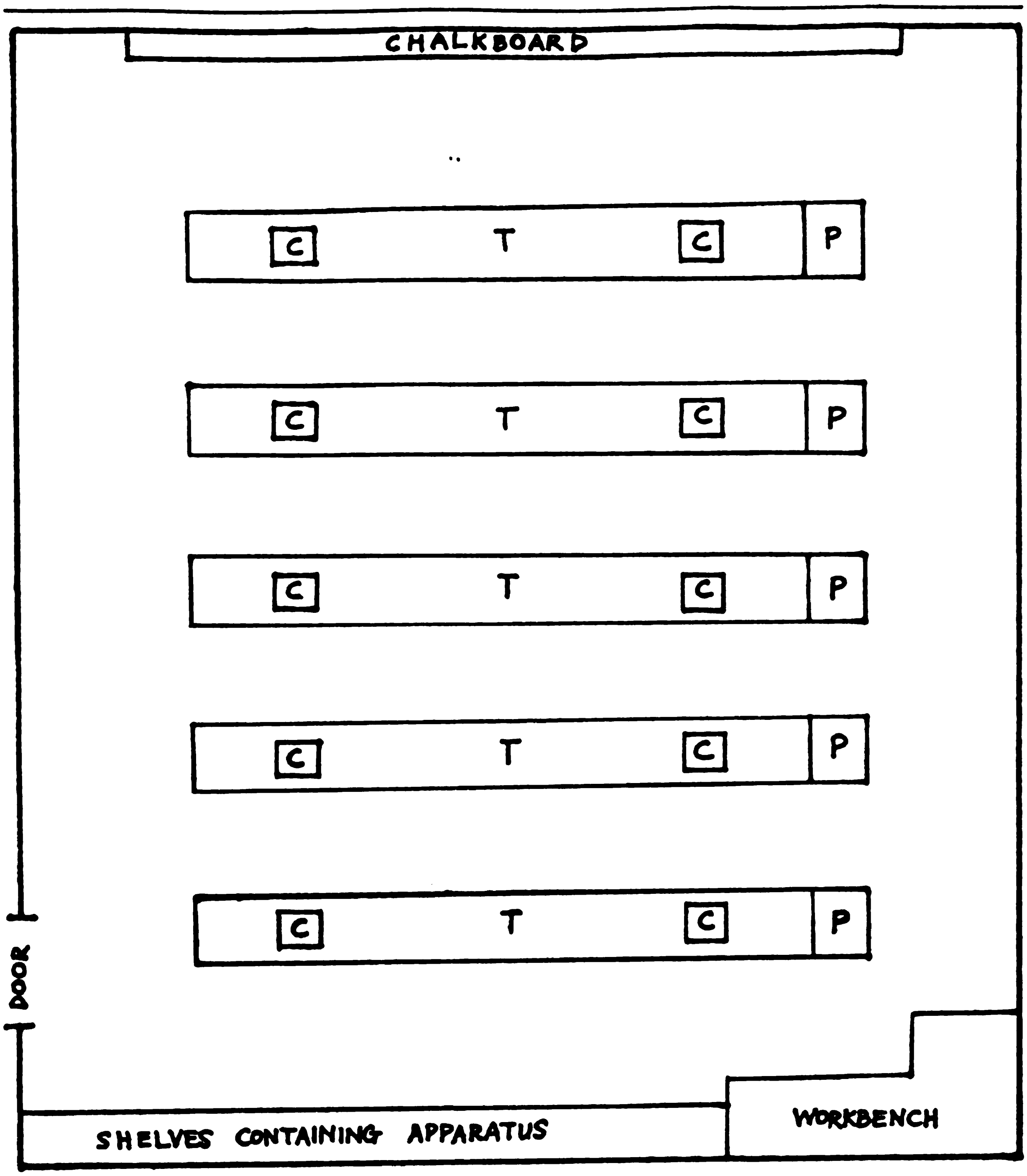
The department has a total of 69 faculty members at all ranks. They are mostly graduates of respected universities in the country and a few are from the United Kingdom and West Germany. The faculty members are mostly active conducting research in almost all physics areas. The research expenditures of the department for the year 1985-86 amounted to more than 10.5 million dollars. Their research is published in respected physics journals. About 300 research articles were published by faculty members and graduate students in refereed journals during the two-year period beginning July 1, 1984.

The department has about 100 graduate students enrolled and more than three-quarters of them are doctoral students. It has about 100 undergraduate students including outstanding students who received awards such as National Merit Scholars. It seems that most of the students enrolled in the undergraduate physics program are excellent students, those who enjoy being in the top 10 percent of their class.

There are many courses offered by the department for undergraduate students. Courses range from general education courses such as "The Science of Sound I: Rock, Bach and Oscillators", and "Energy Consumption and Environment Quality" to typical courses like principles of electricity and magnetism for the freshman and sophomore level. In this study, however, the focus was on introductory physics courses. These courses are required typically for all science and engineering students, though occasionally there are a few humanities and other students. In this department, there are two introductory physics courses that utilize computers more often than the others. These courses, Physics I and Physics II, took place in the same physics lab. Figure 1 illustrates this lab, showing the location of Commodore 64 computers and printers.

Figure 1:

Physics Laboratory at Alpha University



KEY:

C COMMODORE 64 COMPUTER

P PRINTER

T TABLE

Beta Community College

Beta Community College was founded about 30 years ago as a result of a feasibility study conducted by a graduate student at another university in the suburb of the city. It is located in a capital city of a large midwestern state. The college was established in response to an approach made by a Division of General Motors to a university in the suburb of the city that the university consider a two-year program in drafting and technical education. So, a committee of representatives of industry, business, and state government met with university officials, and they decided to approach the city public school with this request. The school hired the graduate student to conduct the study, and he was later hired as the first, and to this date the only President of Beta Community College.

Beta Community College is among the largest community colleges in the United State based on its enrollment. It has a campus located in downtown of a capital city, covering about 30 acres, seven city blocks. It has 14 large buildings and several small ones. Over the years since its founding, the community college has changed tremendously. It was initially established as a technical institute, but now, a comprehensive, complex community college with nearly 300 programs, 2,000 courses, and more than 20,000 students has emerged over its many years of existence. It was founded about 30 years ago with a student body of 224. Now, more than 20,000 students attended for the fall term 1986. Of that total, about 6,000 were full-time students and 15,000 were part-time students.

Partnership with business, industry, and K-12 and university education are still the primary thrusts as the college has continued to respond to the community's needs. The mission of the college is to provide a variety of life-long learning opportunities for the people living in the college's community. The college provides opportunities for individuals in the areas of personal growth and development, job skills development, courses leading to a certificate or associate degree, and professional development. A substantial part of the community college program is to provide the first two years of undergraduate education which is transferrable to four-year institutions.

The college maintains an open admission policy, allowing all residents in its area to have equal educational oppurtunity. More than 70 percent of the students at this college are residents of the community and fewer than 30 percent are non-residents. Fewer than 1 percent are out-of-state and about 1 percent are international students.

Beta Community College has a Science Department in which all areas of science are taught by the faculty members. These courses include physics, biology, chemistry, earth science, and natural science. The building housing the Science Department is a four story modern, functional building. The Science Department occupies only the top floor of this building. The department has its general office, offices for the faculty members, classrooms, and laboratories for teaching, and lounge on this fourth floor.

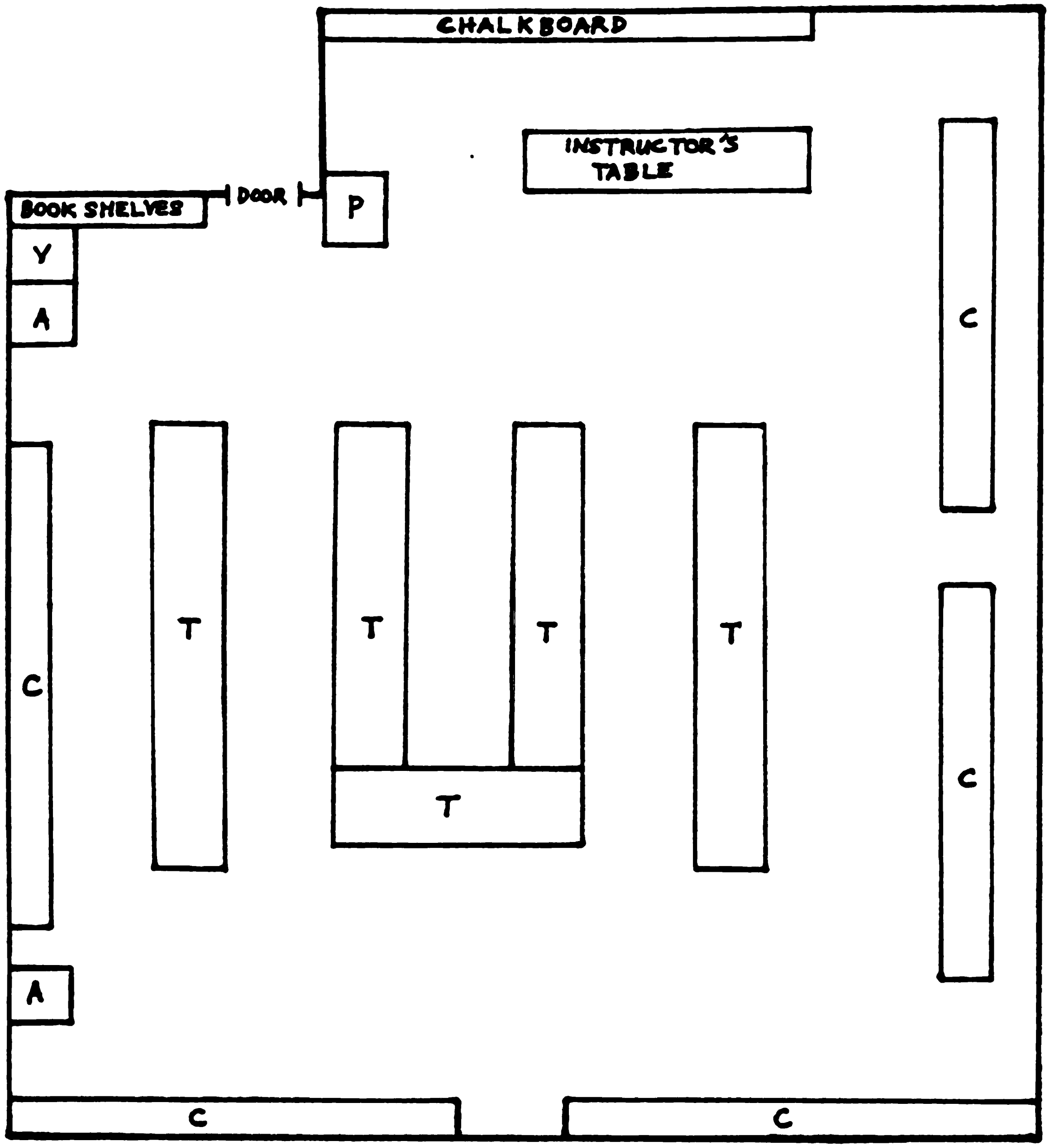
The department has a total of 17 full-time faculty members and about 50 part-time faculty members teaching all science courses offered by the department. The chairperson of the department taught physics and has all three of his degrees from a prestigious university. There are three more physics faculty members in the department. The faculty members in this department seem interested and committed to their teaching responsibilities. They are not required and expected by the department to conduct research or to publish. While there is no current physics research, there are some projects developing and trying out new approaches to teaching, like using instructional technology to facilitate their instruction. Nevertheless, the faculty members are expected to provide an excellent environment to their students in their instruction, to which the college is committed.

There are eleven physics courses offerred by the department. All these courses are typical of introductory physics courses offered by a four-year college. These include courses such as mechanics and heat, optics and modern physics, and labs for these courses. All of the faculty members use computers to teach the laboratory section of the courses. The computers are mainly used for data collection and analysis. All of the lab sections take place in one physics laboratory. Figure 2 shows the physics laboratory, with the location of Apple IIe computers and a terminal (VAX) hooked up to the campus mainframe.

The physics courses are generally required for all students pursuing science and applied science degrees. Thus, most of the students enrolled in these courses are science-oriented students. The students in these courses are on the average about three years older than those in a four-year college. There are many of these students who are part-time students, taking two courses each term. A few of these students are enrolled in a major university located in the suburb of the city taking the advantage of cheaper tuition fees and perhaps less demanding workload of the courses.

Figure 2:

Physics Laboratory at Beta Community College



KEY:

A APPLE IIe COMPUTER

C CUPBOARD

P PRINTER

T TABLE

V VAX TERMINAL

Sigma University

Sigma University was founded by the State Legislature very early in the twentieth century to educate teachers to serve in public schools for the south-western section of a midwestern state. It is located in a city with a population of about 80,000. While the university is still committed to its initial obligation, the preparation of teachers, its role has been enlarged to meet the growing educational needs of the state. Thus, the mission of the university has changed to that of a multi-purpose university. Students may enroll in graduate programs in the Colleges of Arts and Science, Business, Education, Engineering, Fine Arts, and Health and Human Services. There are over 60 graduate programs, but only about 10 of these programs have doctoral programs of study. The university is not recognized as a leading research university, except in one or two departments. Sigma University is representative of numerous other state-supported institutions throughout the United States that focuses more on instruction than on research.

The university has more than 18,000 students enrolled, with about 15,000 of them in the undergraduate programs. In 1985 statistics showed that within the student body, 22 percent were part-time students. Included in the geographic distribution of Sigma University students in 1985 were 90 percent from the state, six percent from other states, and four percent who listed their citizenship from more than 60 foreign countries. More than 80 percent of the incoming freshmen of 1985 were in the top half of their high schools.

The Physics Department is relatively small. There are only twelve faculty members with 10 of them at the rank of at least an associate professor. Most of the faculty members received their doctoral degrees in physics from major research universities in the midwestern United States. Two of them received their doctoral degrees in physics from other countries. The faculty members are not very active in research, and devote much of their time to teaching responsibilities mostly for undergraduate students. The department research expenditures for 1985-86 amounted to merely a quarter million dollars. Most of these research grants were from the federal government, for the faculty members to conduct research in atomic and nuclear physics which are normally conducted at Argonne Laboratory and other research centers in the countries.

The department has about 30 undergraduate students majoring in physics. There are not more than 20 graduate students enrolled in the master's degree program in physics.

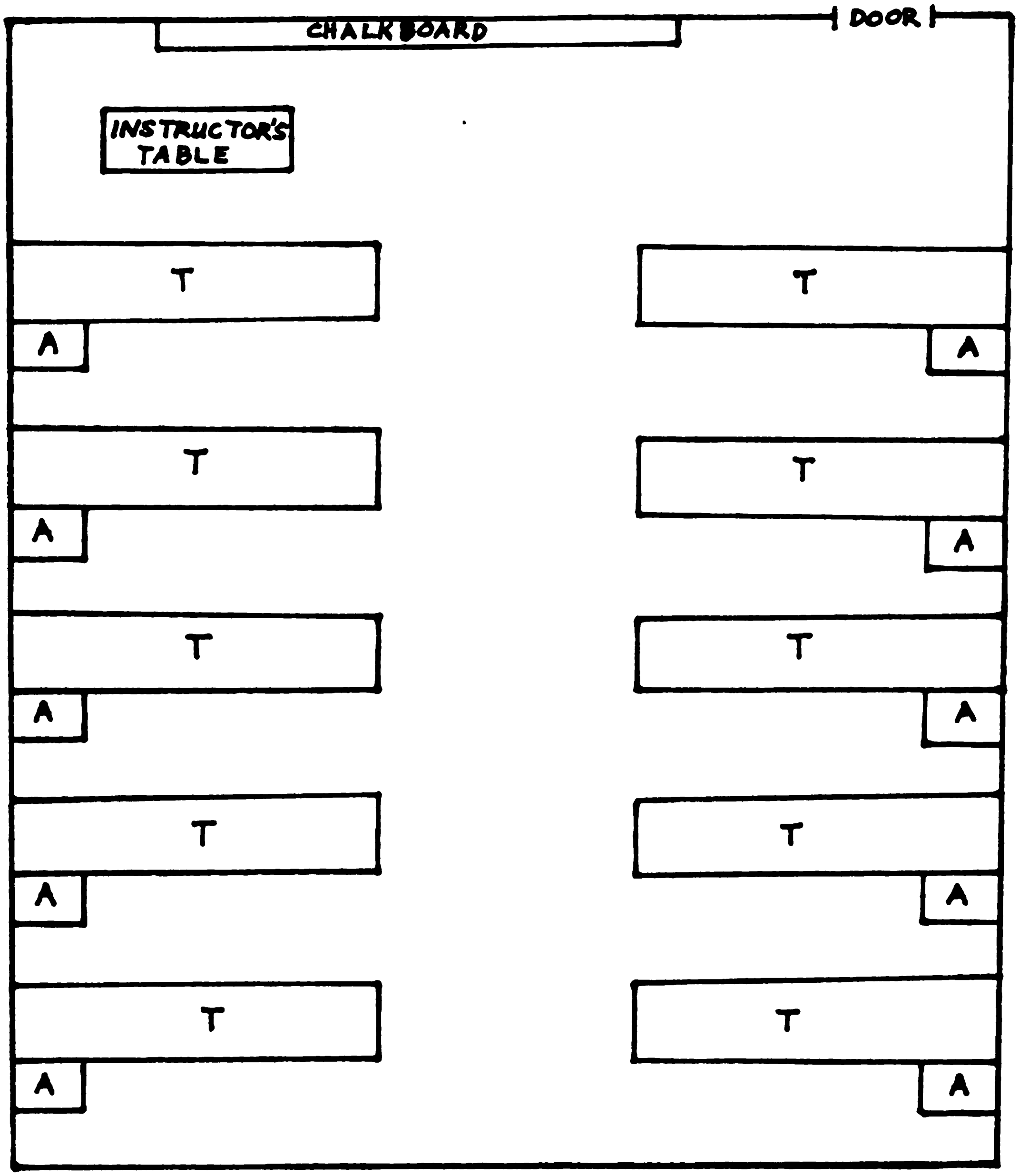
The department occupies two floors of a modern multi-story building which is maintained nicely. The main office of the department is on the ground floor and the rest are used as offices for faculty members and staff of the department. Connected to this building is a big building where all of the lectures and labs in physics, mathematics, computer science are held.

The department offers numerous courses for both undergraduate and graduate students. There are about 30 physics courses offered by the department.

For this research, the focus is on introductory physics courses. These courses are required for all science and applied science majors, though ocassionally there are some students in these courses enrolled to fulfill their general education requirement. In this department, there is one introductory physics course that use computers in the lab more than other introductory physics course, for both data gathering and analysis. Figure 3 illustrates the physics laboratory used for this course.

Figure 3:

Physics Laboratory at Sigma University



KEY:

A APPLE IIe COMPUTER

T TABLE

Theta University

Theta University was founded in the early nineteen century in a frontier town. Later, the institution accepted a gift of 40 acres not more than 50 miles to the west of the frontier town, and subsequently reorganized and relocated to its new location 20 years after it was founded.

Theta University is located in the heart of a city that has a population of over 100,000 people. The city is situated among the glacial hills, woods, and valley surrounding a river. The university has become one of the nation's most prestigious institutions of higher learning, with an enrollment of more than 30,000 students. Out of that, more than 20,000 are undergraduate students, pursuing their studies in more than 150 different areas. The students are from all over the nation, with about five percent from more than 100 foreign countries. More than 60 percent of incoming freshman students have graduated in the top 10 percent of their high school class.

Nearly 200 major buidings on the campus of Theta University of 2,608 acres accomodate 23 libraries with more than four million volumes, several hospitals, nine museums, and hundreds of laboratories, including the nuclear and scanning electron microscope labs. These research and teaching laboratories are internationally renowned in various fields, receiving annual awards and many research grants. Its research expenditure for 1986 exceeded 125 million dollars.

The university is also known for its competetiveness in sports. All its home football games are filled with spectators in a huge stadium and the football team has been selected for many years to play in major bowls. This is similarly the case with other games like basketball, and baseball.

The Physics Department occupies two buidings. The general office of the department and some faculty members offices are in a three story building which was built early in the twentieth century. There is a new modern buiding which houses offices for faculty members, classrooms and lecture rooms, laboratories for teaching and research, and a teaching and research library for the department.

The Physics Department of Theta University has a total of 64 faculty members. The faculty members received their doctoral degrees from respected universities in the country, including a number of them from Alpha University. A few of the faculty members received their doctoral degrees overseas, including the United Kingdom, France, and Japan. The faculty members are active in research, in areas including biophysics, astrophysics, elementary particles and fields, and particle theory. For the 1985-86 year, the department received a total of more than seven million dollars of research grants, mostly from the federal government.

There are about 100 graduate students enrolled in this department and more than three-quarters of them are doctoral students. There are about 100 undergraduate students pursuing their first degree in physics, distributed in groups of about 25 students for each of the four years.

The department offers 40 undergraduate courses. These courses ranges from those required for all science and applied science majors to those only for physics majors, those at the junior and senior levels. But, in this study the focus was on the introductory physics courses; those courses required for all science and applied science majors. The lab portion of these introductory physics courses utilize computers (Commodore Pet) for analysing data. The Commodore Pet computers are in one small room adjacent to a lab, and all the computers are connected to printers. Figure 4 illustrates the computer room and Figure 5 shows the physics laboratory used by students for conducting experiments.

Figure 4:

Computer Room at Theta University

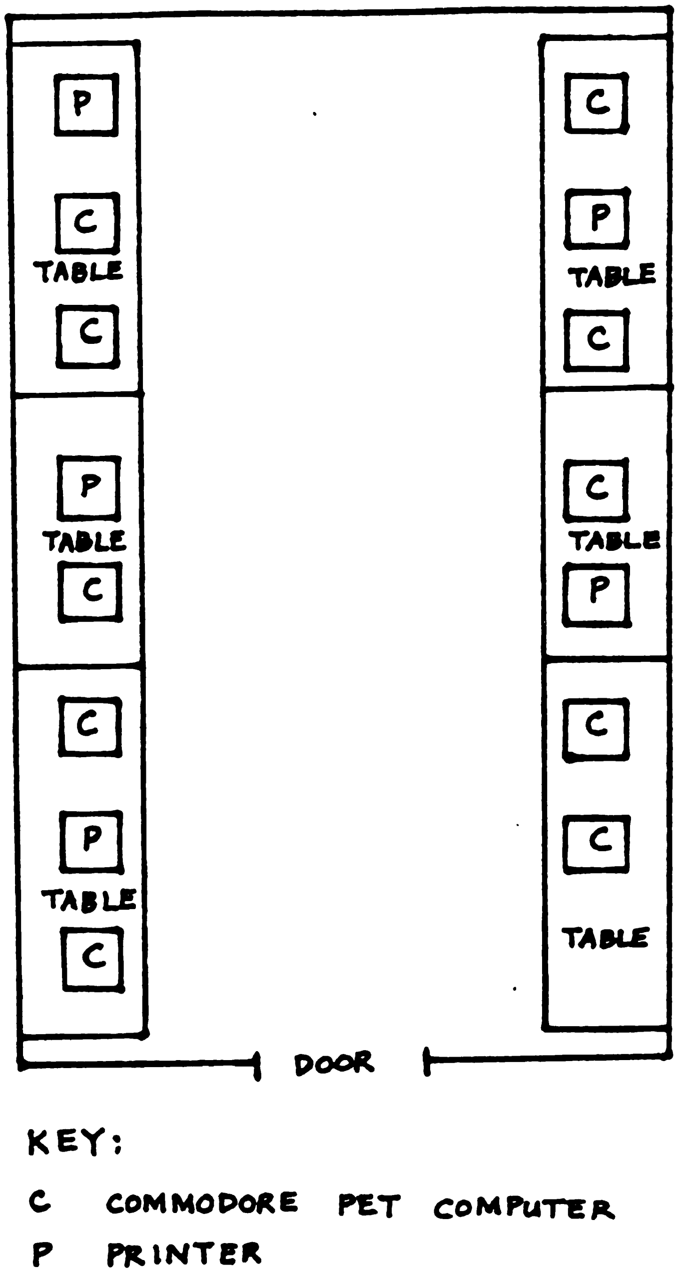
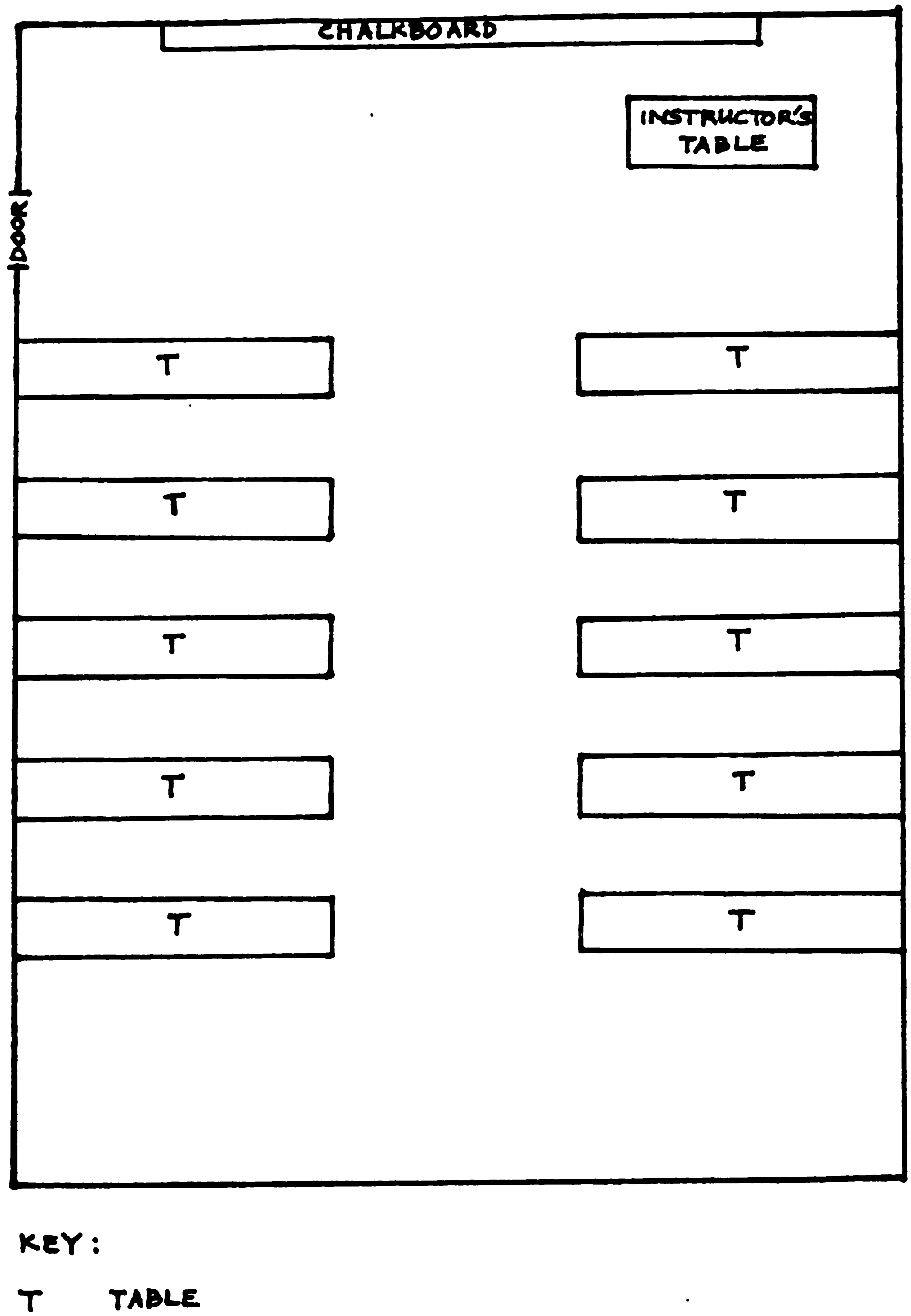


Figure 5:

Physics Laboratory at Theta University



CHAPTER IV

PRESENTATION OF FINDINGS

This chapter provides the research findings by giving qualitative accounts of what went on at the four institutions pertinent to the research and interprets the data using the literature reviewed in Chapter II. Four major issues related to instructional computing are discussed in this chapter. Consequently, each issue is presented in one main section of the chapter. The four issues or sections are: (1) Utilization and Classroom Practices; (2) Role Perceptions of Faculty Members; (3) Policies; and (4) Students' Perceptions. In each main section, there are sub-sections on the issues involved; presentation of data for all four institutions; and a summary. There is also a section on interpretation of data at the end of this chapter. The following section, however, focuses on the information about the data.

THE DATA

The research includes data collected from November 1986 to May 1987 at Alpha University and Beta Community College, and data collected in the months of March and April 1987 for both Sigma University and Theta University.

At Alpha University, the researcher observed 12 lab sessions and three lecture sessions of one hour each, amounting to 27 hours of observation. The researcher recorded 30 interviews, both formal and informal. Altogether eight faculty members in the Department of Physics, four administrators, and seven students were interviewed. The researcher also used documents pertinent to the research as sources of data, including course materials, bylaws of the Physics Department, the annual research report of the department, the faculty members' salary list, papers on instructional computing delivered at professional meetings by a faculty member, the campus newspaper, and the catalog of the university.

At Beta Community College, the researcher observed nine two-hour lab sessions and two one-hour lectures. Altogether there were 20 hours of observation made at this institution and 17 formal and informal interviews of three faculty members teaching physics, two administrators, and five students. Several important documents were also collected by the researcher, including course materials, papers on instructional computing delivered at professional meetings by a faculty member, the faculty members' salary list, the campus newspaper, and the catalog of the college.

At Sigma University, three two-hour lab sessions and one one-hour lecture were observed by the researcher. The total hours of observation was seven. The researcher engaged in 12 interviews of three faculty members in the Physics Department, the chairman of the department, and five students. Documents pertinent to the research were gathered including course materials, an annual research report of the Physics Department, the faculty members' salary list, the campus newspapers, and the university catalog.

At Theta University, the researcher observed three two-hour lab sessions and one one-hour lecture. Thus, the researcher engaged in seven hours of observation at this university. Twelve interviews were recorded. Three faculty members in the Physics Department, the chairman of the department, and five students were interviewed. The researcher collected documents related to the research as another source of data. These documents were course materials, the annual research report of the department, the faculty members' salary list, the campus newspaper, and the university catalog.

All data or findings presented in the next four sections of this chapter were collected as described above. Data collected at Alpha University and Beta Community College were more extensive and detailed than those at Sigma University and Theta University. Thus, a less extensive presentation of the data for both Sigma University and Theta University will be made.

UTILIZATION OF INSTRUCTIONAL COMPUTING AND CLASSROOM PRACTICES

Introduction

This section focuses on the current use and possible effects on classroom practice of instructional computing in introductory physics courses at four institutions. More specifically, the section describes the type and extent of use of instructional computing at these institutions in introductory physics courses. This is pertinent to final research questions 1, 1a, and 1b presented in Chapter I. There will be a discussion of the compatibility of instructional computing with the more traditional notion of classroom practices which is directly related to question 2 of the final research questions discussed in Chapter I.

In order to assess the use and possible effects of instructional computing, data collected from interviews, classroom observations, and document analysis for the research are presented. In both parts of this section, data from each institution will be introduced first; Alpha University is presented first followed by Beta Community College, Sigma University, and finally, Theta University.

CURRENT USE

Alpha University

At Alpha University, one of the physics professors, Dr. Kay, was heavily involved in instructional computing. He devoted about one-quarter of his time to software development to use in teaching his physics labs. In his office, there were both an IBM personal computer (PC) and an Aplle IIe microcomputer for his own personal use. Most of the time, he worked with the IBM PC, and it appeared that the Apple IIe, was more or less, collecting dust in one corner of his office. At an early stage of my research, he told me about the use of computers in instruction in the introductory physics courses, "The use of computers for instruction here is mostly in the labs. There are some faculty (faculty members) who use it in lectures for demo. For example, Dr. Olin used a program to demonstrate projectile motion." This was confirmed by Dr. Olin, who used some programs in his introductory physics course, "I use some simulation programs in my lecture for demonstration, like the projectile motion. Also, I use a ray tracing program for demo in my lecture."

Other interviews and observations confirmed Dr. Kay's statement. Instructional computing at this department was largely restricted to the laboratory. There also was some utilization of computers in lectures in introductory physics courses for demonstrating a principle such as projectile motion.

Dr. Olin later made a comment about the condition of television sets used as monitors in lecture rooms when demonstrating a computer simulation. He felt that the color television sets used as monitors were not very helpful because the color would change during a demonstration. Certainly, it was difficult to show some demonstrations that required a sharp image, because when the colors changed, the image on the screen was not sharp or in focus. He had asked an administrator to change the televisions, but the administrator was not interested. Thus, the televisions remained.

In one lecture, I observed a simulation of a ray-tracing program being shown in his class to reinforce his students' understanding of ray-tracing. From where I sat (at the back of a small lecture hall), I found it difficult to see the demonstration on the televisions connected to an IBM PC that ran the simulation program. Most of the students also seemed to be having problems seeing the demonstration, especially those at the back of the room.

One of the faculty members made the following remark when addressing students in a laboratory session of Physics I, "We are going to use these Commodore computers only for a couple of times. There will be one experiment where it will be interfaced to another piece of equipment for collecting data. For a few experiments, it will be used for analyzing your data and plotting graphs."

Physics I was the first physics laboratory course for a calculus-based physics sequence. This course focused on classical mechanics. There were about 80 students in four sections (see Table 2) enrolled in this course during this study, Winter Term of 1987. Thus, there were about

Table 2:

Extent and Most Common Type of Use of Instructional Computing at the Four Institutions

Name of Institution	Courses Using Computers	No. of Students Using Computers	Most Common Use of Computers
Alpha University	Physics I Physics II	80 17	DA1, DA2, and P
Beta Community College	Phys 111 Phys 211 Phys 221	20 20 30	DA1, and DA2
Sigma University	Phys 116	130	DA1, and DA2
Theta University	Phys 114 Phys 214	500 600	DA2

<u>Key to Most Common Use of Computers</u>

DA1: Data Acquisition in Labs
DA2: Data Analysis in Labs
P: Programming

20 students in one section of the lab. Students taking this course were at least in their sophomore year. Two students were assigned to each Commodore 64 microcomputer in the lab. In this course, students used microcomputers to analyze data (see Table 2) for "The Acceleration of Gravity" experiment. The program for the analysis of data was developed by the professor teaching the lab.

Another course, Physics II, was required for all first year physics majors. The instructor of this one credit hour course stated:

> Physics II is a two hour per week lab for the whole term. Students will have an option to either develop software only, or to develop computer-interfaced equipment for use in labs. Students can also choose to do both, developing software and computer-interfaced equipments.

It seemed this course familiarized physics majors with the use of computers both in writing programs in BASIC language (see Table 2), and in developing computer-interfaced equipment. First year physics majors enrolled in Physics II, a one credit hour course of computing for physicists, at the end of their freshmen year. In this course, students learned at their own pace. Students in this class were busy doing their own "projects" either developing a physics program or a computer-interfaced equipment for use in physics experiments. There were 17 students enrolled in three different sections during this research (see Table 2) with approximately six students per section. Each student had access to one Commodore 64 microcomputer, because there were 10 Commodore 64 computers in the lab.

Notice that only two introductory physics laboratories, Physics I and Physics II, used computers in the laboratory (see Table 2). Other physics labs did not have access to the microcomputers, because only Physics I and Physics II used the laboratory with the Commodore 64s. Other courses used different rooms for their laboratories that did not have microcomputers. Thus, other introductory physics laboratory courses did not use computers.

At least two faculty members suggested that they could not do much instructional computing with the out-dated microcomputers (Commodore 64) available. They preferred IBM PC's for use in the laboratory. One of them made a remark regarding this:

> In this course, we are using these ancient micros (while pointing at one of the Commodore 64 computers in the laboratory). I wish we had IBM PC's in this laboratory, so that students could learn a better operating system that is used widely in business and industry. Perhaps, with the IBM PC, more faculty will begin to use computers in their physics courses.

The important point made by the faculty mermber was that more faculty members would use instructional computing if there were 10 IBM PC's instead of the Commodore 64 computers.

Most faculty members in the physics department preferred to use microcomputers for instruction. Microcomputers allowed them to do computer-interfaced experiments; whereas, mainframe computers would not. Microcomputers were more versatile for the faculty members in the department. In my observation, I found only the microcomputers were interfaced to other equiptment to collect data for experiments in the laboratory (see Table 2).

A mainframe computer allowed students to work at their own convenience, because many terminals were available at key locations on campus. Those students who had microcomputers could work from their homes using a modem and communication software that allowed them to work with the mainframe computer. However, the mainframe computer was not utilized for instructional purposes in the introductory physics courses. Faculty members also voiced their lack of control over the mainframe computer, because they depended on people outside of the physics department who operated the mainframe, the Computer Science Department. The faculty members did not find this arrangement beneficial. As a result, this was one reason faculty members wanted to acquire more microcomputers for physics instruction. One of them voiced his desire to have more microcomputers:

> I would like to have more microcomputers. With the micros, I have more control and there will be no files being thrown out even if they

> have not been used for more than a year. I had one student complained to me yesterday that she could not do her project on the mainframe because she couldn't get the mainframe computer to run the program. When I checked, I found the file was deleted by the computer because it was not used for a long time. So, I spent the whole morning to get the file on the microcomputer this time.

This incident related by one of the faculty members illustrates faculty members' lack of control over the mainframe. This and many other similar incidents seemed to lead the faculty members in the departments to attempt to acquire microcomputers. With microcomputers, they had more control and less trouble than when they used the mainframe computer. The faculty members did not have to deal with people from outside the department giving them the ability to decide the direction of instructional computing with fewer restrictions. On the other hand, with microcomputers, faculty members or the Physics Department were responsible for the maintenance of the microcomputers which could be frustrating at time when the microcomputer brokedown. This required competent technicians to repair them and the Physics Department did not have a technician who could handle all these breakdowns. However, with the mainframe computer, the department or faculty members in physics did not have to worry about repairing or maintaining the computer because this was under the Computer Science Department. Nevertheless, microcomputers seldom breakdown and with its capabilities faculty members perceived that it was a better choice for faculty members in the department.

At the physics department of Alpha University, most software used for instruction with the microcomputers was developed by faculty members themselves. Thus, there were no problems with copyright laws with the software developed by faculty members. Some software was obtained from public domain and purchased for use in the department for instruction at the introductory physics level. Software developed by faculty members was less "user-friendly" than those developed commercially. As a result, students using software developed by faculty members spent more time figuring out how to use them. Most of these students found themselves learning some computer skills after they spent time "playing" with the software. In other words, the locally-developed software allowed students to learn some computer skills which they would not if they used the commercial software.

Througout the seven months of this research, only one course was observed using commercial software for experiments in the laboratory. This course was taught by a non-tenured faculty member who had recently begun teaching at the university. In the other courses utilizing computers, the software was developed by staff members from the department, some in collaboration with a technician in the department, and some in collaboration with students. The last two of these has obvious benefits. It saved the faculty members time, thereby overcoming the lack of time for faculty members to write and test the programs. For some faculty members who did not have programming knowledge, assistance from technicians and students was highly desirable. One of the faculty members, who was active in nuclear physics research stated:

> I don't know how to program and this is true for most older faculty members in the department, but not younger ones. I have graduate students working with me who will write programs for me in my research. Same with Professor Olin, he asks his students to do it.

Furthermore, it draws on the programming abilities of the students, and most important of all, it reinforces the students' knowledge of that particular area of physics.

Beta Community College

At Beta Community College, one faculty member made a remark regarding the use of computers for instruction, "We mostly use the computer for labs, we really are not using them very much for classes, almost zero. The only thing we use for classes are already written programs. These are mainly programs that have visual impact. Only like a demo." This remark showed that like Alpha University, computers were mainly being used in the laboratory at Beta Community College. About 70 students used computers in three different physics labs (see Table 2). There was little use during lectures or classes according to the faculty member.

She, however, added that some programs were used for demonstration purposes during lectures. This was supported by another faculty member:

> I use computers mostly in my laboratory for analyzing data using the spreadsheet program. In one experiment, I have a digitizer connected to an Apple IIe which could essentially collect data automatically. So, I use it mostly in labs, and during lectures, almost zero.

The faculty member's statement above supported what the other faculty member suggested earlier. This was especially true with the use of computers in the laboratory for acquiring and analyzing data (see Table 2). The faculty member also said that there was little use of computers in his classes or lectures. Later, he told me that he used computers in lectures to demonstrate a principle that was difficult for students to comprehend. This was achieved using simulation programs.

All the physics faculty members interviewed liked to use microcomputers for instructional purposes. They used microcomputers for data collection in the laboratory. At one instance, I observed the students using the HIPAD digitizer interfaced to an Apple IIe microcomputer running a program written by a faculty member. With this set-up, students used the digitizer to locate points for the flight of a ball from a photograph of a projectile motion of the ball. The photograph was taken by the students earlier in conjuction with the experiment they were doing. Following the procedures carefully, students were able to have the data read to the microcomputer. Later the computer calculated average speeds needed for the experiment.

In lectures, the faculty members used microcomputers to demonstrate phenomena, such as centripetal force, using simulation programs. These simulation programs were used to help demonstrate principles or phenomena that were difficult for students to understand.

There were some limitations that faculty members had to deal with when using microcomputers. For example faculty members could not make multiple copies of the programs, nor could they use a single copy of the program to boot all the microcomputers. These are all restrictions stated in the copyright laws. Unless faculty members had enough money to buy more copies of the programs, they could not use these programs on the Apple IIe. The only programs they used were those that they used only one copy at a time, such as the one for the projectile motion experiment, and also programs for demonstrating phenomena to the whole class during lectures. Writing their own programs was difficult and took much time, as was mentioned by the faculty member.

Most of the time the faculty members used the mainframe computer; perhaps, because they had access to the software the college had bought, so they did not have to worry about copyright laws. Students were able to complete their assignments on the many mainframe terminals on campus.

For those students who owned computers and modems, they could run programs on the mainframe from their homes. The faculty used the mainframe in the physics laboratory for data analysis of the experiments the students performed. All of the faculty members liked a spreadsheet program called SS 2020 developed by Digital Corporation which was available on the mainframe computer. They used the spreadsheet regularly to do calculations of data obtained from the experiments students did. Almost all of the students' experiments during the terms that this research was conducted, required them to use the spreadsheet program to do the calculations involved in the experiments. For example, in one experiment on centripetal force, students used the spreadsheet to calculate angular velocity, angular velocity squared, centripetal force, and gravitational force. Students first collected the data manually and then entered them into the spreadsheet program. Calculations were completed quickly, presuming they did not have difficulty using the computer or the spreadsheet program.

In one laboratory session I observed, the instructor told students, while giving a handout pertaining to SS 2020, a spreadsheet program during the beginning of the term, "We are going to use this spreadsheet throughout the term in every experiment." Thus, the students used computers in the laboratory most of the time to do calculations using the spreadsheet program.

According to the faculty members, they had some bad experiences using the mainframe. One of them told me that the computer science department took away the terminal in the physics laboratory in the middle of the fall term. Without the terminal, she was not able to show the students in the laboratory how to use the spreadsheet program. Before the beginning of the winter term, she managed to get the terminal back into the physics laboratory. This incident remarkably suggested that the physics faculty members had little or no control of the mainframe.

Another faculty member said that the computer science department did not comunicate its plan for changes to the mainframe system. For instance, the computer science department did not notify him of the changes in the spreadsheet from an older version of SS 2020 to a newer one. In one lab session, he was about to use the spreadsheet and found he was using the newer version. For that day there was a lot of changes in his plan. He stayed in the laboratory for the entire day figuring out how to use the new spreadsheet. It took him the whole week, however, to learn the new commands for the new spreadsheet. This incident occured during the middle of the term, and he felt that it should have been done during term break or summer. Inevitably, the incidence had a negative impact on the faculty member's perceptions of using the mainframe computer for teaching physics at Beta Community College.

Sigma University

In my first meeting with a senior faculty member of the department, who was also the former chairman of the department, I asked him about the use of computers for instruction in the introductory physics courses. He answered, "There is not much use of computers for instruction except in the labs. Most of the time students use the computers to collect and analyze the data." This demonstrated that computers were used in physics labs in acquiring data and analyzing data (see Table 2).

I later asked him whether computers were used in lectures for instructional purposes. He replied, "Yes! but, occassionally to demonstrate a phenomenon. For example, using a simulation program with a monitor in front and text on the monitor bigger than normal so that all students could see. Dr. Reel is interested in its use during lectures." From my observations and interviews, I found there was very little use of computers for demonstration during lectures other than in the physics laboratory. Since he mentioned Dr. Reel was keen in using computers in his lectures, I went and talked with Dr. Reel to find out.

Surprisingly, he did not use computers in his lectures but he told me he was keen of the idea. Dr. Reel told me, "I don't use computers in my lectures to demonstrate something to the class. I find it difficult to because there is no big screen for all students to see in the big lecture hall. I like the idea. Anyway, I use other things for my demo." When I asked if computers were used in the laboratory, Dr. Reel responded, "We are using the computer in 201 labs for a few experiments. It's not more than three experiments and may even be two." This remark was rather surprising because computers were used four times in the 201 introductory physics laboratory where about 130 students were enrolled during Winter of 1987 (see Table 2). There were seven lab sections for Physics 201 with about 20 students in each lab section. In one experiment of "Hooke's Law and Simple Harmonic Motion" students used the Apple 1le computer as a timer to measure the period of oscillation; and to calculate the standard deviation of the period. In that experiment as well as in other experiments, each pair of students shared one Apple IIe computer.

Another faculty member related his thoughts of using Apple IIe computers and a program he used in the physics labs.

> I have eleven Apple IIe's in the laboratory, one of them as a backup just in case if one of them breaks down. So far there was no need to use the backup Apple. I use the computer for both data acquisition and analysis in the introductory physics laboratory. One program that I use is Precision Timer II. We have an agreement with the company that makes the software allowing us to copy more than one copy of the program for us to use on all the 10 microcomputers that we have. So, we don't have to worry of the copyright laws.

Interestingly, the faculty members in the department did not have to worry about using the program for more than one computer because of the agreement they had. In this department there appeared to be no need for faculty to develop their own programs, probably because of this agreement. The faculty member later showed me the software and its manual. He later told me that this program allowed students to use an Apple IIe computer as an accurate and flexible timer. In addition, the program also helped them to store data, print data tables, do simple statistical analysis, and graph the data.

Theta University

One of the faculty members who was the coordinator for introductory physics laboratory at Theta University said this, "I use computers in all introductory physics labs for data analysis but not for data acquisition because the computers will do everything and student will not benefit with this." My observations and discussions with other faculty members in the department, confirmed what the coordinator said that the use of computers in the introductory physics laboratory was limited to analysis of data (see Table 2). The use of computers for data analysis occurred not more than three times in the winter term for each introductory physics lab. The coordinator also told me that two introductory physics courses used microcomputers in labs, and more than 1,100 students used microcomputers in these courses to analyze their data in the labs (see Table 2). None of the experiments used computers to gather data as mentioned by the lab coordinator. The coordinator felt that the computers should not do everything for the students in the laboratory. He implied, perhaps, that computers should not be used in data collection because students would not be able to fully participate in the lab. Consequently, students would not understand what was going on in the lab.

There were 10 Commodore Pet computers in a physics laboratory at Theta University and the department planned to replace them with 10 Apple MacIntosh computers in the Fall term of 1987. The Commodore Pet computers were used to do data analysis of the experiments the students performed in the introductory physics courses.

All the programs used in the data analysis were developed by faculty members. These programs were used freely by faculty members because they were not copyrighted. All of them agreed that by writing their own programs for instructional purposes, they did not have to worry about copyright laws.

EFFECTS OF INSTRUCTIONAL COMPUTING ON CLASSROOM PRACTICE

Alpha University

In the Physics I laboratory course that I observed at Alpha University, the instructor spent much of the time for the session teaching students how to operate or use computers. In one session I observed, the instructor wanted students to copy a program he had written. A couple of the students had difficulty copying the program. One of them, Bob, took more than 10 minutes to copy it and that was with the assistance of the instructor:

Bob:	What do I do to copy?
Instructor:	Just follow the instruction I told you.
Bob:	I did, but it didn't work.
Instructor:	Try it again.
Bob:	O.k. let's see.
Instructor:	No! I guess you need to format your disk. (After Bob had spent more than five minutes trying to copy the program.)
Bob:	What do I do?
Instructor:	Put in this DOS disk first and type format and follow the instructions on screen.
Bob:	I got it (about one minute later).
Instructor:	Now, you can begin copy the program.
Bob:	Let's try the program that I had copied (two minutes after).

Instructor: (After seeing Bob's program worked) Who else wanted to copy this program?

In another instance, two students came to the instructor complaining they had problems working with BASICA, a BASIC language interpreter for the IBM PC microcomputer. One of them told the instructor that he could not run the program he copied with the BASICA he had access to. The instructor told them that they must first download BASICA onto the computer. After that, the instructor said they could load the program by typing LOAD GRAVITY.BAS and finally they could run the program by typing RUN. One student interjected that she had tried that but it did not work. She added she was sure she had exactly followed the steps the instructor told them. The instructor seemed puzzled and doubtful. The students then said they would try that again. In a laboratory session a week later, the students told the instructor they had managed to run the program. There were other examples similar to this where students had problems using computers. The instructor spent class time showing students how to use the computers.

The course format of Physics I did not differ significantly from the traditional introductory physics laboratory. Students had handouts on the theory and procedures of the experiments. In addition, students read a textbook on error analysis. For each lab session, the instructor normally first gave a short written quiz that lasted less than fifteen minutes. During this time, the instructor gave back graded quizes and lab reports to students. The instructor later discussed the experiments for that day and, if essential, demonstrated some new sophisticated equipment used for the experiments. Most of the time the instructor would do the talking and the students would listen. There was little interaction between students and the instructor, except for a few students asking the instructor to clarify the procedures of the experiments or the theory of the experiments during the discussion. Most of the presentations by the instructor were done in front of the laboratory using "talk and chalk" and some demonstrations on the use of certain equiptment. Thus, during this presentation or discussion the instructor did not use other audio-visual equipment like the overhead projector, instructional television and computers. An exception was only in two experiments when microcomputers were used to analyze the data. Nevertheless, the microcomputers were used just like another piece of equipment in the laboratory, but not to help the instructor in his teaching or presentation. In other words, the instructor talked about the microcomputers because the students were going to use them in their analysis of data.

After the brief discussion, students began to do the experiments in pairs. In the meantime, the instructor went around from one group of students to another helping them with the experiments. Normally, there were two announcements made by the instructor to correct some of the mistakes students made in the experiments. At the end of the lab session, the instructor reminded students of the coming experiments and things to do before the next session.

In this laboratory, the instructor used traditional methods to evaluate student performance in the laboratory. Grades for students were derived from students' lab report, quizzes, and a practical examination. Surprisingly, there was no evaluation of students done by the microcomputers, even though there were microcomputers available in the laboratory.

In lecture courses, faculty members relied on textbooks as a source of instructional material. Faculty members assigned readings and problems from the textbooks. Even their lectures were based on the textbooks they were using. One student made a comment, "I think it would be better for me just read the text because his (the professor) lectures were basically the same as in the text." This statement made by one of the students indicated that the professor followed the textbook and it seemed that the student felt there was no use for him to go to the class and listen to the professor lecture. Three faculty members made strong assertions that the majority of the faculty members would only use instructional computing until integrated materials were produced by the textbook publishers which reinforced this point about the centrality of the textbook for most faculty members in this department. As mentioned earlier, in the Physics I laboratory there was some use of the textbook for students to read on error analysis. Thus, there was less reliance on textbooks as compared to lectures. This, however, was not surprising because the traditional physics laboratory also does not rely heavily on textbooks.

Beta Community College

In one physics lab that I observed at Beta Community College, the faculty member who was the instructor for the lab planned to introduce her students to the SS 2020, a spreadsheet program used for the whole term. The instructor first gave each student a handout of the spreadsheet program which briefly described how to use the program. The instructor asked students to define a spreadsheet. One student responded, but it was not sufficient. The instructor then provided a practical definition by saying, "Spreadsheet is a computer program which people can use to put in data in rows and columns." A few minutes later, the instructor asked the students whether they had their graphs for last week "free fall experiment" printed. Only one student said that he had, but added he was not sure if he had done it correctly. Realizing that most of the students were not able to print out their graphs using the spreadsheet program, the instructor told the students the procedures to print the graph were in the handout provided earlier. While explaining the procedures, she wrote on the chalkboard:

> To save data for Plot Program:
>
> Save Spreadsheet --- Save, Write, Date,
>
> Student # and SS 2020
>
> / Command Mode
>
> S Store
>
> E Export
>
> D Data File
>
> Data File: Student #. Date[Ret]
>
> Range [0...15, 0...41]

She later told her students that she wanted to see each student hand in one of each of the following graphs: (1) Position vs. Time; (2) Velocity vs. Half-Time; and (3) Acceleration vs. Time.

During the last hour of the lab, the instructor showed the students how to use the spreadsheet program using a dumb terminal in the lab. She asked two students who were unfamilar with computers to try the program, with her assistance.

> Instructor: Who's afraid of computer?
>
> Student A: I am.
>
> Instructor: O.K. You can be on demo...
>
> Who else is afraid?

Student B: (Raised his hand).

Instructor: All right let's go to the terminal and plot the graphs.

All students went to the terminal located at the front corner of the lab. Student A then operated the computer while the instructor provided the procedures to the student. The student followed the procedures carefully. This took more than 30 minutes. The rest of the lab time was spent with Student B at the terminal. The instructor taught her students how to use the spreadsheet program. There were other instances similar to this where most of the lab time was spent teaching the students how to use the computer instead of teaching the physics concepts involved in the experiments. This one took the whole lab session while other instances normally took less than half-hour by the instructor. I was told by the instructor and other faculty members in the department that they did not have to teach students how to operate the computers when they used simulation programs to demonstrate some principles or concepts to students.

From my observations, I found that there were few deviations from the traditional modes of classroom practices. The classroom was still dominated by the instructor giving procedural matters to students in the lab and lecturing most of the time during lectures. Occassionally, students asked questions and answered the instructor's questions. But most of the time the instructor dominated the classroom albeit instructional computing was used. One of the students told me, "This is just like a typical introductory physics laboratory, with little changes."

Students in the laboratory were evaluated based on their lab report. This is not uncommon in the traditional physics laboratory where students' performance are evaluated based on their written lab reports. Interestingly, computers were not used as a tool to evaluate students performance in the laboratory, even though computers were available for them in doing the experiments.

During lecture part of the introductory physics courses, the faculty members used textbooks as a source for their teaching materials. Students read the textbooks they used, and did all of the problems assigned from the textbooks. The faculty, perhaps, literally followed the textbooks in delivering their lectures. Thus, the faculty members were very dependent on the textbooks in their lectures. One of the students summed it up, "The structure, the organization, and the format of the introductory physics course are all very similar to another introductory physics laboratory."

Sigma University

At Sigma University, little time was spent on teaching students how to use the computers in the laboratory for both data collection and analysis. One of them told me:

> We told the students to read the lab manual before they come to class which includes how to use the computer for the lab. Normally, there was not much problem in getting the students to use the computers. So, I don't have to teach them how to use the computer in the lab. A few of them, however, have some questions on how to run the program for example which did not take long for me to answer.

The faculty member's observation showed that he spent little time teaching the students how to operate the computer to gather and analyze data. But one must remember that the software used here was all purchased. None of the software was developed by the faculty. The software used was all user-friendly and could be used without many problems. As a result, the faculty members here did not devote most of their time teaching students how to use the programs. Instead, they were able to concentrate on physics concepts pertinent to the experiments.

The faculty members in physics here at Sigma University adhered to the traditional classroom practices. The faculty members dominated classroom interactions. Only a few students interacted either with the faculty members or their friends, especially during lectures. In the introductory physics laboratory, students were graded based on their written lab reports and a practical examination. Finally, the faculty members relied heavily on textbooks for their instruction, particularly in their lectures. Students were assigned to read and solve problems from the textbooks. This was reaffirmed by both the faculty members and students.

Theta University

At Theta University, the faculty members taught the students how to use computers for analyzing data at the beginning of the term. The laboratory coordinator for the introductory physics laboratory related this to me, "During the beginning of the term, we will show students how to use the EXPFIT program which will help them in the data analysis. I think the program is quite easy to use." The faculty member was correct in saying the EXPFIT program was rather easy to use because it was menu-driven. However, the program was was not quite user-friendly, despite the faculty member's assurances. For example, the program did not always provide enough information for the user to go on to the next step in the data analysis. He told me that he was going to update the program during summer so that it would be more user-friendly. Students were not expected to have any problems using the revised program.

The faculty members did not deviate from the traditional classroom practices. The classroom atmospheres were mostly dominated by the usual "teacher centered" practices. The lab instructor was the focal point for everybody in the lab, either in terms of procedural knowledge or conceptual knowledge. Perhaps, this was why all of the students sat facing the instructor in front of the laboratory. Students were evaluated based on their written lab report. The students relied heavily on a textbook (lab book) to carry out all experiments for the whole term. Everything they needed to know concerning the lab was available in the lab book. This lab book was written by the lab coordinator and it was already in an eleventh edition.

Summary

At Alpha University, instructional computing was used mainly in the Physics I labs for performing experiments and analyzing data. In short, computers were used as a tool in the labs. Students used microcomputers only twice during winter term. There were about 80 students in the Physics I. However, first year physics majors, enrolled in Physics II, a one hour credit course of computing for physicists at the end of their freshman year, used computers every session throughout the term. But the number of students in this course was only 17. In this course, students were expected to develop skills in programming BASIC. On the other hand, in lectures, one faculty member used a few simulation programs to demonstrate phenomena during lectures.

In both Physics I and Physics II, microcomputers were used for analysis of data in the labs. The mainframe computer was not used by the students in the physics labs. This was perhaps due to the low cost of microcomputers and their capability to perform most of the work mainframe computers do. Furthermore, faculty members found that with the mainframe computer, they did not have direct control of the computer. This certainly put them at a disadvantage. On the other hand, with microcomputers they had almost total control and found microcomputers could be used in the lab for acquiring and analyzing data. To overcome the problem of copyright laws, faculty members developed their own programs for their own use on the microcomputers. Thus, most of the programs used for instruction with the microcomputers were developed by the faculty members.

At Alpha University, faculty members using computers in the laboratory spent some of the time teaching students how to use the computers, reducing the time used to teach physics concepts involved with the experiments. On the other hand, faculty members using instructional computing in lectures to demonstrate principles or phenomena did not have to teach students how to operate the computers. In both cases, however, there were few differences in the classroom practices compared to the traditional or typical classroom practices and organization. This was characterized by whole group delivery of instruction, teacher dominated conversation, and reliance on textbook materials.

At Beta Community College, the utilization of computers for physics instruction was mostly limited to the labs. Three physics courses with a total of approximately 70 students regularly used computers in the labs. Students in these labs used computers mostly in the physics laboratory for data acquisition and analysis. In lectures, the physics faculty members used computers on limited occassions to demonstrate phenomena in their lectures. It appears that the faculty members did not have the skills to develop instructional computing.

The physics faculty members at the college interviewed liked to use microcomputers for instructional purposes. They used microcomputers for data collection in the laboratory occassionally. However, most of the time they used the mainframe computer in the physics labs for analyzing data using a spreadsheet program.

At Beta Community College, physics faculty members spent much of their time in the lab teaching students how to use the computers for acquiring and analyzing data. But this was not true for faculty members who used computers to demonstrate phenomena during lectures. There were not many differences from the typical or conventional classroom practices, both in the lab and lecture. The faculty members still employed whole group delivery of instruction, teacher dominated conversation, and reliance on textbook materials.

At Sigma University, the use of instructional computing in the introductory physics courses was limited. Computers were used mainly in the laboratory to do data collection and analysis. About 130 students enrolled in a physics course requiring students to use computers in the labs. In lectures, however, there was occasional use of computers; to demonstrate a principle, for example.

The physics faculty interviewed at Sigma University preferred to use microcomputers rather than the mainframe computer in teaching introductory physics courses. An agreement with a company that made the program the faculty members used in the labs allowed them to use the program for more than one microcomputer. This certainly made it easier for the faculty members to use microcomputers.

Since the program used by faculty members at Sigma University was more "user-friendly," little time was spent teaching students how to use the computers in the laboratory for both data collection and analysis. Students were more involved with the experiments per se rather than with learning how to run the microcomputer. Overall, the traditional notion of teaching practices were present and there seemed to be no changes of these with the advent of microcomputers.

Lastly, at Theta University, the use of instructional computing in the introductory physics courses was limited to the analysis of data in labs. Amazingly, there were about 1,100 students enrolled in two introductory physics courses using computers in labs for data analysis. This is a relatively large number of students compared to the other three institutions.

The three faculty I talked to believed microcomputers were a better choice for instructional purposes in the introductory physics courses. Students in four introductory physics courses used Commodore Pet computers to analyze data. Faculty members developed all the programs used in the labs. Thus, there was no problem with copyright laws here because faculty members freely used the programs.

At Theta University, the faculty members taught the students how to use computers for analyzing data during the beginning of the term. Students used the computers later in the term, whenever necessarry. Apparently, the use of computers did not change the traditional notion of teaching at this university since the computer was used simply as a tool to analyze data from standard laboratory exercises.

At the end of this section, a summary is provided in Table 3 to help readers.

Table 3:

Summary of Data on Hardware and Software Use

Sub-Issue	Alpha University	Beta Community College	Sigma University	Theta University
Most Common Use of Computers	DA1, DA2, and P	DA1 and DA2	DA1 and DA2	DA2
Software Used	Locally Developed	Vendor	Vendor	Locally Developed
Computer Used	Micro	Mainframe and Micro	Micro	Micro
Microcomputer Used	Commodore 64	Apple IIe	Apple IIe	Commodore Pet

<u>Keys</u>

DA1: Data Acquisition in Labs
DA2: Data Analysis in Labs
P: Programming

FACULTY MEMBERS' PERCEPTIONS AND ROLES PERTAINING TO INSTRUCTIONAL COMPUTING

Introduction

This section focuses on the faculty members' perceptions of the use of computers in teaching physics at the four institutions. This includes a discussion of faculty members' views of using computers in the physics laboratory and in lectures, and the use of microcomputers and mainframe computers in instruction. Related to this, there are discussions on faculty members' roles in the departments which are basically either as a teacher or a researcher. These will help to answer final research questions 3 and 3a discussed in Chapter I.

This part presents data collected mostly from interviews with faculty members at the four institutions. In addition, some data presented here were acquired from classroom observations and analysis of pertinent documents. Data from Alpha University is presented first, followed by Beta Community College, Sigma University, and Theta University.

Alpha University

All eight faculty members whom I interviewed from the physics department at Alpha University were not supportive in the use of computers as a tutor in teaching. One of the faculty members I talked to at Alpha University said, "It's a mistake for anybody to use computers like in

CAI that is for tutorial and drill and practice. But in the labs it is essential because computers are just another piece of equipment needed, just like voltmeter." This view seemed to be widely held by the faculty members at the department because they felt that computers would not improve physics teaching or learning if they were used just like a tutor to deliver instruction. They, however, believed that computers were necessarry in the laboratory for students to carry out experiments.

One of the faculty members who was heavily involved in using computers in the laboratory surprisingly said, "When we are unsure of ourselves on the fundamental issues such as teaching of mechanics, the issue of how to use computers in the curriculum automatically becomes sort of secondary consideration." This reflects not only his view but many others in the department who were concerned with the broader issue of how to teach physics effectively. Moreover, his statement suggests that most of the faculty members had experienced the difficulty in teaching physics to the students. A few of the faculty members indicated their frustration with students because of their difficulty in understanding the concepts involved even after "proper" instruction. This made the faculty members less receptive towards instructional computing because of this unresolved issue which was more fundamental than instructional computing. In fact one of them mentioned, "We don't know how to teach (physics) without computers, so why do we think using computers, that is if we use computers, we simply make the same mistakes all over again that we made without them and so the issue doesn't become whether or not to use them, it becomes that we don't know how to use them." Thus, one of the main concerns of the faculty members towards the use of instructional computing was the growing evidence that students do not understand the fundamentals of physics satisfactorily as a consequence of regular instruction, and professors did not see how computers would be useful until they knew how to help students learn physics more effectively.

A few of them even argued that research showed that computers as tutors did not significantly improve students' achievement in physics compared to other modes of instruction. As one of the professors told me, "Most research on using computers to deliver instruction such as at Illinois, the PLATO project, found there were no significant differences with the traditional mode of instruction. That's why we are not using it here." One of them cautioned those who use computers in their teaching, "Computers should not be used like a black box and not used a lot because students might not be able to understand the phenomena they are studying."

Most of the faculty members agreed to the remark made above. They were concerned that students who used computers for their learning would not be totally involved in learning the concepts. Instead, the computer took over some parts of the learning process. The computer for example, calculated the value of G (gravitational constant) automatically using data students had collected and entered into the computer. In less than a minute, the computer finished with the calculation and had the value printed for the students. In this case, students missed the actual process of calculating the value of G which faculty members perceived as crucial for them in their learning process. That is probably one of the main concerns the faculty had of using instructional computing more often. Thus, it appears here also that physics professors are reluctant to change from traditional instruction modes because of their concern about students' learning.

The faculty members also viewed that it cost a lot of money to implement instructional computing, and since it had not been proven successful, they felt that it was not necessary to have instructional computing.

Three faculty members in the department told me that there was already a lot of materials in the syllabus for them to teach, and to add computer skills to their course would further overload the students and the faculty. They further said that with the extra materials like computer skills students might not be able to learn physics concepts well because students needed to devote some time with computers. Thus, the primary objective of teaching and learning physics concepts could not be achieved satisfactorily with the addition of new concepts pertaining to computers in the course syllabus.

On the other hand, all of the faculty members interviewed agreed that students should have some knowledge of using computers to solve physics problems. There was already a course required for all first year physics majors that taught them how to write programs to solve physics problems and to interface with laboratory equipment in collecting data. A few faculty members agreed that this course of only one credit should be expanded and given more than one credit.

Most of the faculty members interviewed in the physics department preferred to use microcomputers for instruction. They thought that microcomputers would allow them to do computer-interfaced experiments that the mainframe computers would not. One of them related the usefulness of microcomputers in the laboratory, "I think these micros are really neat in the laboratory. A lot of things you can do with them. You can use them as a timer, counter and sensor. This helps students in getting more precise data than before."

One point that was not discussed earlier concerned the faculty member's remark about the microcomputers helping the students in getting more accurate data. Consequently, this means students will be able to obtain better results from the experiments they were doing, and perhaps enhance the students' learning of physics concepts and principles.

This perception was generally shared by most of the faculty interviewed.

One of the faculty members at Alpha University, Dr. White, however, believed that both the microcomputers and mainframe computer were useful for students. His response to my question of his preference toward microcomputers or mainframe for instruction is stated below:

> You have to balance between those two. If it's going to take you two hours to run on microcomputer and two minutes on the mainframe, then the mainframe will be the choice. But, if it takes two minutes on microcomputers, then microcomputers will have the advantage. I think students should use appropriate machines.

Dr. White's thought was cautious and he seemed to say that both the microcomputers and the mainframe computer should be used by students whenever it is appropriate.

Two of the faculty members who were developing software for instructional purposes found the task was time consuming and difficult. One of them related that so much time was needed to develop good instructional software, "For every hour of instructional software you develop you need to spend 2000 hours of professional time and this was stated by Arons. But I do not have that much time to spend for developing the software." The statement made by the faculty member indicated he needed more time to develop the softwares. Perhaps, the department could give some released time for those faculty members who were active in developing instructional software. The department gave one of them released time to develop instructional software; he was assigned to less teaching for the year and was able to spend more time on this developmental work.

Most of the faculty members in the Physics Department at Alpha University viewed themselves as physicists rather than physics educators. They viewed themselves as doing research in physics areas such as solid state and nuclear physics. Thus, they did not devote their time to doing research on teaching physics, such as finding out the most effective methods for teaching quantum mechanics. Consequently, they were involved in professional organizations that were active in physics research rather than in organizations that were active in pedagogical research.

One of the faculty members made a comment pertaining to the lack of interest toward teaching of faculty members in the department:

> It's difficult for us to develop a sophisticated software for instruction because we have no interest. We are not interested in social science that's why we went into physical science and what we are talking now is social science; how you teach is social science, even when you are teaching physics.

Another faculty member voiced his opinion about the role of physics faculty in the department:

> We are all trained as physicists not as educators or social scientists. So our interests are in physics research rather than in educational research. Also, most of us do not believe in social science or psychology which is part of educational research. And physicists are not up-to-date on literature in learning and teaching.

These two faculty members appeared to be typical of members of this department. They were clear about where their interests and background lay. They were not interested in conducting research in teaching physics since they were trained to be physicists, not educators. Moreover, the faculty members recognized that they were not in tune with the recent development of research in learning and teaching.

Nevertheless, two of the faculty members interviewed showed interest in doing research in teaching physics, or at least they were innovative in their approach towards teaching physics. One of them regularly attended American Association of Physics Teachers meetings. He also regularly presented papers at those meetings related to new approaches in teaching physics. As an instructor, he was innovative and started a course in using computers for all freshman physics majors. In fact, he devoted his time totally to find better ways to teach physics. The same was true for the other faculty member. Both of these faculty members were full professors and senior members in the department. One of them told me that he would not advise any non-tenured faculty members to start doing research in teaching physics, but instead he would want them to devote their time to physics research and be part of the professional organizations that are active in their research areas.

Beta Community College

At Beta Community College, all three physics faculty members interviewed agreed positively to the utilization of computers for instruction, especially in the laboratory. They believed that computers were important equipment in the physics laboratory for students to do experiments in acquiring and analyzing data. One of them made this statement:

> I feel, there are positive aspects of computers in terms of instructional activities. It relieves the students of some of the drudgery of, for example, like labwork. In case of computer use interfaced lab device or use as computational tools such as the plot program, you relieve the students of the burden of cranking out numbers, burden of staying with equipment for a long period of time and being able to watch anything supposed to happen as opposed to the computer taking over and basically running the experiment, taking the data, saving the data, and then allowing the students to analyze the data anyway they want, plotting anyway they want, interpreting any way they want.

This suggests that computers could take over some of the lab work students do in carrying out experiments. The faculty member further added, "So, it allows for some of the higher level activities, namely, hypothesis formation for example and testing, rather than some of the other tasks, taking the temperature of something every five minutes or taking light intensity every 1cm." This perhaps, will facilitate students in their learning of the concepts and principles involved in the experiments as well as higher order learning skills.

Another faculty member at the community college felt that computers were essential in the laboratory, but was a bit skeptical of their usefulness when they were used a lot:

> I think to allow the computer to do too much for the students in the laboratory would be bad. There is a fine line between too much and too little obviously, but it's possible to allow the computer to do too much for the students. So that the students will, in fact, not think. I've a student who came in and used the plot program to plot the same data using three or four different things. He used linear fitting, he used square function, he used third degree function, he even used the exponential on the same graph paper. He asked me "Which one you want? I got all these plotted." I said which one I want is which one you think is the appropriate one for the experiment you did.

The example of the student over reliance on the computer above was not the only one. Similar incidents to this happenned during my research. This underscores the faculty concern that there must be a balance between using the computer in the laboratory to collect and analyze data, and students doing both the data acquisition and analysis themselves. The faculty member suggested that in order to make students' experience in the laboratory meaningful, the students must have both experiences, using the computer to execute the experiments and doing the experiments manually.

The faculty members at this community college interviewed did not agree to use computers for delivering instruction, like for drill and practice, and tutorial. One of them related his disagreement, "I have a negative feeling about using computers for instruction such as drill and practice. I would be very reluctant to use computers in place of instructors." This and similar remarks were found througout my research at this community college, although one of the faculty members felt that drill and practice programs could be useful for some students, especially with good physics programs. Furthermore he added, "A computer is not going to substitute for thinking, is not going to substitute for initiative, but we try to teach our students how to think, how to do problem solving, how to study. That sometimes might be helped with computers, but not always." Most of the faculty members agreed to this remark.

The faculty members at the college interviewed liked to use microcomputers for instructional purposes. They used microcomputers for data collection in the laboratory and the mainframe computer for data analysis. One of the faculty members at Beta Community College told me, "I want to have more Apple IIe's, although there were some 'elements' in the college promoting the mainframe computer for instruction."

The remark made above showed the desire of the faculty member to have more microcomputers though there were others in the community college pushing the mainframe computer for instructional purposes. This feeling was shared by other physics faculty members. One of them, however, was cautious in her statement regarding the use of microcomputers for instruction, "We can do a lot of things with the Apple IIe but we did not have enough software to go around for all students. We cannot make copies of the software because of the laws and to write our own programs is difficult and takes a lot of our time." The concerns of the faculty member were genuine because the faculty members could not make copies of the programs. Also, they could not use one copy of the programs to boot all of the microcomputers. These were all restrictions stated in copyright laws. Unless, the faculty members had the money to buy more copies of the programs, they could not use most of the programs for the Apple IIe. The only programs that they used were those that they used only one copy at a time such as the one for the projectile motion experiment and also programs for demonstrating phenomena to the whole class during lectures. To write their own programs was difficult and took a lot of time as mentioned by the faculty member.

The physics faculty members at this college were more interested in their teaching and did not do much in the research of physics teaching. As expected, the faculty members did not do any research in physics areas, such as nuclear theory and condensed matter physics. They attended all the state level professional organization meetings that were heavily involved in matters pertaining to physics teaching such as MAPT and MSTA.

One of the faculty members related this to me, "We are basically a teaching institution. I have 18 hours of class time and that does not include office hours and preparation time. I think it is an excellent place to do research on teaching." This is further supported by the chairman of the department who said that the department was heavily involved in teaching. The faculty also pointed out that the college was an excellent place to do research on teaching. However, there did not seem to be much research in teaching going on in physics except for trying out new methods in teaching like instructional computing. The chairman also viewed this as true but he added that there was very little research of any kind undertaken by the faculty members.

This new approach to teaching physics would be shared with other physics educators in the state by giving talks at the state association of physics teachers or the state science teachers association meetings. One of the faculty members told me that he presented a paper on the use of computers in the classroom at the state science teachers association meeting which was held at the college. All three physics faculty members from the college were at the meeting. In other professional meetings organized by MAPT, at least one of the faculty members attended.

Sigma University

At Sigma University, the three physics faculty members interviewed agreed to the use of computers in the introductory physics laboratory. They felt that computers should not be used like a tutor, that is for tutorial purposes. This was best described by one of them, "I don't think computers could do a good job in teaching. But they should be used in the laboratory." This reflects his opposition towards using computers to deliver instructions such as in tutorial programs. On the other hand, he believed that computers are essential for students doing experiments in the laboratory. This was further supported by another faculty member's remark, "I will not use computers in my lectures because I am not sure what to do with them. Also, I found that computers are not used in lectures because of tradition. Here, we use computers in the laboratory."

However, one of them made an interesting statement when I asked him if the computers were used in the laboratory:

> We are using the computer in labs but I feel that's not good for students because they did not understand the process itself by letting the computer do everything for them. The computers for example gather data, analyze the

> data, and print out the graph. So, students were not fully engaged in the experiment.

The faculty member's remark suggested his disagreement towards the use of computers in the laboratory.

The other faculty member in the department provided an interesting insight of the use of computers for instruction:

> I think it is imperative to use computers in teaching because in industry computers are used on a daily basis. Most of our students are going to be engineers or even if they are going into medical field, they are going to be using computers and so I feel very strongly we need to introduce them to computers. We need to get them familiarized, so that they will be ready for them when they start their jobs.

The faculty member justification of the use of computers for instruction was well taken. In fact, all of the faculty members agreed to this statement.

The physics faculty members interviewed at this university preferred to use microcomputers rather than the mainframe computer in teaching introductory physics courses.

The faculty members at Sigma University were not positive about the use of the mainframe computer for teaching introductory physics. Two of them told me that they had problems using the mainframe a few years ago such as not being able to use the mainframe freely because it was managed by the computer science department. Also, they said that students had to go to the terminals which were not in the physics laboratory and this consumed the laboratory time. To sum it up, the physics faculty members found it was not convenient to utilize the mainframe computers in their teaching.

At Sigma University, the faculty members were active in physics research in areas such as atomic and nuclear physics. The untenured faculty members were especially less active in improvement of teaching such as using computers for instruction, perhaps because they were busy doing their research in physics areas. At least one of the senior faculty members devoted most of his time in trying new methods in teaching.

The chairman of the department who received the Outstanding Scholar Award from the university for his excellent physics research related this to me, "I think our department is quite active in research. We received grants from (NSF) National Science Foundation and DOE (Department of Energy) for our research." This seems to suggest that the faculty members in general were active in physics research. The chairman was active in the area of accelerator atomic physics and received a grant from DOE. He also commented that the untenured faculty members were active in their physics research and were able to get grants from outside and added that they were so busy with their research that they had little time to develop innovations in teaching. The chairman later told me that the former chairman who came to work for the department earlier than he, was responssible for introducing the use of computers in the laboratory. The former chairman also won the Best Teaching Award from the university for that year. This is a good indication of his commitment towards innovativeness in teaching physics.

Theta University

At Theta University the three faculty members I interviewed felt that computers were essential in the introductory physics laboratory to do data analysis, but not acquisition of data. One of them related to me, "My students are using computers in the laboratory to analyze data they have collected. They don't use computers to collect the data because I think they will miss a lot in doing so. Thus, they will not benefit from it."

None of the faculty member felt computers could be used to replace lectures. This is best described by one of the faculty member's remark when I asked him about the traditional CAI:

> I don't think CAI has been proved to work so far. Also, CAI kind of slow in its use elsewhere. We dont use it here. In addition, there are no good programs available because it's difficult to write. Programs like PLATO at Illinois are expensive and it's not successful, so I'm skeptical of CAI.

The faculty member's comment above reflected his negative perception of using computers as a tutor or for drill and practice which he referred to as CAI. It is also interesting to note that he felt that there were no good programs for CAI. Perhaps, he would have used CAI if there were good quality programs available at a reasonable price.

I found that the three faculty members I talked to believed microcomputers would be a better choice for instructional purposes in the introductory physics courses. One of them, for example, related his opinion of microcomputers for instruction as essential, especially with the low prices of microcomputers, and students need to be familiar with the microcomputers before they graduate and start working in industries.

At Theta University, the faculty members were very active in physics research in areas such as elementary particles and condensed matter physics. The faculty seemed to devote most of their time to research, which left little time for teaching physics.

One of the faculty members who was the coordinator of the introductory physics laboratory related this to me, "I view myself as a physicist. I mean I spend more than half of my time on research. If I had a choice of what to do, I probably wouldn't be teaching this much. I would do more research than teaching if I had a choice." According to him the preceding statement reflects the attitude most of the faculty members in the department. This was supported by two other faculty members in the department who also perceived research as being more important than teaching.

It is interesting to know that the coordinator was assigned by the department to manage and organize the introductory physics laboratory where he introduced the use of computers for analyzing data. However, the other faculty members told me that the lab coordinator was very active in elementary particles research, which the coordinator also had told me.

<u>Summary</u>

Faculty members from the physics department at Alpha University were not positive about the use of computers as a tutor in teaching introductory physics courses. All of the faculty members that were interviewed thought that computers would not improve students' learning of physics if they were used just like a tutor to deliver instruction. Most of them, however, felt that computers were essential tools in the laboratory for students to carry out experiments. Some of them felt that they as physicists were still grappling with the question of how to teach physics effectively. Thus, the issue of using computers in teaching physics was not their main concern.

A few of the faculty members were concerned that to add computer skills or literacy in the introductory physics courses would overload the courses with too much material to cover. They preferred to have a different course by itself which would teach students computer skills essential for physicists.

The physics faculty members at Alpha University generally liked to use microcomputers instead of mainframe computers for instructional purposes. They felt that microcomputers were useful, especially in the labs. However, the two faculty members who were developing programs for use in the physics labs felt that it took a lot of time and it was difficult to develop programs for use on the microcomputers in the labs.

Almost all the physics faculty members interviewed at Alpha University perceived themselves as physicists rather than physics educators. In other words, they perceived themselves as actively involved in physics research in areas such as nuclear physics, and solid state but not in finding new ways to improve teaching and learning of physics.

At Beta Community College, the physics faculty members thought that the use of computers for instruction in the laboratory was desirable. On the other hand, they did not like the idea of using computers to deliver instruction, like for tutorial, and drill and practice.

The physics faculty members at this college preferred to use microcomputers instead of mainframe computers for instructional purposes. The community college however, seemed to be pushing mainframe computers for use in teaching. Also, with microcomputers, faculty members felt that they had to follow copyright laws in the use of software.

The physics faculty members at the community college devoted most of their time to teaching, including development of new approaches to teaching which would be shared with colleagues during professional organizations' meetings. There was no research in physics areas at this college.

At Sigma University, physics faculty members also felt that computers ought to be used in the introductory physics laboratory. They rejected the notion of using computers as tutors.

The physics faculty members at this university were supportive in using microcomputers rather than mainframe computers for teaching introductory physics courses. They found that using mainframe computers for instruction was problematic compared to microcomputers.

The physics faculty members perceived themselves as active in research, and this was especially true with the untenured faculty members. However, one of the senior faculty members devoted most of his time to finding new ways to improve physics teaching.

At Theta University, the physics faculty members thought that computers were necessary in the introductory physics laboratory to do analysis of data, but not for acquisition of data. The faculty members were negative about the use of computers as tutors.

The faculty members perceived microcomputers would work better than mainframe computers for instructional purposes at the introductory physics courses.

Faculty members at Theta University perceived themselves more as physicists than as physics educators. They were active in physics research and teaching was of secondary concern.

The findings are also summarized in Table 4. This table provides brief account of the findings.

Table 4:

Summary of Data on Faculty Members' Perceptions About Instructional Computing

Sub-Issue	Alpha University	Beta Community College	Sigma University	Theta University
Faculty Members' Notions of Instructional Computing	Labs not Tutor	Labs not Tutor	Labs not Tutor	Labs not Tutor
Faculty Members' Attitudes of Mainframe vs. Micro	Micro	Micro	Micro	Micro
Perceived Roles or Duties by Faculty	Researcher	Teacher	Researcher	Researcher

POLICIES PERTAINING TO INSTRUCTIONAL COMPUTING AND CRITERIA FOR FACULTY PROMOTION

Introduction

This section focuses on the policies of instructional computing and criteria used in promoting faculty members at the four institutions. This includes findings or data on policies of the institutions and departments towards instructional computing that promote or hinder instructional computing; and data on the promotion practices of faculty members at these four institutions that may effect the current practice of instructional computing. Both of these will help to anwser questions 4 and 4a of the final research questions.

The data presented in this section were collected mainly from interviews of four administrators at Alpha University and faculty members at the Physics Department. The four administrators interviewed were the provost, the dean of Science, an officer at the Academic Computing Office, and the chairman of the Physics Department. At the other three institutions, most of the interviews were with the faculty members and the heads of departments. Data was also collected through observations and document analysis. Data from Alpha University are presented first, with Beta Community College, Sigma University, and Theta University following.

Alpha University

The provost of Alpha University stated this to the researcher which was pertinent to the university policy on instructional computing:

> The policy of the university is to have a ratio of one microcomputer for 40 students. Now, we have about 600 (microcomputer) so we need about 1,000. Most of the computers are not used for classroom instruction. Students Students use them mainly as a glorified typewriter or glorified calculator.

Significantly, he was the provost at the university, and he seemed to indicate the only policy the university had on computers was to have at least one microcomputer for every 40 students. Obviously, this was not a policy requiring students to be computer literate before they graduate from the university. Importantly, this is not a policy requiring, or even encouraging faculty members to use computers in their teaching.

Another administrator of the university who was the dean of science, felt the limited amount of money available made it impossible for the university to have a policy on instructional computing. He noted:

> There is no campus-wide policy of instructional computing here .... It costs a lot of money to have a policy of that nature. For example, if you want to have all biology students to have computer skills before they graduate, easily it requires $300,000 to buy hardware, software, proper room with air-conditioning, a new faculty, teaching

> assistants, and rooms for them .... We have other priorities at this university, so if we used that amount of money for computers there will be less money for other areas.

One of the administrators, the campus academic computing officer, felt that each individual department should determine its policy on instructional computing. During an interview with him, the researcher posed a question on policy of instructional computing. His reply was, "Well, we want the department to determine that. For students who want to learn word-processing we have courses teaching that and for students who want to be computer literate, they should take CPS 100 and CPS 115."

One of the physics professors who was an advocate of instructional computing knew there was a policy in the Physics Department requiring all first year physics majors to enroll in a course in developing computational skills in solving physics problems in introductory classical mechanics. He related to the researcher the historical development of the course:

> That course was conceived a few years ago when the Chairman approached Dr. Hill and me, asking us to write a proposal to NSF requesting micros and money. This was sponsored by Apple, Atari and IBM. Since we had only one week to work on the proposal, we decided to ask for five Ataris for use in that course. We got the computers and $500, so I started recruiting students to enroll in the class which was not required at that time .... But in one term there were only three students enrolled, this could be because I did not recruit students for that term. So,

> I told Dr. White that this shouldn't happen and it would be better to stop the course or make it compulsory for all physics majors. They did the following year requiring all physics majors to enroll at the end of their freshman year.

This course is a two-hour per week laboratory for the whole term. Students in this course were introduced to the application of microcomputers in solving classical mechanics problems and also constructing devices to be interfaced to the microcomputer for data collection and also analysis. In other courses, instructional computing was used, but there was no policy on it. For the other courses, the instructor would decide if he would like to use computers in his class. The chairman of the department expressed the departmental attitude when he said, "The faculty in the department are not required to use computers in their teaching. But, it is o.k. if they want to use it in their teaching."

This does not seem to be an encouraging tone for faculty members to use computers in their teaching. The chairman did not encourage the faculty members to use computers in their teaching. So, for faculty members who like to intergrate computers in their teaching, they can go ahead, but probably will not get full support from the chairman. Moreover, with previously expressed views on utilizing resources for computers, a practice emerges that is not strongly conducive to using computers for teaching at this university.

The chairman of the department made this statement concerning the promotion of faculty members in the department which could suggest why instructional computing was not widely used in introductory physics courses, "The faculty is promoted based on their research, teaching, and service. Research is weighted more than teaching and service when we consider a faculty for promotion. This is written in the by-laws of the department."

The chairman's remark suggested that the faculty members would more likely be promoted if they were active in their research. So, for non-tenured faculty members to be tenured, they must show their capability to be good researchers first, besides being able to teach and give public service. One faculty member made this remark:

> I think the faculty is valuable to the department by becoming valuable in his profession, in his research profession, because then he can move. When he can move, the university has to do something to keep him here, to show he is valuable. If he does innovation in teaching, the fact is only a value to the local college or university, but not to others. They are not going to be hired by other universities for that so the university does not have to pay attention to him. But if he does some new research in a discipline, other universities might hire him away. Whether he moves or stays, he wins because to keep him here, they have to give him pay raise and so on.

This preceding remark suggested that the faculty members would be likely rewarded if they were active in research rather than innovative in their teaching. There is no doubt that being an outstanding researcher, the faculty member can bargain or negotiate for better pay, and also a better working environment. There was one faculty member in the department who was excellent in his research and was about to leave the department to join another university which offered him better pay and a better research facility. The department and the university bought him a VAX minicomputer to keep him and this amounted to a huge sum of money. But there were no cases where faculty members who were innovative in their teaching had job offers forcing the department to give incentives to keep them. It appears the opposite, because one of the faculty who was an advocate of instructional computing found that being innovative in teaching, the department did not provide incentives to keep him in the department. The department, however, gave some released time for him to develop the software and course materials but this seemed minimal compared to what the outstanding researcher received.

The provost of the university had this to say on this point, "I do believe that research and scholarship are ultimately what determines excellence of faculty at this campus. You know, you're not a scholar, you're not engaged in keeping up with your field and finding out new things....So, the research scholarly dimension is crucial." This strongly showed that the university in general viewed research as a very important aspect of faculty life. Perhaps, it appears that the provost regarded research as important in the promotion of the faculty members. However, the provost later said:

> I think we should reward outstanding ability in any area but at the same time encouraging people in general to have a balance in research, teaching, and service. So, outstanding research should be rewarded, outstanding teaching should be rewarded and outstanding public service should be rewarded.

This statement suggested his willingness to view research, teaching, and service as important to the university. Thus, the Provost felt that the university should reward all faculty members who were excellent in any area, but most faculty members in the Physics Department did not agree that was happenning at that time. Also, as indicated earlier, the chairman felt the faculty members would be promoted or rewarded if they were active in research.

It is pertinent that the department had a world class research facility in nuclear physics which was mostly funded by the federal government. The department research expenditures for the year 1985-86 amounted to more than 10.5 million dollars (see Table 5). This is an indication that the department was very active in research and perhaps suggested the department would reward the faculty members who were active in research. Undoubtedly, the faculty members were more attracted to do research for their professional development because of research support

Table 5:

Research Expenditure in Physics at the Four Institutions for 1985-86

Name of Institution	Research Expenditure in $	No. of Faculty Members	Research $/Faculty Member
Alpha University	10.5 million	69	152,174
Beta Community College	*	4	*
Sigma University	0.25 million	12	20,833
Theta University	7 million	64	109,375

* No Research Expenditure

available and other incentives that were provided through pay raise, promotion, and prestige.

The discussion that follows provide a description of what happened at Alpha University when the Physics Department made an attempt to get funds from the university to buy 20 IBM PCs and it was not accepted. Since this incident only happenned at Alpha University but not at other settings, there will be no discussion of this for the other three settings. Also, I find this is important for me to describe in this research because it will shed some light on the problems faculty members faced in implementing instructional computing.

At the Physics Department of Alpha University, there were 10 Commodore 64 microcomputers available for the introductory physics laboratory, and one IBM PC used for demonstration in lectures. A proposal to buy 20 IBM PC's to be placed in a room was not accepted by the Office of Academic Computing. A few of the faculty suggested the university administrators hand-picked the respective departments to receive microcomputers. Furthermore, there seemed to be lack of interest by the chairman to provide a third of the total cost of buying the IBM PC microcomputers. Perhaps, one reason that the chairman had for not providing funds to buy IBM PC's for the Physics Department was that the money was needed for research equipment and thus not available for instructional equipment due to departmental priorities.

I was surprised the only type of microcomputer available in the laboratory was the Commodore 64 which was not very useful for the students because it was already being phased out by other institutions. In short, the Commodore 64 was obsolete. Students had to learn an obsolete operating system that used cumbersome commands. Furthermore, there were not many software programs available in the market for the Commodore 64 that could be used for physics courses. One day, I asked the instructor why they were using these microcomputers, but not the new ones like the IBM PC or the Apple MacIntosh. His reply to my question was interesting, "I had asked and written a proposal to acquire a room full of IBM PC's last year, but it was declined. Instead, they gave them to Natural Science, ATL and Resident College."

Later, I met the instructor again. This time I asked him to tell me why the Physics Department was not given the IBM PC's. His reply was:

> There must be politics involved, I think. Anyway our department did not match one-third of the total amount of the expenditure to buy the micros. This year, the chairman is willing to give money for that because there seems to be money available. Last year, the chairman believed the department was underfunded.

Then, I interjected that the Office of Academic Computing wanted the department to be committed. Obviously, if the department was not willing to provide money to buy the microcomputer, there was a strong indication that the department had not shown its commitment to the proposal of acquiring IBM PC's. Dr. Kay absolutely agreed to that. He however, raised another factor that could explain the difficulty of the department to get financial support in buying the IBM PC:

> For some reason, which I am not quite sure, they want to buy some computers for the Resident College. They wanted to do it so badly that they had urged those people at the college to put a proposal in. The Provost wants to give them computers, they probably didn't have to ask for it. He made them give the proposal in, so he gave what he wanted to give. So, here the proposal sort of came after the decision and most of it happenned like that. Mathematics got theirs, the same way, from the top down.

There is a perception of favoritism in terms of allocation of funds to buy microcomputers. This is obvious as suggested by Dr. Kay. According to faculty perceptions, the provost had determined departments that would receive funding to buy microcomputers. It was perceived that was not done systematically and fairly because the decision was made before proposals were received from all other departments requesting financial support to buy microcomputers.

Another faculty member in the department Dr. Jay, had a strong reaction and also a suggestion for the decision being made by the Academic Computing Office and the provost.

His reaction and suggestion was:

> I think the people at the Office of Academic Computing should have given us a couple of PC's and when the faculty started using them, give them a couple more. That's what they could have done, but they gave us nothing. On the other hand, one of the reasons the department was not funded was because the department proposed not to put any money on it, of its own. Other departments proposed to put some of their money in it. The Physics Department proposed not to.

I further asked Dr. Jay whether the provost's comment was true that the proposal by the Department of Physics was not good enough as compared to ATL. According to the provost, "Most of the proposal being made was to use computers like a glorified calculator or glorified typewriter. But ATL had a better proposal than just using the computer for word processing." Dr. Jay immediately rejected that as a good justification. He further said that:

> The Provost can view it that way but the faculty can view it as the administration not being receptive to proposal. We used to have an Educational Development Program which received the proposals and helped to evaluate them and try to make sure that something got done about that and that was abolished. It was closed down about six years ago. I'm not claiming that they were terribly effective. What I'm saying, for a major university do not have any place that advocates educational development is very strange. Of course you can submit your proposal to the provost if you put through the Department's chairman and your dean and so on. But the way the Educational Development Program Office works is not you put through those but you submit it directly

> to the office. So, it's evaluated on its own merit not whether the chairman and the dean favoured it. I mean suppose what you're doing is for the benifit of the university not for your department, then your chairman will be against it because it doesn't help further the objectives of the department. That's why you need such an office.

Dr. Jay suggested that the Educational Development Program should not have been abolished since it encouraged innovation and promoted instructional development efficiently. It seems Dr. Jay suggested that the chairman was not quite favourable towards buying the IBM PC's, because the chairman did not want to put some money into buying the microcomputers. Without the Office of Educational Development Program, faculty members were having problems developing a new mode of instruction that required some money.

There seemed to be an unequal treatment in the allocation of funds for buying microcomputers, according to the faculty members. The university administrators (the provost and head of the Academic Computing Office) made the decision of the allocation of funds without much consultation with others in the university. Most of the funds given to departments at the university were selected by the university administrators and were not necesarrily based on proposals forwarded by various departments.

The administrators had determined to give fund to certain departments before the departments had put in proposals. This caused an unhappy situation with some physics faculty members because they perceived that their request for funds to buy microcomputers was not accepted by the university administrator. The administrators, however, perceived that the Physics Department did not really want the microcomputers because the department was reluctant to give some money to buy the microcomputers. According to faculty members, this would not happen if the Office of Educational Program Development were still around because it would support innovations in instruction. Faculty members in all departments would be given a fair chance to have their proposals reviewed by the Office of Educational Program Development.

As pointed out earlier, the administrators felt that they had better ways of implementing instructional computing by giving computers to departments that used them more than just a "super-calculator." Nevertheless, the Physics Department could not use more up-to-date computers in their teaching and this might have discouraged some faculty members from using computers in their teaching.

Beta Community College

The chairman of the department related his policy in instructional computing:

> Here in the department, there's encouragement for using computers in teaching. Whenever the faculty in the department determine that some instructional computing would be advisable, we encourage it. So, there's encouragement for it and yet there's no requirement in

> instructional computing in all courses here. There's a policy to encourage it whenever it is appropriate. That's my policy.

While the policy was not a formal one, the faculty members had a choice whether or not to intergrate computers in their teaching. The faculty members also felt the same regarding this. One of the faculty members told me:

> There's no policy requiring us to use computers for instruction in our physics class. The Chairman encourages us to use computers for instruction whenever we feel it is necessarry. We can intergrate computers in our teaching whenever we want to. But to do that we need money to buy hardware and software. When it comes to money it is a difficult thing to talk about because the department doesn't have money to buy all that. Surely, it's easy to say we encourage you guys to use computers but what support do we get.

The faculty members fully understood the informal policy of instructional computing in the department. They seemed to suggest that the department could not do much to support instructional computing because the department did not have the money to buy the need hardware and software. To get financial support for instructional computing, the chairman had to ask the college.

At Beta Community College where teaching was the main mission of the college, the physics faculty members were rewarded primarily for their teaching. It seemed that faculty members would be rewarded for their research in teaching physics, but not for research in physics.

After I asked the chairman of the department the criteria for promoting faculty members. His reply was, "Teaching is the only criteria considered for promotion. The dean receives faculty members' teaching evaluation scores from students and chairman of departments. Based on this, faculty are promoted."

Later, I asked the chairman if a faculty member who used computers for instruction was given a special consideration in promotion. His response was that not only would instructional computing be regarded as a plus in the faculty members promotion, but other innovations in teaching would be considered as well. This suggests that the faculty members would be rewarded for their innovative efforts in teaching. I found this was true when I found that two of the physics faculty members who were innovative in the use of computers for instruction left the department a couple of years ago. They were promoted to take a responsible position related to computer use in the college. One of them was promoted to be the coordinator of computer assisted instruction for the School of Arts and Science and the other was promoted to become the system manager of the college's mainframe computer. This however, suggests that the college was not supportive towards instructional computing in physics courses and one of the faculty members related this:

> I hate to say that we're getting away from instructional computing. We're using it less and less. Because for years, there were two people in physics who were very knowledgable with the computer and now there aren't. They both had left, one of them is the CAI coordinator and the other became system manager for the VAX. The people who really had the vision to use computers happened not to be here anymore.

This is an interesting comment because the faculty were telling me this was the reason there was limited use of computers for instruction in physics at the college. Without the competent faculty members in instructional computing, it is probable to expect that both development and use of instructional computing would fall off.

The chairman of the department and faculty members also told me that physics research would not be counted for promotion, but research in physics teaching would be considered for promotion. However, there was no on-going research in the teaching of physics during my study and only a small effort in development of new physics teaching methods.

<u>Sigma University</u>

The chairman related to me the policy of instructional computing of the Physics Department during the early stage of my research:

> We don't have a policy on instructional computing at this department. So, we don't require our faculty to use computers in their teaching. That's our policy now. But, we do

> want our faculty to use computers in their teaching. We like to promote the use of computers in the introductory physics courses.

The department or at least the chairman of the department felt there was no policy on instructional computing. Thus, the faculty members were not required to use computers in their teaching of introductory physics courses. This can be regarded as the informal policy or unwritten policy. Not surprisingly, the chairman liked the faculty members to use computers in their teaching and also supported this cause. To me he proved his support for this cause by providing financial support from the department's equipment fund to buy 11 Apple IIe's three years ago for use in the introductory physics courses. This was a big sum of money for him to allocate for buying the Apple IIe computers. Perhaps, this showed that the department was committed to instructional computing although there was no policy on instructional computing.

At Sigma University, faculty members in the Physics Department were promoted based primarily on their research in physics, and this was especially true for promotion from associate professor to full professor positions. However, faculty members were also expected to be competent teachers and provide service to the public in order to be promoted.

The chairman of the department had this to say pertinent to promotion of faculty members in the department:

> The criteria for promotion is pretty much spelled out in the faculty union contract of the university. There are three aspects, professional competence which deals primarily with teaching, professional recognition, I guess it's called, deals with research and service which deals with community work within the department or the college or the university, and also service to the profession through national committees or state committees in professional organizations.

The chairman further added the criteria used by the department which were somewhat the same as written in the faculty members' contracts:

> The basis of promotion such as from assistant professor to associate professor is excellent contribution or outstanding contribution in one of the three areas (teaching, research and service) with substantial contribution in the others. So, in fact, promotion could be primarily based on teaching or primarily based on service or primarily based on research. Although competent teaching would be a requirement under any circumstances, circumstances sort of average or at least average or better. But for promotion to full professor, I think the department has a hole and I personally required significant research contribution in addition to high level in other categories. A good teacher who has outstanding research and good service would be recommended for example. I am speaking as the chair of the deapartment, but I think that's also the sentiment of the rest of the faculty in the department.

It seemed that the department here regarded teaching as an important aspect in promoting a faculty member. The chairman appeared to believe that the faculty members must be at least average in their teaching in order to be promoted. However, faculty members also needed to be competent researchers and to provide service to be promoted. One could speculate that the emphasis on teaching as an important criteria for promotion appeared to be true, because the departmental research budget amounted to only a quarter million dollars for 1985-86 which was much less than Alpha University and Theta University (see Table 5). Thus, the department was not an excellent place for physics research based on the amount of money it spent on research. For promotion to full professor, the Chairman felt that the faculty members must be outstanding in their research, and in addition, they must be a competent teacher and provide service. Other faculty members agreed with the Chairman's notion of promotion.

Theta University

One of the faculty members told me his perception of the department's policy on instructional computing:

> In this department, we can use computers in our teaching but we are not asked by the department. I know that the chairman likes us to include the use of computers in our teaching, but we don't get financial support to start with. So, we have to get funds from the university or outside. That's not easy to get.

Notice that the faculty member knew there was no policy requiring the faculty members to use computers in their teaching of introductory physics courses. The faculty members were encouraged by the chairman to use computers in the introductory physics courses. This was further found to be valid after talking with other staff members in the department. The faculty member, however, felt that it was not an easy task to use computers in his teaching because he would not get financial support from the department to buy hardware and software.

At Theta University, the faculty members in the Physics Department were promoted primarily based on their research productivity. The faculty members were also expected to be able to teach and conduct service to the public in order to be promoted. But, the main criteria used to promote a faculty member in this department seemed to be research.

One of the senior faculty members in the department said this:

> At least at this university and I'm sure at Alpha University of the way you're promoted to achieve tenure is by doing research. Though, teaching and service are also considered when you are reviewed for tenureship. But, research is what counts most. This is also true for promotion to full professor and pay raise.

The faculty member's remark suggested that the faculty members at the department were promoted or rewarded predominantly based on their productivity in research. In addition, his remark also suggested that teaching and service were also important criteria used to reward faculty members in the department. The research expenditures of the department for the year 1985-86 amounted to a grand total of more than seven million dollars (see Table 5). This is an indication that the department placed great emphasis on research. One of the faculty members agreed to this by saying, "At this department there is emphasis on research. The departnment receives a lot of research grants from outside. Surely, I believe faculty is promoted based on mostly research. Teaching and service as well, I think are components also, but not as great as research." There is no doubt that research was a predominant factor used by the department to promote a faculty member in the department. The other factors that were considered minimally in promoting the faculty members were teaching and service.

<u>Summary</u>

All three administrators interviewed at Alpha University suggested there was no campus-wide instructional computing policy at this university, seemingly due to lack of funds to implement it. In the physics department, however, there was an introductory computer course that all first year physics majors were required to enroll in. This course prepared students to use computers as tools in solving physics problems, especially in doing experiments in the laboratory.

At Alpha University, faculty members in the Physics Department, which was highly regarded in its research, were promoted primarily based on their research in physics areas. Teaching and service by the faculty members carried somewhat less weight in the reward system of the department. Faculty members tended to think that being innovative in teaching such as using instructional computing would conflict with their main duties as researchers and would be minimally rewarded.

An attempt or proposal by a faculty member to acquire 20 IBM PC's with funds from Alpha University was turned down. Apparently, the university had already decided to give the microcomputers to other departments and the Physics Department was not ready or enthusiatic to have it, according an officer at the Academic Computing Office.

At Beta Community College, there was no policy in the Science Department requiring the physics faculty to intergrate computers in their teaching. Also there was no policy in the department requiring physics students to be computer literate. However, seemingly there was a policy encouraging the faculty members to use computers in their teaching.

The faculty members in physics at the community college were primarily rewarded for their excellence in teaching. This includes faculty members' development of new teaching methods such as using computers in their teaching.

The unwritten policy of instructional computing at Sigma University was not to require its physics faculty to use computers in their teaching of introductory physics courses. Nevertheless, the faculty members were encouraged by the chairman of the department to use computers in their teaching of introductory physics. The Physics Department was supportive in instructional computing by allocating money to buy 11 Apple IIe's for use in introductory physics labs.

Faculty members at Sigma University were promoted based on their research, teaching, and public service. For promotion to associate professor, faculty members needed to be excellent in one area with average performance in the other two areas. For full professor positions, however, faculty members had to show they were competent researchers in physics first, with average performance in teaching and public service.

Finally, the policy of instructional computing at Theta University was also similar to the others. There was no policy requiring the physics faculty members at this university to use computers for instruction in the introductory physics courses. Perhaps, because there was no allocation from the university and the department to implement this. The faculty members, however, were encouraged by the physics department to use computers in their teaching of introductory physics courses.

Faculty members at Theta University were promoted primarily based on their research excellence. In addition, faculty members were also expected to be able to teach and provide public service before they were promoted.

Table 6 provides a summary of data discussed in this section. This table will help readers to get a quick and brief idea of the data discussed in this section.

Table 6:

Summary of Policy Data

Sub-Issue	Alpha University	Beta Community College	Sigma University	Theta University
Policy to Use Computers in Introductory Physics	Yes	No	No	No
Main Criteria For Promotion	Research	Teaching	Research and Teaching	Research

STUDENTS' PERCEPTIONS OF INSTRUCTIONAL COMPUTING

Introduction

This section provides findings on students' attitudes or perceptions towards instructional computing in introductory physics courses at the four institutions. This includes data pertaining to students' receptiveness or lack of receptiveness in instructional computing in the courses. This data will help to provide part of the answer on why instructional computing was not widely used at the four institutions. Specifically, this will help to answer question 5 of the final research questions provided in Chapter I.

The data presented in this section were based on interviews and casual talks with students enrolled in introductory physics courses that utilized computers for instruction. First, data from Alpha University are presented, followed by Beta Community College, Sigma University, and Theta University.

Alpha University

I found that seven students that were interviewed at Alpha University were positive about using computers in the physics labs. As one of them said, "I did my least square fit at least five times using the program the instructor gave which would be difficult if not impossible if I were to do it manually." The student's remark showed that the computer allowed him to do the experiment faster, because the software available helped him in analyzing the data faster than if he were to do it manually.

In contrast, three of the students thought that the computer made them rely too much on it, and consequently they did not understand the physics concepts involved in the experiment. They felt computers helped them in learning how to use the program, but not physics concepts involved in the experiment. These three students indicated that the computer had isolated the data analysis from them. All three students were having a difficult time understanding the program which was written in BASIC, and students needed to understand the program before they could do the data analysis or else they could not understand what they were doing. One of them commented, "We should do our own program so that we understand it better; so, we can use different languages as we wish, like FORTRAN and PASCAL."

The student made an important point. However, he did not question the amount of time needed for students to write their own programs for this course since there was a lot of material to be covered in this one credit course as viewed by the instructor. Instead, the same student felt positive toward the use of computers in the physics lab by saying, "It is necesassry in our everyday life, so it would be good to have them in the labs. I guess I will be more prepared to work with the computer knowledge." He was referring to computer knowledge as essential in contemporary physics and thus the use of computers in doing the experiment would enable students to be equipped with the computer skills. Another student also felt positive toward the use of computers in the lab, but he cautioned it by saying, "It must be used properly." Obviously, this student thought that the use of computers in the laboratory was not necessary beneficial if not used appropriately. Based on my observation in the laboratory, students seemed to enjoy using computers in the lab. Several of them even copied programs that were not required for them to run. A few students also told the researcher that they would like to see more use of computers in the physics laboratory. One of them related, "I enjoyed having computers in the physics laboratory and I would like to have more of it in the lab. I find it is beneficial for me to learn this."

Five of the seven students had their first experience with computers in high school. Two of them had their initial exposure to the computer when they were in middle school. Not surprisingly, their first experience with using computers was in learning BASIC language. At the university, all of them had at least taken a computer course in FORTRAN language, and most of them had difficulty with BASIC. This is best described by one of them, "It has been more than four years since I learned BASIC, it's a problem for me to write a program in BASIC now, but not FORTRAN. I just had a course in FORTRAN from Computer Science, so it is still fresh."

Those students who had difficulty with BASIC language had a negative opinion about the use of computers, though they liked the idea of using computers in the laboratory. They preferred to have the programs written in languages they had just learned at the university such as FORTRAN. Students felt that their knowledge of FORTRAN was much more than BASIC which they had learned a couple of years ago and most likely they had forgotten. Thus, they were more confident writing and using FORTRAN than BASIC language.

Beta Community College

At the community college, five students were interviewed to provide data for this section. One of them I interviewed at Beta Community College related her comment on the use of computers in the physics lab, "I like the use of computers in the lab, we can do the experiment efficiently. I wish we had more of this. I find it is useful for me." Another student also reacted positively when asked about the use of computers in the physics laboratory, "I think with the use of computers in the lab, it convinces us of that what we do is up to date. I find we need the knowledge of using computers in our jobs. So, this is a plus for us besides being able to learn physics, we also learn how to use computers." The preceding remark made by the student illustrated the general feeling of the students at this community college. Since many of the students were working either part-time or full-time in business or industry and at the community college while attending the college, they regarded the use of computers in the laboratory positively. As the student said, they could learn how to use computers which were essential for their jobs.

One student made an interesting comment of the usefulness of computers in the labs, "The computers help me to do the experiment, it helps to organize all the data and this helps to reduce the amount of work." He added, "In terms of learning, the computer somewhat helps me to understand, but it doesn't matter a lot. I think the computer interferes in my thinking and this certainly doesn't help me in my learning of physics."

The computer seems to get in the way of students' learning of physics. This is especially true if the computer was used to do everything in an experiment and left nothing for the students to do besides punching in keys on the keyboard. In this regard, computers act as barriers in the students' learning process of physics.

There were times when the computer did not work as expected and this frustrated the students who were using the computers. One of them related his frustration, "When the computer doesn't work it made me feel bad. More often the programs don't work and don't do as I have expected. It made me angry and at that time I wished I didn't have to use computers anymore." The student made this statement when he could not get the computer to print out a graph for the experiment he did. There were other instances when students felt similarly because they had some difficulties with the computer.

Sigma University

Five students at Sigma University were interviewed to find their attitudes about the use of computers in the physics laboratory. One of them related his perception on this, "I think the computer helps me to do the experiments faster. It cuts down the amount of work I have to do and it tremendously cuts down the amount of time to do the experiment." This statement was supported by many other students because they agreed that the presence of computers in the laboratory helped them to accomplish their tasks more efficiently. But there were times when the computer caused the students some problems. As one of them told me:

> I think computers can be a useful lab partner but sometimes they are not. I have experienced the computer did not do what it was supposed to do. It did not stop its timer for the simple harmonic motion experiment. I tried many times to stop the timer but I couldn't until I got hold of the instructor to stop it, and it took him a while to stop it.

This shows some of the problems students faced in the laboratory when they used computers. These problems had negative impacts on these students because instead of doing the experiment with more efficiency, the computer got in the way of doing the experiments.

A few of them were skeptical of the computers role in helping them to learn physics. This is best described by one student, "I don't know if it's helpful in my learning because the computer does almost everything, but it helps me to do the experiments much quicker." The student's remark seems to show his concern of computer effectiveness in helping him learn physics concepts and principles. He implied that the computer did not help him a lot in learning physics because the computer took most of his duties in doing the experiments. This was especially true if a program was being used that would do the data analysis and also graph the results nicely, and print the graph. This did not allow the students to be actively engaged in the experiment and thus inhibited students' learning of physics. But, he believed the computer helped him to do the experiments more efficiently.

Theta University

Five students I interviewed at Theta University believed that computers they used in the laboratory for data analysis were useful though they were not sure if this helped them learn physics. One of them related his perception, "In the experiment I just did, I find the computer helps me to do the data analysis much faster. Without it I am still doing the analysis with my calculator. The computer did the calculations so fast that I am not sure I really understand what's going on." Because the computer did the calculation so quickly and easily, the student was not involved in the experiment. The computer took part of the student's responsibility in doing the experiment. Thus, this could lead to the student missing part of the concepts involved in the experiment and leaving him with doubts about the experiment.

Another student made an interesting comment regarding the use of computers in the laboratory, "I know it is good for us to have some knowledge in using computers because computers are everywhere. Because of that I like the idea of using computers in the lab. But all we have here are some old Commodore Pet computers which are no longer used at other places." This student was positive towards using computers in the laboratory because he knew that computers were used in industry and government agencies. Thus, he found it essential for him to have some skills in using computers. He was, however, given the Commodore Pet computers to work with which most other institutions were not using because they were obsolete. Most students were not happy with these out-dated computers because the computers were less powerful and used commands that were cumbersome to learn.

Summary

All students interviewed at Alpha University agreed that computers should be used in acquiring and analyzing data in the experiments they conducted. The students interviewed viewed computers as tools that could help them in doing the experiments faster because the programs available for them helped them to analyze the data more efficiently. Thus, this allowed them to easily analyze the data more than once.

At Beta Community College students responded positively towards the use of computers in the laboratory, albeit they were a bit cautious of their effectiveness to help them learn physics.

At Sigma University students who were interviewed accepted the use of computers in the laboratory to collect and analyze data. They felt that the computer helped them to do the experiments, to acquire data and to analyze the data.

Students who were interviewed at Theta University felt that using computers in their laboratory for analysis of data was helpful. They, however, were not certain whether the use of computers in the lab helped them in their learning process.

In conclusion, students at all four settings agreed that computers helped them in some ways in doing the experiments in the laboratory. However, they felt using computers did not necessarily help them to learn or understand physics concepts involved in the experiments.

INTERPRETATION OF DATA

In this research, the utilization of instructional computing in introductory physics courses was studied systematically using ethnographic research methods. This study was guided by a theoretical framework discussed in Chapter II, and also by research questions provided in the first chapter. This section relates the findings of this research in light of the literature reviewed in Chapter II, including the theoretical framework. This section also provides answers to the research questions which were also used as guides for this research. Thus, the interpretation section first presents assertion based on data that were pertinent to the research questions. Next, the theoretical framework is used to interpret the data. To illuminate and support the assertions there will be some evidence discussed briefly and more extensive evidence will be referred to from the previous related pages or sections. In some instances where evidence was not discussed earlier, the evidence is provided together with the assertions. All of these interpretations are synthesized in one section referred as findings.

Questions and Assertions

Question 1: To what extent was instructional computing being used in the introductory physics courses at the four tertiary settings?

Assertion 1: Generally there was a very limited utilization of instructional computing in introductory physics courses at these four settings. All four institutions used computers in introductory physics laboratories for analayzing data. With the exception of Theta University, computers were also used to acquire data in introductory physics laboratories. At Alpha University, students wrote computer programs as part of their project in computer literacy for physicists' course. There was, however, some occasional usage of computers in lectures to demonstrate phenomena. Thus, computers were mainly used as a tool in introductory physics laboratories at all four institutions; but at one institution, Alpha University, they were used as a tutee (Taylor, 1980), to write programs in BASIC language.

According to Taylor (1980) there are three general categories of instructional computing. They are tutor, tool, and tutee. As tutor, the computer becomes the means of delivering instruction or becomes the medium of instruction. As tool, the computer is litterally a tool, used to plot graphs or acquire data in the laboratory. Lastly, the computer can also be used as tutee or becomes the object of instruction. In this research, the use of computers was mainly as tool. The evidence was provided in (p. 88-94, 97-99, 102-105). Most of its uses were in the laboratory to gather and analyze data, and only a few times was it used during lectures to show a phenomena.

Question 1a: Were there different levels of use at the four settings? If so, how did they differ?

Assertion 1a: In general, three of the four settings used computers mainly for data collection and analysis in the laboratory as described above. However, it appeared that Beta Community College used instructional computing more often than other settings included in this study. The students used it througout the term in the laboratory for gathering and analyzing data. But, at other settings students only used computers about two or three times in a term. At Alpha University and Sigma University they were used for both collecting and analyzing data in the laboratory, whereas at Theta University they were only used for data analysis.

This assertion agrees or is parallel with a report by the Office of Technology Assessment (1982) that said community colleges show the greatest ability to be innovative and adopt new methods to education as compared to other types of institutions of higher education. Because the students used computers more often at Beta Community College (see p. 99-100), this suggests that computer usage had been more thoroughly intergrated in the community college teaching of physics. Througout the winter term, students in one class at the community college used computers once a week in the laboratory for gathering and analyzing data. But at the three universities, students used the computer only about three times in one term in the introductory physics laboratory.

One possible reason for this may have been the emphasis of teaching at Beta Community College (see p. 134-135 and 158-160). But for the other three universities, there seemed to be less emphasis in teaching (see p. 127-130, 137-140). This is in agreement with Medsker and Tillery (1973) that community colleges generally expect the faculty members to occupy their time in teaching and counselling, and the faculty members are not required to conduct research.

Question 1b: What were the types of computers being used and how were they used at these four institutions? What were the problems related to the type of computers used?

Assertion 1b: All four institutions included in this study used microcomputers for instructional computing in their introductory physics courses. Beta Community College also used the mainframe computer as well as microcomputers in teaching physics. One common problem with the use of mainframe computers was the lack of control of the physics faculty members. Using microcomputers, on the other hand, the faculty members had to deal with the issue of copyright laws and faculty member and student accessibility to computers.

At all three universities, most faculty who used microcomputers for instruction did so predominantly in the laboratory (see p. 92-94, 98-99, and 102-104). At Alpha University, the faculty members used 10 Commodore 64 computers and locally developed programs in the introductory physics laboratory. The faculty members at Sigma University used 10 Apple IIe computers and commercially developed, user-friendly programs to gather and anlyze data in their introductory physics laboratory. The introductory physics laboratory at Theta University had 10 Commodore Pet computers and locally developed programs which were mainly used to analyze data. At Beta Community College, the faculty members used three Apple IIe computers to collect and analyze data in the laboratory. The faculty members also used a mainframe computer which was mainly used to analyze data using the spreadsheet program. Thus, most of the faculty members at these four settings used microcomputers for instruction instead of the mainframe computer.

One common problem faced by faculty members who used the mainframe computer was being unable to control the computer. The mainframe was normally being managed by the Computer Science Department and thus, the physics faculty members did not have direct control over it. For example at Beta Community College, one physics faculty member experienced a sudden change in the spreadsheet program without prior notification by the Computer Science Department (see p. 101 -102).

Faculty members who used microcomputers faced a problem involving Copyright Laws. At Alpha University and Theta University most programs used were written by faculty members. Thus, the faculty members did not have to worry about these laws. At Beta Community College, a few programs were written by faculty members. However, most of the faculty members found that it was time consuming to write their own programs and very few of them had all the skills required to write good instructional programs which is important to ensure that the use of computers really facilitates students in understanding physics concepts and principles. At Sigma University, the Department of Physics had an agreement with the software developers allowing the faculty members to make more than one copy for use on the Apple IIe in the laboratory (see p. 103-104). Undoubtedly, the faculty members at the other three settings needed to rationalize the pro's and con's of using commercially developed programs that are user-friendly, but are restricted to their use and locally developed programs that are not user friendly with no restrictions on their usage.

Question 2: How has the traditional notion of teaching physics in introductory physics courses changed as a result of instructional computing? Is instructional computing compatible with the traditional notion of teaching physics?

Assertion 2: Faculty members who used computers in the laboratory for data collection and analysis found themselves spending some of the lab time teaching students how to use the computers. This is not compatible with the traditional notion of teaching physics. Other than that, there seemed to be not much deviation from traditional notions of teaching physics. The faculty members adhered to the whole group delivery of instruction, teacher dominated conversation, and reliance on textbooks. This showed that the professors in this study adopted instructional computing so that it was compatible with traditional notions of teaching physics. Computers were used to fit within the larger traditional framework of instructional delivery within the physics departments at these four settings, as a supplement to lectures, and as a tool in the laboratory for data analysis and data collection. Thus, it is an evolution, not a revolution in the delivery of instruction using computers.

The faculty members who used computers for instruction in the introductory physics laboratory devoted some of the lab time in teaching students how to use computers (see p. 103-114). This particularly happened during the first time students needed to use the computer in the laboratory. Thus, this meant problems emerged because time was always limited in the lab, and therefore, the faculty members had to compromise with the time they needed to teach physics concepts involved in the experiments. The usage of computers in the lab brought in another aspect of instruction that the faculty needed to deal with. This required the faculty members to spend less time in some of the experiments or even reduced the number of experiments. Perhaps, one solution to this would be to require students to have a computer background before they enrolled in these courses. This would ease the time constraint physics professors have and allow them to maintain the number of experiments covered in the laboratory program.

There was little difference from the traditional notion of teaching physics at the four settings (see p. 103-116). The faculty members employed whole group delivery of instruction, instructor dominated instruction, and reliance on textbook materials. However, there were occasional slight variations from these routines in the usage of computers for teaching physics. For example, a faculty member occasionally taught small groups, rather than the whole class, how to use the computers. Thus, instructional computing seemed to be adapted with the current practice of teaching the introductory physics lab. According to Rogers and Shoemaker (1971), the desirable characteristic of innovation includes the compatibility of the innovation with the practitioner's value and past experiences. This appeared to be true and perhaps looked like one important factor; instructional computing was utilized in the introductory physics labs.

<u>Question 3</u>: What were the perspectives of physics faculty members regarding the teaching and learning of

physics and the place of instructional computing in introductory physics courses?

<u>Assertion 3</u>: The physics faculty members supported utilization of instructional computing provided it was used appropriately. Perhaps, the faculty members seemed interested in it, particularly, in the laboratory where they felt that the computer was an invaluable tool. This is especially true of its role to help analyze data collected in the experiments, and also to acquire data in the experiments. However, the faculty members did not agree to totally replace the faculty by delivering instruction in CAI or to tutor students (Taylor, 1980). There were a few faculty members who felt that there were more important issues than whether or not to use computers in physics teaching; issues pertinent to how to teach physics so that students understand it. If these isuues could not be resolved, these faculty felt that it was not important or useful to ponder on the use of computers in their teaching.

The faculty members at all four settings believed computers were invaluable tools in the introductory physics laboratory (see p. 122-140). Tinker (1981) supported this and added that using computers in physics labs allowed students to do the experiments with greater speed. This allowed the students to devote more time to understanding the concepts involved in the experiment (Hawkins, MacIntire, and Sutton, 1987). The faculty members however, felt computers were not useful for delivering instruction (see p.

122-140). Some of the faculty members believed that using computers might distract students' engagement in their learning activities and this would not promote learning of physics concepts and principles (see p. 122-140). This is supported by Arons (1984). Thus, the faculty members were not really positive of the usefulness and effectiveness of instructional computing in their teaching of introductory physics. This could be an important factor of the limited use of instructional computing at these settings. In their research Rogers and Shoemaker (1971) found that one of the desirable characteristics of an innovation was the perceived advantage of an innovation over what the individual is currently doing. This implies that the faculty members were only using a little of instructional computing because they did not perceive the advantage of it. This was especially true with the CAI type of application.

A few of the faculty members voiced their concerns were with broader issue which is still unresolved; to find how to effectively teach physics (see p. 123-124). They found students were having problems in understanding physics concepts even after instruction. Several researchers have found and concluded that students still hold to their naive conceptions on physics concepts after instruction (Champagne et al., 1980; Clement, 1982; Minstrell, 1984; Trowbridge and McDermott, 1981). The faculty members felt that until this issue is solved, then only they would think about other narrow issues such as the use of computers in their teaching. Thus, the ferment in the physics department regarding students' difficulty in learning physics seems to be an important factor in the limited use of instructional computing.

Question 3a: How did faculty members perceive their main role or duty as a faculty member in the Physics Department?

Assertion 3a: At the three universities, the faculty members perceived themselves more as physicists, whose bigger role was in research, than as physics educators. At Beta Community College, the faculty members recognized that their role was in teaching physics. In other words, they considered themselves to be physics educators rather than physicists.

At all three universities, the physics faculty members seemed to perceive themselves more as physics researchers than as physics instructors or teachers (see p. 127-130, and 137-140). Perhaps, this partly explains why there was low utilization of instructional computing in introductory physics courses at these universities. On the other hand, the physics faculty at Beta Community College perceived themselves as physics instructors (see p. 134-135). This could explain why there was more usage of instructional computing at the community college than at the three universities.

Question 4: What were the policies of instructional computing in the Physics Departments?

Assertion 4: All Physics Departments in this study, except Alpha University, did not require their faculty members to use computers in teaching introductory physics. At Alpha University, there was one course required during the freshman year for all physics majors, an introduction to the use of computers for physicists. Besides that course, the Physics Department at Alpha University did not require the faculty members to use computers for instruction in the introductory physics courses. At the other three institutions, the departments encouraged their faculty members to use instructional computing to teach introductory physics courses. The lack of a policy requiring faculty members to use computers at these three institutions may be attributable to an emphasis on research instead of teaching and a consequent lack of funds to support instructional uses of computers.

With the exception of Alpha University, there was no evidence that the departments included in this study required their faculty members to employ instructional computing in their introductory physics courses (see p. 147-148). Thus, faculty members could choose whether or not to use instructional computing in teaching introductory physics courses. At Alpha University there was one introductory physics course, namely Physics II, required for all first year physics majors. The course was intended to teach students the use of microcomputers in solving physics problems in introductory classical mechanics. This seemed reasonable because the number of students majoring in physics was not many, about 20 each year. However, use of instructional computing for all introductory physics courses would require large expenditures to buy the computers needed. Even with limited usage of computers in instruction, faculty members did not have the financial support they needed to buy the hardware and software to implement their intentions (see p. 146-165). This was probably due to faculty members and administrators choosing to use their budgets for equipment and supplies needed for research; therefore, less money was available for development in teaching. Gross, Giacquinta, and Berstein (1971) found that the administrators needed to provide the resources to successfully implement an innovation. Without an administrative directive to do otherwise, money was not available to support instructional computing. This at least partly explains the low utilization of instructional computing in the introductory physics courses at these four settings.

Question 4a: What was the predominant factor used to determine promotion of faculty members?

Assertion 4a: At the two leading research universities, Alpha and Theta, the faculty members were promoted primarily based on their research and publication in physics. At Sigma University, faculty members were promoted based on their competency in research, teaching, and service, but research was viewed as very important. At the other extreme, faculty members at Beta Community College were promoted based on their teaching, and research was not encouraged by promotion policies.

At both the leading research universities, faculty members were promoted based on their capability in physics research (see p. 148-165). The reward systems at the two research universities were based primarily on research (see p. 148-165). This is an important factor because faculty members would not be attracted to devote their efforts in instructional computing. Dykes (1978) found that 100 faculty members surveyed showed their willingness to accept innovation was related, in part, to their perceived reward for participation. This is further supported by Kozma (1979). At Beta Community College, faculty members were promoted based on their teaching performance (see p. 158-160). Again, this possibly was due to the priority in teaching at the community college and the reward system at the college (see p. 158-160). Perhaps, this partly explains why the faculty members at Beta Community College were using a lot more instructional computing than those at the universities. Finally, at Sigma University the faculty members were promoted based on a combination of criteria based on teaching, research, and service (see p. 161-163). There seemed to be higher priority on teaching at Sigma University than at Alpha and Theta universities. Nevertheless, at Sigma University faculty members were also expected to conduct research and public service to be rewarded for promotion. The use of instructional computing at the four institutions seemed to parallel the institutional emphasis in teaching and appeared to be inversely related to the institutional research emphasis.

Question 5: How did students who experienced instructional computing in the introductory physics courses perceive it?

Assertion 5: Students who used computers in the introductory physics courses were positive about the use of computers. They thought that computers were essential in daily life, and thus they needed to have some knowledge in using computers. However, some of them felt that computers interfered in their learning process.

Students in the introductory physics courses felt it was essential to have some knowledge of computers to function in everyday life (see p. 169-176). They also felt that by using computers in the lab they were able to do the experiments more efficiently (see p. 169-176). But, a few of them felt that the usage of computers in the lab distracted them from learning physics concepts in the experiments (see p. 169-176). Thus, some students were not optimistic to the effectiveness of computers in helping them to learn in the introductory physics courses. This is an important factor that the faculty members must look at before they begin to invest their energy and resouces in instructional computing. Arons (1984) warned that using computers might jeopardize students' learning of the concepts involved. Perhaps, some faculty members might be influenced in their decision to use computers based on the students' perceptions of the effectiveness of computers in helping the students learn physics. This emphasis by students on learning the subject matter of physics parallels faculty members' concern about students' learning. As indicated earlier, many physics professors believed that computers would not help resolve the fundamental problems in teaching physics; namely students' lack of understanding of physics concepts and principles after instruction. The fact that students and faculty members shared the concern that computers may interfere with student learning, or at best, enhance it minimally, is further reason for limited enthusiasm for instructional computing on the part of many physics professors.

Interpretation Using Theoretical Framework

In this section, the data of this study will be compared to Gamson's typology of frameworks which was cited by Dill and Friedman (1979). It was discussed at great length in the Chapter II. Briefly, the typology identified four frameworks for viewing innovation and change. They are diffusion, complex organization, conflict, and planned change. The findings of this study will be compared to the first three frameworks and to the research described under each framework. Finally, there will be a discussion to interpret the data using organizational culture as a framework.

The first framework to be examined in relation to the findings of this study is the diffusion framework. This framework offers an explanation of the manner in which an innovation product spreads through the system. Diffusion may result from planned dissemination procedures or may occur in a less systematic manner. This framework is particularly applicable when the central administrators of an organization are involved in developing ideas or physical products with the express purpose of bringing about changes in an organization.

One characteristic of the diffusion framework is that higher echelons in the organization support the innovation under consideration. Winstead (1982) related that successful implementation of innovation required a strong commitment to the innovation by the higher echelons of the administration. There seemed to be some display of support towards instructional computing by the administration at Beta Community College. This provides an explanation of why there was more use of instructional computing at Beta Community College than other institutions. Theta University had a well known advocate of instructional computing who was the Vice-President of Academic Computing for the university. Presumably, he would be very supportive in using computers for instruction. But instructional computing in the introductory physics courses at Theta University was more limited than in the other institutions. However, if one looks broadly, there was little support or incentives given to the physics faculty members' efforts in teaching at Theta University. This was also true at Alpha University. The lack of incentives given to faculty members for their effort in teaching could account for the limited use of instructional computing at these institutions. Dykes (1978), and Kozma (1979) had similar findings.

In analyzing the use of instructional computing at all four settings, there was some evidence suggesting that the use of computers for teaching introductory physics could be explained partly by the diffusion framework.

The second framework to be compared to the findings is the complex organization. Dill and Friedman (1979) described this framework as one that "attempts to correlate innovativeness in social systems with variables which characterize the system as a whole." These variables included institutional age, affluence, size, centralization of authority, complexity, and stratification. The analysis of innovation in this framework is normally related to the rate at which an organization adds new and different innovations.

There are some factors that emerged in this study that are linked to the complex organization framework. Two of the variables in the complex organization framework were found to be common factors in the use of instructional computing in the introductory physics courses. These variables are size and availability of funds for instructional computing.

Glover (1980) found that smaller colleges were more likely to implement change or innovation. In this study, Beta Community College, the smallest institution included in this study, showed more use of instructional computing than the larger institutions. At Beta Community College, there was a campus-wide effort to encourage faculty members to use computers for instruction.

Hefferlin (1969) found that financial resources were a key element in the change process. This was also the case in this research, where lack of money for instructional computing limited the use of instructional computing in introductory physics courses. For example, at Alpha University there was not enough allocation of funds to buy hardware and software for use in teaching introductory physics. This was also true at the other institutions. The preceding discussion provides an illustration of two critical factors of innovation that emerged in this study, namely size and lack of funds for instructional computing, provide support to the complex organization framework. This framework, however, partly explains the limited use of instructional computing.

The third framework to be examined is the conflict framework, also known as the political framework. This viewpoint suggests that during the change process interest groups form and put pressure on the organization either for or against change. Levine (1980) in his study of why innovations fail found that institutions have established boundaries which are protected by interest groups. Innovations tend to threaten the status quo of established boundaries and generate conflict. To implement an innovation successfully, conflict needs to be minimized.

One factor that emerged from this study was that, the use of instructional computing threatened the established syllabus in the laboratory. Some faculty members also voiced that the limited amount of time available to cover the course syllabus was the reason they did not use computers in the introductory physics courses. So, to include computers would require them to sacrifice some of the materials. Some faculty members felt that computers should not be used in lectures because they would detract from their lectures, which were an essential part of the established instructional plan. To these faculty members lecture was an important, effective instructional mode and they felt there were no reason to change to other modes of delivering instructions. At Alpha Univertsity, there was conflict or politics involved in deciding whether the Physics Department should get IBM PC compatibles. Also, the Physics Department was viewed as encroaching the interest or roles of the Computer Science Department and the Mathematics Department.

Thus, there was evidence of boundary expansion in this study, which supports the conflict framework. The usage of instructional computing in teaching introductory physics courses threatened the status quo of established boundaries, roles of the Computer Science Department and the Mathematics Department, and thus conflict tended to limit the use of computers in physics teaching which partially explains the low utilization of instructional computing at these four institutions. Therefore, the conflict framework provided a useful framework to explain the limited use of instructional computing at these four settings.

The last framework to be examined is the organizational culture framework. The culture of an organization communicates values and beliefs that provide meaning to life in the organization (Ouchi, 1981). In other words, organizational culture helps employees to determine their behavior and to make meaning or sense out of the behavior of others. Barrett (1984) suggested that an individual is subjected to conform to the culture of the individual's environment for the individual to be accepted by fellows. In this research, the faculty members at the four institutions must conform to the culture at each of the four institutions in order for them to be recognized and also rewarded.

The values, beliefs, and mission at each school influenced how the college and universities used computers in the teaching of introductory physics in this study. Each institution used and promoted instructional computing that was congruent with its culture and supportive of its fundamental goals and saga, or a common belief of an established group that was unique.

At the two leading research universities, there was more emphasis on research instead of instructional development or teaching in general. Clark (1987) also found similar notions by professors at research universities. In this study, the emphasis on research and consequent deemphasis on instruction was obvious in the overall use of the resource. As a result, the faculty members and administrators were not very enthusiastic about instructional computing. The faculty members and administrators perceptions' of their roles were shaped by the organizational culture of the universities. This was especially important knowing that most of the resources were channelled towards research, and that promotion, tenure and status all depended on research productivity. Therefore, the reward structure in the physics departments of these universities stressed research instead of teaching. Consequently, the faculty members here were more interested in doing research than in devoting their time in developing instructional computing.

On the other extreme was Beta Community College. Here teaching in general was their main mission. This is in agreement with Clark (1987). The data showed that there was more instructional computing here than at the other three institutions. Contrary to what happenned at the two leading research universities, at Beta Community College the resource was used for teaching or instructional development and this was in agreement with the mission of the college.

Thus, faculty members were promoted and given tenure based on their teaching performance. Consequently, this created an environment where the faculty members were enthusiastic in their teaching. Thus, it was not surprising to find more use of instructional computing here than at other settings. Nevertheless, this usage was still limited to the laboratory.

Organizational culture played a major role in understanding the use of instructional computing in this study. This framework helped the researcher to more fully understand the factors that influenced instructional computing at these settings. Thus, it was true according to Pascale and Athos (1981) that culture of an organization influenced behavior of individuals in situations involving change such as the use of computers for instruction in the introductory physics courses.

In this study all four frameworks, including organizational culture, converged to provide explanations of why there was not much utilization of instructional computing in the introductory physics courses at the four institutions.

Findings

There was a very limited utilization of instructional computing at the four institutions for several reasons. The usage of instructional computing in introductory physics courses at the research sites was limited mainly as a tool for data acquisition and analysis in the laboratory. It appeared that faculty members of physics at Beta Community College used the computer for data acquisition and analysis more than those at the other three settings. This study thus, examined the factors that influenced the infrequent or limited usage of instructional computing in the introductory physics courses.

Several factors were found to be critical in inhibiting more usage of instructional computing. All of these factors were related to the individual faculty members; some of these factors or conditions also were influenced by administrators. These factors are listed below:

1. Faculty members' perceptions of instructional computing. This factor will likely determine the use of instructional computing. Kozma (1985) suggests, "Instructional change is personal, and to a large extent faculty members do whatever they want to do in the classroom...." This remark suggests that faculty members must perceive the usefulness of instructional computing first, before they begin to use it. In other words, the faculty members will make the decision whether or not to use it. As such they are the "gatekeeper" on its usage.

2. Students' inability in learning physics. The deep feeling and experience faculty members had with many students who could not learn physics despite instruction. This generated uncertainty that seemed to bother them. The

faculty members felt that they should resolve this problem first before they could embark on instructional computing.

3. The faculty members' perceptions of their main role in the department. This factor could determine the faculty members' engagement and efforts in instructional improvement. At the two leading research universities, the faculty members perceived themselves more as researchers rather than teachers and thus, devoted more of their available time to research. Consequently, there was little use of instructional computing at these two institutions.

4. Lack of time available. The limited amount of time faculty members had available to use computers in their teaching also contributed to the limited use of computers. Also, all faculty members recognized the time required to set up and maintain instructional computing as well as time required to develop programs for their use. Since time spent on instructional computing would detract from the time available for research, most faculty members had little motivation to pursue it.

5. The encroachment of established boundaries. The faculty members had to ensure that the utilization of instructional computing did not interfere with the interest or roles of Computer Science Departments or other departments. If that happened, the faculty members would not get full cooperation and support from administrators. In his study, Levine (1980) noted similar findings.

6. Students' perceptions of instructional computing also influenced the use of instructional computing. This could have influenced faculty members' perceptions of instructional computing. Most students were positive about computers, but some shared faculty members' concerns that computers could detract from learning.

7. The emphasis of research instead of teaching did not provide a conducive environment to increase the use of computers in teaching.

8. Another factor was small incentive for faculty members who were devoted to teaching. Without appropriate incentives to encourage faculty members to be creative or innovative in their teaching, the faculty members did not seem attracted to use instructional computing in teaching introductory physics courses. In this regard, there must be appropriate incentives given to faculty members who are devoted and innovative in their teaching so that instructional computing will be used widely.

9. Limited amount of money to acquire hardware and software was one factor that determined the use of instructional computing at these departmets. Hefferlin (1969) in his research found that financial resources were the key factor to innovation in education. Without financial support to buy hardware and software, the faculty members had difficulty gaining access to computers which resulted in a low usage of instructional computing at the departments. Thus, the departments and institutions need to

give financial support to see instructional computing being used.

In summary, the three factors (7-9) on which faculty members and administrators have influence should be considered by the administrators if they want to implement instructional computing, not only in physics courses, but others as well. Thus, to implement instructional computing, the institution must provide a conducive environment to the utilization of instructional computing. Moreover, the other six factors (1-6) related to the autonomy of faculty members were equally, if not more important, determiners of utilization of instructional computing. Therefore, both the faculty members and administrators must be supportive and receptive towards the utilization of instructional computing to ensure a widespread usage of instructional computing. However, the faculty members had a greater influence because they will make the decision ultimately whether or not to use instructional computing.

CHAPTER V

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

This chapter provides the summary and conclusions of this research, followed by sections on limitation of the research, policy recommendations, and suggestions for further research.

Summary

Computers have been utilized for quite some time in the teaching of physics. There are computer programs available to tutor students, to simulate laboratory experiments, to acquire and analyze data in the laboratories, and for drill and practice of physics courses.

This research attempted to find the current status of utilization of instructional computing in introductory physics courses at four tertiary settings. More important, this research was designed to find the principal factors that influenced the extent of the use of instructional computing in the introductory physics courses. Initially, four research questions were formulated, but as the research progressed it was found essential to reformulate and add questions.

Ethnographic methods were the best method in responding to the research purposes and questions. Data were collected primarily by interviewing physics faculty members who had experience in the use of computers in their teaching, administrators who were involved in making decisions that influenced utilization of instructional computing, and students who were using computers in the introductory physics courses. The researcher also observed classrooms and laboratories that used computers for instructional purposes, and analyzed documents that included course materials, bylaws of the departments, annual research reports of the departments, faculty members' salary lists, faculty members' papers on instructional computing delivered at professional meetings, campus newspapers, and catalogs of the institutions.

The data collected were simultaneously analyzed, and as this was done, new questions were raised that modified the focus of the research. This process helped the researcher to be critical in carrying out the research, and thus allowed this research to be done with more efficiency. More comprehensive and intensive analysis of data was done at the end of the research. At these junctures, additional notes were made to record new patterns that were identified. This necessitated that the researcher to return to the field to verify these new patterns.

The four institutions that were chosen for this research were Alpha University, Beta Community College, Sigma University, and Theta University. These institutions were in a midwestern state. Alpha University and Theta University were two leading research universities in the nation. Thus, these two universities tended to give priority towards research over learning in the use of their resources. Beta Community College on the other hand focused its resources for teaching purposes and virtually no research was conducted there. Sigma University had both teaching and research as important in its mission, however, it seemed teaching was its main mission.

Gamson's theory of innovation and change (Dill and Friedman, 1979) was used as one theoretical framework to interpret data. Four models of innovation and change were identified: (1) diffusion; (2) complex organization; (3) conflict (or political); and (4) plannned change. The first three models were used to guide interpretation of this research. The planned change model was not used because as the name implies, it is more relevant to changes or innovations that were planned systematically. A second theoretical framework, organizational culture, was added in analyzing and interpretating the data to complement Gamson's theory.

The diffusion model helped to explain the manner an innovation was brought into a system. For this framework, the researcher studied the manner in which this innovation was adopted or not adopted by the system. This adoption or nonadoption was directly pertinent to the attributes of the innovation and the system, including compatibility with current practice, perceived relative advantage, characteristics of the innovation, ability to trial test the innovation, complexity, and attitude toward the innovation.

Complex organization framework is a framework used to find relationships between innovativeness in institutions with factors that characterize them. In this framework, centralization, formalization, affluence, size, complexity, and age are the variables included as important factors to determine the success of an innovation.

Conflict framework or political framework suggests that interest groups control the innovation process. These groups exert pressure on the institution either for or against change. Among the variables related to this framework are level of satisfaction with the change or innovation, job mobility, intensity of conflict, duration of conflict, and the extensiveness of organizational change.

Organizational culture as a framework was useful in helping the researcher to more fully understand the data collected. Organizational culture aided the researcher in describing and understanding how differing beliefs, values, and missions at each of the four institutions influenced faculty members' behavior and attitude towards teaching in general, and instructional computing in particular.

At all four settings in this research, there was limited utilization of instructional computing in the introductory physics courses. However, physics faculty at Beta Community College appeared to utilize instructional computing relatively more than those at the other three institutions. Most of the faculty members in these four settings used computers in the introductory physics laboratory for data acquisition and analysis. There was, however, limited utilization of computers in lectures to demonstrate phenomena.

All four institutions seemed to be moving towards using microcomputers for instruction in the teaching of introductory physics courses. However, the movement tended to be slow and without a coordinated plan. In both the laboratories and lectures, the faculty members adhered to the traditional classroom practices of whole group delivery of instruction, teacher dominated conversation, and reliance on textbooks. Thus, using computers in teaching introductory physics seemed compatible with the traditional notion of teaching physics.

The low price of microcomputers in recent years and the potential for control over, and ready access to microcomputers prompted many faculty members to use microcomputers in instruction. Nevertheless, there were not enough microcomputers for use in the introductory physics courses at any of the institutions. At Alpha University and Theta University students were using obsolete equipment. Certainly, this lack of adequate equipment did not encourage more faculty members to use computers in their teaching of introductory physics courses.

Using microcomputers, faculty members were faced with the problem of federal copyright laws since copyrighted programs could not be duplicated for use on several machines. To avoid copyright problems, some physics faculty members resorted to developing their own software and thus did not have to face the problem of illegal copying. Most faculty, however, found that it took a lot of time for them to develop good software, so very few of them were willing or had the time to develop instructional software. A few enlisted students to write programs, as they often were more fluent in programming than the professors. Without appropriate incentives to the faculty members to write these programs, or the resources to purchase commercial ones, it is unlikely there would be a dramatic increase of use in instructional computing in introductory physics courses. Faculty members at Beta Community College frequently used a spreadsheet program available on the mainframe computer. This alleviated problems with copyright laws.

At all four settings, faculty members who used computers in the laboratory to gather and/or analyze data had to spend extra time in teaching students how to use the computers. This was especially true with software developed by faculty members that tended to be less "user-friendly" than commercially developed programs. However, this was not the case for faculty members who used computers to demonstrate phenomena in their lectures. Since students were passive observers, not operators of the equipment, it was not necessary for faculty members to teach students how to use computers.

Most of the faculty members interviewed at the four settings were very supportive of the use of instructional computing, and in fact they appeared to be quite interested in it provided that it was used approprately. The faculty members in general believed the computer could be a valuable and useful tool in the laboratory, but not as a means to deliver instruction like in the conventional computer assisted instruction (CAI). This suggested that CAI, started more than a decade ago in a number of higher institutions, had little impact on the faculty members at these four settings. A few of them related to me that they felt CAI was not an effective means of delivering instruction and a few others felt that the software available for CAI was not good enough. Some of the faculty members related that they were more concerned with students' difficulty in learning physics despite "good" instruction than to implement instructional computing. At Alpha University, the faculty members liked the idea of teaching computer literacy in a separate course for first year physics majors because they were not able to incorporate it in the existing introductory physics courses due to the amount of subject matter content required, and the time constraint.

Physics faculty members at the two leading research universities placed a higher premium on research in physics than research in physics teaching and in the teaching of physics per se. They devoted much of their time to doing research in areas such as elementary particle and condensed matter physics. Thus, they were considered more as physicists than physics educators. On the other hand, the faculty members at Beta Community College were not active in physics research or research in physics teaching and placed greater emphasis on their teaching. Faculty members at Sigma University, however, were generally expected to be both competent in teaching and research. Thus, they were more of a blend of both physicists and physics educators.

All four physics departments supported the idea of faculty members using computers for teaching in the introductory physics courses. With the exception of one, a computer skills or literacy course for physics majors in their freshman year at Alpha University, none of the departments required its faculty to include computers in their teaching of introductory physics; this was probably due to financial constraints. Other physics departments did not have a course similar to this and did not have a policy requiring introductory physics students to be computer literate after taking the introductory physics courses. Faculty members in physics at the two research universities were promoted primarily based on their research in physics, though teaching and service were also included in criteria for the promotion. However, it was evident from conversations and interviews with faculty members that promotion would not be granted to faculty members who focused their efforts on instruction in lieu of research productivity. At Beta Community College, where teaching was the main emphasis of the college, research in physics was not rewarded. It seemed innovative teaching was rewarded well at the community college. On the other hand, at Sigma University faculty members were promoted if they demonstrated teaching competence. In addition, competence in research and service to the public were also emphasized.

Most students in the introductory physics courses at the four settings held positive views towards the use of computers in the courses, especially in the laboratory. They felt that computers were essential in everyday life and thus they needed to have some experience with computers. However, some students thought computer use in the laboratory interfered in their learning process because they felt they were not actively engaged in doing the experiments.

There were several factors that emerged as critical in influencing the use of instructional computing in introductory physics courses at these four institutions. One factor was the emphasis on research at the two research universities. This did not provide a good atmosphere for faculty members to increase the use of computers in their teaching. Another factor was the lack of incentive given to faculty members who were active in introducing and trying new methods of teaching. Without proper incentives for these faculty members, there would not be many of them interested or willing to spend their time developing new methods of teaching such as using instructional computing.

Another factor that is also related to incentives was the amount of money available from the institutions to buy hardware and software to enable the faculty members to use computers in their teaching.

More important were factors related to faculty members in the department. The first factor was the faculty members' perceptions of using computers in physics instruction which strongly influenced their decisions to use computers in their teaching of physics. The second factor was faculty members' concern about more fundamental issues related to students' difficulty in learning physics despite "proper" instruction. Another factor was the faculty members' views of their main role in the department. This perceived role determined the faculty members' efforts and engagements in instructional computing. The fourth factor that the faculty members must be aware of was the encroachment of established boundaries. For instance, the faculty members had to be sure that the use of computers in their teaching did not coincide with the roles or interest of other departments, such as Computer Science. Another factor was limited or lack of time faculty members had for them to develop and incorporate instructional computing in their teaching. The last factor that could influence the use of instructional computing was students' perceptions of instructional computing which might influence faculty members' perceptions of instructional computing.

Conclusions

Based on the findings of this research, the following conclusions were drawn:

1. Instructional computing was not implemented in a revolutionary way, but was implemented in a piecemeal (evolutionary) fashion and was adapted to the traditional introductory physics courses. The use of computers in teaching introductory physics courses was infrequent and used largely as tools in the laboratory for data acquisition and analysis.

2. There were not enough hardware and software available, to foster further development of instructional computing at these four institutions.

3. To compensate for lack of software, some faculty members developed their own software. However, this is a difficult and time-consuming task for which faculty members received little or no recognition from the departments.

4. The beliefs and values which comprised the cultures of the four institutions, have not engendered significant reform in the teaching of physics including, the development of instructional computing. At the research universities for instance, there was common understanding among faculty members and administrators that research was placed higher on the agenda than teaching. As a result, limited resources and time were available for development of instructional computing.

5. Individual faculty members decided what they would do in their courses even though the Physics Departments have general guidelines that the faculty members must follow for each courses. Nevertheless, the faculty members made the decisions themselves including choice of textbook, instructional approach, and use of instructional computing.

6. Introduction and implementation of instructional computing at the tertiary level is a complex process. To ensure its success, multiple factors need to be considered including (a) adequate resources to acquire hardware and software; (b) allocation of faculty time to acquire and test software and intergrate them with textbooks, lectures, labs, and other parts of the instructional format; and (c) acquisition of skills by staff members or assistant to use and maintain the hardware and software appropriately. These factors lie at least partially, beyond the control of faculty members. Thus, cooperative planning is needed between administrators and faculty members.

Limitations of Research

Ethnographic research attempts to describe and explain events using field research methods that rely on the knowledge and cooperation of the participants and the skill and insight of the researchers. Thus, such research is limited by the conscious and tacit understandings of their subjects and by the abilities and perceptiveness of the researcher. This research shares these general limitations as well as others.

The design of the research was limited in two ways. First, the research was limited to an investigation of those faculty and students willing to participate. Second, the results of the study are not readily generalizable since they apply only to the particular institutions studied. However, the results of this research can serve as the basis for questions, hypotheses, and speculation about similar issues at other institutions of higher education. The results can also serve as a guide to those who establish and enforce policies within institutions of higher education, as well as those who set policies for government. On the other hand, because the research was a set of case studies, the depth of knowledge acquired about these questions is important.

Policy Recommendations

This research is particularly useful to administrators in institutions of higher education, and faculty members considering using computers for instructional purposes. There may be some instances in the research that are similar to circumstances in other institutions that are using computers for instruction. The research may benefit all institutions of higher education by expanding our knowledge of the innovation process in institutions of higher education, particularly on instructional computing. This research helps administrators and faculty members to understand the process of using a new teaching method, and what it takes to make it succeed or what causes it to fade away. The following are several recommendations that will be useful for the four institutions as well as other similar institutions.

One factor that was found to be critical to ensure a widespread use of instructional computing was the organizational culture of the institution. The two leading research universities channeled funds and gave promotion and tenure based on faculty members' research and publication in professional journals. This priority in research did not foster faculty members' interest in instructional innovation and improvement. Unless this priority is changed to excellence in teaching, efforts to improve teaching, including the use of computers in teaching will proceed in a piecemeal manner. Because instructional computing requires rather substantial investments in equipment, software, and staff time, instructional computing will be slow to develop unless universities provide adequate resources and investments to foster its development.

Faculty members interested in instructional computing who are not familiar and competent in instructional computing should be given assistance and training. This could be done at the departmental level or centrally in the university. Faculty members in the four departments who were competent in instructional computing must be encouraged and given incentives to conduct workshops for faculty members who did not have skills in instructional computing. This is important knowing that no instructional computing can take place unless faculty members want it. Hence, it is essential to provide conditions and skills that will stimulate faculty members to use computers in their teaching.

Administrators must plan an instructional computing program properly to ensure its success. This suggests that there must be a well-developed long-term plan for instructional computing at these institutions for all areas or departments. This plan needs to be monitored carefully when it is implemented, by having enough faculty members overseeing this with support from the institution. As stated earlier, instructional innovation is a difficult endeavor, certainly proper planning will help.

Administrators can play a leadership role, usually as supporters and facilitators of instructional computing rather than as initiators. High-level administrators can best facilitate the use of instructional computing by establishing procedures and incentives to ensure that the institution explores all the possibilities of using computers for instruction. Perhaps, computers in general and instructional computing in particular require new ways of thinking and new ways of organizing oneself to take advantage of its potential.

Nevertheless, even if it is agreed that instructional computing does have a place in higher education, despite some resistance among faculty, administrators, and students, then great care must be taken to use computers in the most appropriate ways, so as to fully exploit their potential for teaching. Since most research in instructional computing, and the approaches observed in this study, use computers as an adjunct to standard instructional models, with little or no added gain in student achievement, serious thought and efforts could be given to explore new ways of using computers in different instructional models to enhance students' learning.

In conclusion, these recommendations that have been developed by the researcher will be helpful to these four institutions in improving the current practices of instructional computing in introductory physics courses. Moreover, the researcher feels that these recommendations will be of value to other institutions of higher education.

Suggestions for Further Research

At the outset of this dissertation, it was stated that systematic research on the utilization of instructional computing in introductory physics courses was limited. Thus, more research needs to be conducted on the utilization of instructional computing in introductory physics courses. There are many issues and questions pertaining to the usage of instructional computing that need to be resolved by future researchers, including the appropriate amount of instructional computing which will be beneficial for students; types of courses and students that will definitely benefit from instructional computing; and the best uses of instructional computing.

This research was limited in scope. Institutions selected for this study were limited to three types of institutions. All of these institutions were in one state in the midwest. Future research could include parallel studies to this one to see if the findings are similar in different settings. One possible avenue to expand this research would be to find out if different states or geographic areas influence the findings. Another approach would be to include other types of institutions such as small private colleges to see if the findings differ from this study. Another possibility would be to find out the use of instructional computing by all science departments in one institution. Perhaps, this indepth study of one institution could provide a different perspective on the use of computers for instruction by different science departments. One meaningful approach is to find out the extent of utilization of instructional computing in physics at the University of California at Irvine where Bork is working, who is one of the most prominent figures who advocates and envisions the use of computers in teaching physics. This research would provide interesting findings for other institutions and most likely would be of great value to those who are interested in developing instructional computing.

Another possibility to expand future research is to examine in detail the students' learning experience using instructional computing. These findings would have great impact on the future usage of instructional computing. There are still some questions pertaining to the effectiveness of instructional computing in teaching that need to be answered. Finally, one way to expand this research is to find out faculty members' perceptions of teaching and learning. This research will provide empirical data that would be useful to our knowledge and be able to explain the faculty members' attitudes towards instructional computing. It is hoped that all these questions will be resolved soon.

APPENDIX

DESCRIPTION OF RESEARCH, CONSENT LETTERS TO PARTICIPANTS, AND EVOLUTION OF THE RESEARCH QUESTIONS

DESCRIPTION OF PROJECT

Ahmad N. Md. Zain
1551-J, Spartan Village
East Lansing
Michigan 48823

I wish to conduct a research in the physics department at selected tertiary institutions in Michigan to find out the utilization of computers in introductory college physics courses.

Very little systematic study has been done on how computers are used in the introductory college physics courses. Most of the research has been looking narrowly to one aspect of computer useage, namely computer-assisted instruction. Thus, there is a need to study other aspects of the utilization of computers in introductory college physics courses.

I will employ the research method used in ethnographic research which is to focus on a setting and to discover what is happenning there. Several sources will be used to collect data including classroom observations, interviews with members in the physics department and students, and review of pertinent documents.

I plan to carry out this research from November 1986 to April 1987. During this six months period I will be observing classrooms, interviewing staff in the physics department and students, and reviewing materials related to this research. My observational work would be as unobstrusive as possible.

This study will help us understand the current practices in the use of computers in introductory college physics courses and thus will help us in implementing and using computers more effectively in these courses in the future.

I am working with Dr. James J. Gallagher, Professor of Science Education at the College of Education, Michigan State University for this study.

If you have any questions, feel free to call me at home (517) 355-3149 or Dr. James Gallagher at his office (517) 355-1725.

PARTICIPATION AGREEMENT OF FACULTY MEMBERS IN PHYSICS DEPARTMENTS

November, 1986

Very little is known how college physics faculty members perceive the use of computers in teaching introductory physics courses as well as the factors that shape the use of computers in these courses. I am proposing a study to examine the utilization of computers in introductory college physics courses. Also I am interested in learning about factors that influence the introduction of computers in these courses. This study is for my doctoral dissertation at Michigan State University.

This study will run from November, 1986 through May, 1987 and will include classroom observations and interviews with physics faculty and students which will be recorded. The tape recordings are to insure an accurate record of what was said and will be used for data collection purposes only. They will not be made public. Documents pertinent to the research will be collected.

Every possible effort will be made to guarantee confidentiality and disguise the identity of all participants at all times. Participation by faculty and students in this study is entirely voluntary. Individuals may decline to participate and free to withdraw at any time, without penalty.

If you have any questions, please feel free to call me at home (517) 355-3149 or my advisor Dr. James J. Gallagher at his office (517) 355-1725.

Ahmad N. Md. Zain

I have read this proposal, and I agree to participate under these conditions.

Signature ______________________________ Date ____________

PARTICIPATION AGREEMENT OF STUDENTS

November, 1986

Very little is known how computers are used in intoductory college physics courses. I am proposing a study to examine the utilization of computers in introductory college physics courses and how students perceive this utilization. This research is for my doctoral dissertation at Michigan State University.

This study will run from November, 1986 through May, 1987 and will include classroom observations and interviews with physics faculty and students which will be recorded. The tape recordings are to insure an accurate record of what was said and will be used for data collection purposes only. They will not be made public. Documents pertinent to the research will be collected.

Every possible effort will be made to guarantee confidentiality and disguise the identity of all participants at all times. Participation by faculty and students in this study is entirely voluntary. Individuals may decline to participate or withdraw from it at any time without penalty. Students' participation or non-participation in this research will have no effect on their course grade.

If you have any questions, please feel free to call me at home (517) 355-3149 or my advisor Dr. James J. Gallagher at his office (517) 355-1725.

Ahmad N. Md. Zain

I have read this proposal, and I agree to participate under these conditions.

Signature ______________________ Date ____________

Evolution of the Research Questions

After a month or so grappling with the initial research questions (see p. 5), the researcher went to collect data at Alpha University and Beta Community College. At the outset of this data collection, it was difficult for the researcher to limit himself to the initial research questions. Given the naturalistic approach of this research, there were many variables that seemed important and related to the initial research questions when the reseracher was at the sites. In other words, the researcher had a better picture of what went on at these sites and thus, new issues became evident that were related to the research.

Unquestionably, all these data collected helped the researcher to think clearly and focus his research with the data available. For example, the researcher found that the criteria used for promoting faculty members influenced faculty members' involvement with instructional computing. Thus, the researcher focussed his data collection on the policy and practice of promotion at these research sites. Consequently, the researcher reformulated the initial research questions and added some new questions as the research continued. In other words, the initial research questions continuosly evolved as the researcher became more familiar with the research site. After sometime, the evolution did not progress further and the researcher felt confident that the key issues were being included. Discussion with the advisor and committee members often enriched my understanding of issues until, ultimately, it was decided that this process must come to an end.

Thus, after months of work at the sites collecting data at the sites, the researcher was able to develop the final set of research questions (see p. 6) which were more specific than the initial research questions. The final set of research questions helped the researcher to focus the data collection and made the data collection and interpretation processes more efficient.

Moreover, as the researcher began his research, he perceived that the factors that influenced instructional computing were: (1) Limited financial resources for instructional computing; (2) Lack of support from the administrators, (3) Lack of incentives for faculty members involved in instructional computing; and (4) Priority of the institutions in research instead of teaching. But now it is evident that the problem is more complex and these factors must also be included: (1) Faculty members' concern towards students' difficulty in learning physics; (2) Faculty members' perceptions of their main roles; (3) Constraints on faculty members' time; (4) Conflicts with other departments especially, Computer Science Departments; and (5) Faculty members' observation of students' attitudes toward instructional computing.

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