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AN EMPIRICAL DETERMINATION OF INSTRUCTIONAL OBJECTIVES RELATING TO THE COMPUTER IN THE COLLEGE-LEVEL GENERAL PHYSICS SEQUENCE

by

CARL WAYNE STEIDLEY

A DISSERTATION

Presented to the Division of Teacher Education
and the Graduate School of the University of Oregon
in partial fulfillment of the requirements
for the degree of
Doctor of Philosophy

August 1983

APPROVED: Meredith D. Gall
Meredith D. Gall

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An Abstract of the Dissertation of
Carl Wayne Steidley for the degree of Doctor of Philosophy
in the Division of Teacher Education to be taken August 1983

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Approved: Meredith D. Gall
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This study investigated the perceptions of college and university physics professors concerning the amount and kinds of instruction about the computer that should occur in the undergraduate general physics sequence. Data were collected in two phases: a semi-structured interview of experts in applications of the computer to physics education; and a structured interview of a stratified sample of two-year and four-year college and university professors of physics.

The first panel of experts identified objectives within each of the following seven domains: programming and algorithms, skills in computer usage, hardware and software principles, major uses and applications, limitations of computers, personal and social aspects, and relevant values and attitudes. The responses of this panel were used to generate a universe of computer literacy objectives. The sample of physics educators then identified objectives within the universe that they felt were appropriate for helping students become computer literate within the context of the general physics sequence.

Analysis of the data revealed that, according to professors, a computer literate graduate of the general physics sequence should have developed fundamental skills of programming in the BASIC language, should be able to translate the traditional mathematics tools of physics to the computer to save time, should be able to use the computer for laboratory data acquisition and analysis, and should be able to use computer simulations in the laboratory. Professors felt that the ability to use word processors for physics reports was a nice but unimportant frill. Additional findings about sequencing of the computer objectives in the curriculum were obtained.

The results of this study should be useful to curriculum designers and textbook writers for including computer instructional objectives in the general physics sequence.

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Yakka --

    though it wasn't doing dishes,
    we'll have fonder remembrances
    of togetherness --

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CHAPTER I

INTRODUCTION

The computer has been recognized for decades as an important tool for use in physics research. Recently it has found increasing use as an aid in physics teaching. This trend is almost certain to increase as lower computer costs bring more powerful computing facilities within reach of most institutions, and as physicists continue to apply their research expertise in their teaching. The present project examined how physics educators feel this powerful tool should be introduced into the introductory college physics sequence.

Purpose of the Study

The study had three major goals. The first goal was to identify the universe of computer instructional objectives for students in the college-level, lower-division general physics course sequence (or, as it is sometimes called, engineering physics). The second goal was to identify a minimum subset of these objectives which physics educators perceive that students should have achieved after completing the sequence in order to be considered "computer literate." The third goal was to determine how this level of computer literacy should be achieved.

Background

Many educators and computer scientists believe that students at most levels of education have an inadequate understanding of computers and the impact of computer technology on their lives. Luehrmann (1980), President of Computer Literacy Corporation and former director of computing for the Lawrence Hall of Science, stated that computing plays such a crucial role in everyday life and in the technological future of this nation that the general public's ignorance of the subject constitutes a national crisis.

Luehrmann also stated that the ability to use computers is as basic and necessary to a person's formal education as reading, writing, and arithmetic. As jobs become increasingly oriented toward the use of information, society demands and rewards individuals who know how to use information systems. The American computer industry, which is the world leader today, depends for its future upon a mass of computer-literate workers and consumers. Despite computing's critical importance, however, the overwhelming majority of this country's general public is ill-prepared to work in the Age of Information, as some have called it.

John Kemeny, President of Dartmouth College, argued that:

> The computer is so essential in everyone's education that colleges and universities that do not provide adequate student computer facilities should not be accredited. Such usage should be part of any undergraduate curriculum (Bork, 1981a, p. 144).

For example, students planning a career in science will eventually use computers in their research. But the computer can interfere with scientific inquiry if used improperly. Just as students learn to use essential pieces of laboratory equipment properly, science courses are increasingly concerned with the proper introduction of computers in subject matter context. The goal is to display to students the strengths and weaknesses of numerical and symbolic approaches in addition to the purely analytical approach common in undergraduate courses. This approach to computers is referred to as the tool use of computers (Bork, 1981b).

Historically, the focus of computer use in science instruction has shifted several times. In 1968 the National Science Foundation funded research on how the computer could be used in science instruction. After two years and some disappointing materials, the project directors recommended a subsequent grant concentrating on computer simulations. In 1970 the Huntington II project placed new emphasis on computer simulations (Logsdon, 1980). Before that time the available computer instruction materials were generally limited to problem solving, programming, and computer-assisted instruction. The resulting simulation packages were both typical and revealing of the ways that computers have been used in education. They were implemented to teach traditional concepts using new situations and in this fashion represented poor use of the computer in teaching science. As Seymour Papert of the Artificial Intelligence Laboratory at MIT stated:

> Technology in education usually means inventing bright new gadgets to teach the same old stuff in thinly disguised versions of the same old way. If the gadgets are computers the same old teaching becomes incredibly more expensive and biased towards its dullest parts, namely the kind of rote learning in which measurable results are obtained by treating students like pigeons in Skinner's box (Logsdon, p. 191).

Any change in the content of science courses will be gradual. The first step is to identify the areas of the traditional science curriculum which lag behind the new technologies. These then represent prime targets for innovative uses of computers, since the computer can be used to enhance the subject matter and stimulate interest in science.

Significance of the Study

The purpose of the general physics sequence is to provide a broad-based introduction to physical phenomena and to the methods of solving problems encountered in engineering and science. This sequence is usually required of physical science, engineering, and engineering technology majors.

According to Peckham, modern scientists and engineers depend upon the computer as routinely as their predecessors depended upon the slide rule (Peckham, 1971). However, Tinker (1978) observed that the field of applications of the computer to physics teaching is continually expanding, but is fractured and disorganized. The Commission on College Physics (Peckham, 1971) concluded that there is a lack of widely available textbook materials for the undergraduate science curriculum that are computer-oriented. According to Hubin (1980) little has been done to remedy this problem in the past ten years. The number of such texts is still small, and the material contained in them is limited.

The findings of the present study should be of use to physics educators and curriculum developers in assessing the kinds of materials and instruction needed to help students achieve the desired level of computer literacy. Additionally, the findings should help these groups to determine priorities among computer literacy objectives.

Research Objectives

This study involved the compilation of a list of basic objectives concerning skills, knowledge, and attitudes about computers and computer technology for use in the general physics sequence. The study was designed to answer the following research questions:

1. What is the universe of objectives which define computer education for students completing the college-level general physics sequence?
2. Which of these objectives define a minimum subset of objectives that constitute computer literacy for students completing a general physics sequence?
3. Is the rating of computer literacy objectives by physics educators affected by the type of institution in which they teach (i.e., two-year, four-year, or university)?
4. Do physics educators perceive that this level of computer literacy should be achieved as a prerequisite or as part of the sequence?
5. What are the methods that physics educators can use to introduce the computer into the general physics sequence?

CHAPTER II

REVIEW OF THE LITERATURE

Introduction

This chapter is organized into five sections. In the first section studies which review the role of the computer in science are considered. These studies indicate that the computer is becoming an indispensable tool of science. In the second section studies which review the role of the computer in college science instruction are considered. These studies indicate that the computer is being used at an increasing rate in college science instruction. Next, studies of computer literacy in physics instruction are reviewed. These studies indicate that the use of the computer in undergraduate physics courses lacks organization and direction. Then studies of general computer literacy are considered, to determine the broader constituents of computer literacy. Finally, the methodology of needs assessment in curriculum development is considered, since this was the methodology used in this study to determine the objectives of computer literacy for students completing the general physics sequence.

The Role of the Computer in Science

The explosion in computer technology over the past five years has resulted in the introduction of the computer into nearly every facet of modern life. Nowhere is this phenomenon more evident than in physical and engineering sciences and technologies. The modern scientist, engineer, and technician depend upon the computer routinely for doing the work of their professions.

As far back as 1967 the Commission on Education of the National Academy of Engineering recommended that:

> Every electrical engineer should understand the capabilities and limitations of computers. He should know how to use computers as an aid in solving complex technical problems . . . . Students should obtain more experience with simulation techniques and model making. They should also learn the factors that limit the usefulness of these techniques . . . (Commission on Engineering Education, 1967, p. 1).

In the area of chemistry so many minicomputers and microcomputers have turned up in chemistry labs for experiment and process control that the American Chemical Society has established Computers in Chemistry as a separate division. The professional physics community has come to rely so heavily on the use of the computer that Springer-Verlag, in association with the physics community, has published Computer Physics Communications, a bimonthly journal, since 1969. This journal publishes articles in two areas, computational physics and computer programs in physics, both of which cover problems that the practicing physicist encounters using the computer in his work. One need only browse through the journal listings of any research library to note that all of the physical as well as many of the biological and social sciences are relying more heavily each day on the computer as a tool to accomplish their work.

The computer has had profound effects on instrumentation and on the collection, analysis, and storage of data (Abelson, 1983). Scientific instrumentation evolved rapidly during the past two decades. In many instances, sensitivities increased by several orders of magnitude. It became possible to make new kinds of measurements in studies of phenomena that occur, for example, in 10^{-12} seconds or less. Instruments containing dedicated microcomputers have become common. The computer can free scientists from the limitations imposed when they must attempt to hold all variables except one constant during a measurement (Enke, 1983). The computer also frees the scientist from the necessity of finding sensors that are linear in the quantity measured.

Present day instrumentation can obtain and record enormous amounts of data. The volume of these data is so great that computers and associated memory devices have become essential in data management. Goldstein (1982) tells of activities of many companies in developing optical disks, one of which is designed to store 200 billion bits of information or the equivalent of about 500,000 pages of text. Video and optical disk computer memories will have an important role in storage of scientific information, and they may provide a new publication mechanism.

A large fraction of the total number of scientists active in research and development have ready access to computers (Abelson, 1982). Many have terminals near their desks, and increasing numbers have them at home. By using telephone or other linkage, it is possible for them to send electronic mail to distant colleagues and to tap into a large number of databases. The development of scientific numerical databases has been slow, but they are being formed and they will be valuable.

Until recently the telephone was the crucial link between members of "invisible colleges" of researchers (Newell and Sproul, 1982). Among those who are familiar with computers, there is the beginning of an evolution toward using computer networks as the crucial linkage. The pioneering example was ARPANET, which serves the needs of computer scientists by providing electronic mail among the participants. The network links a number of universities, national laboratories, and other installations. Another network is SUMEX-AIM (Stanford University Medical Experimental Computer-Artificial Intelligence in Medicine). It links a group of medical scientists around the country who are concerned with computer applications in medicine. Recently, a group of geneticists formed a network (GENET) to make use of computers in work related to recombinant DNA. Other networks have been authorized or are being planned.

Scientists routinely use the computer to automatically plot the results of a computation. Computer-generated animation in particular provides an effective visualization tool, allowing researchers to view dynamic simulations of chemical, physical, mechanical, or strictly mathematical construction (Knowlton, 1981). Another application of computer graphics is in chemistry, where it is probably the only reasonable method for investigating the interaction between large molecules (Langridge, Ferrin, Kuntz and Connolly, 1981). Whereas the traditional plastic model of molecules is usually bulky, fragile, and difficult to modify, the computer model has none of these drawbacks.

At the other end of nature's scale, computer animation applied to astronomy permits several million years of galactic interactions to be compressed into a few seconds. Astronomers test models of galactic evolution and interaction by comparing a computer-generated view of model galaxies to the static views seen through their telescopes. The realistic animation of Voyager spacecraft maneuvers for the Jupiter and Saturn flybys, shown to the general public on network newscasts, is a NASA mission planning aid as well as a great public relations device (Blinn, 1981).

These examples demonstrate that the computer is becoming an increasingly important tool of science. Consequently there is an increasing need for more scientists who are trained to use the computer. The present study is an effort to determine how much and what kinds of computer training should be given in the introductory college physics sequence.

The Role of the Computer in College Science Instruction

The role of the computer in physics instruction became more clearly defined at the Irvine Conference of the Commission on College Physics in 1965. Three modes of computer utilization were distinguished: (1) computational, (2) simulation, and (3) tutorial.

The tutorial mode brings the student into active dialogue with the computer. The computer presents the student with problems, evaluates her response, possibly supplies remedial assistance, and guides her into the next problem. This type of instruction is generally known as CAI (computer assisted instruction), or as Taylor (1980, p. 7), called it, "computer assisted learning, tutor mode." Bork (1981) and his colleagues at the Educational Technology Center of the University of California, Irvine, developed a general physics sequence that utilizes the computer primarily in this mode.

Wooley (1976) found that computer-aided instruction did not improve students' ability to cope with the mathematics that they encounter in an introductory college-level astronomy course. It should not be expected that the use of the computer would improve mathematics skills, but a given level of computer literacy may improve insight into physical principles. This would be due to using the computer to implement more simple numerical methods. Liu (1976) found that supplementary computer-assisted instruction in college physics problems helped students to enhance their problem-solving ability.

The computational and simulation modes (collectively referred to by Taylor as the tool mode) are the modes that are generally used by practicing engineers, scientists, or technicians in their work. The tool mode saves time and effort by transferring tedious and sometimes routine clerical tasks to the computer. This benefit also should be attractive in physics instruction.

Mead (1976) evaluated the tool mode use of computers in an introductory college physics course by teaching students in an experimental group to write computer programs to solve the same problems assigned to a control group to solve by traditional methods. He found that students using the computer did not achieve higher scores on examinations than did the control group. Also, these students did not have more favorable attitudes than the control group toward either problem solving or physics at the end of the course. Mead observed informally that students complained that programming the computer to solve these problems took too much time.

It may well be that the students of Mead's study had a legitimate complaint, since the problems assigned to the experimental group required extra work. If the problems were sufficiently rudimentary to allow the control group to solve them by hand, the additional difficulty of writing programs to solve the problems and to implement the solutions would appear to these students as a punishment (extra work) for taking part in an experiment. Furthermore, this is an example of misuse of the computer in education since it does not demonstrate for students the power of the computer as a problem solving tool.

Stannard (1970) used the computer in an experiment in a general physics course over a two year period at the State University of New York, Binghamton. This experiment utilized computer programs that simulated physical problems that were otherwise difficult to investigate. The student specified all calculated results in both tabular and graphical form. Prior to the simulation, a tutorial series of multiple-choice questions was used to familiarize the student with the problem to be simulated and to help him make an intelligent parameter selection. Similar questions were available to guide the analysis of the results of the calculations and to allow him to repeat the simulation with variations of any or all of the parameters. The program ensured that the student could not consider physically meaningless parameter values. In addition, programs for error analysis were made available so that with minimal computer literacy the student could apply the computer to his laboratory data analysis without having to write his own programs.

Stannard reported that student opinion was generally in agreement that if the computer had been used for the laboratory data analysis applications alone, a net savings in time would have been effected. Further, students estimated that the time required by the computer averaged about an hour a week, and they felt this was worthwhile.

The use of computers in physics instruction is growing (Bork, 1980). Several textbooks (Ehrlich, 1973; Merrill, 1976; Bennett, 1976) are available for instructing students how to write physics simulations in BASIC and FORTRAN. Much of the instructional computation previously done on mainframe computers will probably be adapted to PET, APPLE, Radio Shack, and other inexpensive personal computers as physics teachers realize that they can cut loose from centralized computers under the control of others and get video graphics and fast response as a bonus.

Helpful as computer-assisted instruction, drill, problem solving, and simulations are, they are not necessarily the most valuable uses of computers in physics instruction. Physics depends upon measurement, and microcomputers, particularly the inexpensive single-board variety, can be made into versatile laboratory measuring instruments.

Rafert and Nicklin (1982) argue that microcomputers should become as common as voltmeters and scopes in labs at all levels. Microcomputers can be made into very sophisticated timers, data loggers, and data manipulators. Also, microcomputers can easily turn any oscilloscope into a storage scope and any strip chart recorder into a hard copy display for transients. They also assert that they see little evidence that much use is being made of microcomputers to monitor and control experiments in the introductory physics lab.

Many applications of the computer in the general physics sequence have been reported. For example, Turner (1976) reported the use of the computer in the introductory lab to facilitate the evaluation of propagated error. Dowd (1978) used the computer in the general physics laboratory to provide simulations that encourage active, discovery-based learning. Farquhar (1977) reported on the use of the computer in the introductory physics lab to tutor students through interactive curve-fitting analysis procedures. The range of hardware used in these laboratory applications is extraordinary, from a minimal BASIC machine to an IBM 360/65. Increasingly typical is the stand-alone, dedicated laboratory microcomputer that can do all of the above and that, in addition, is relatively inexpensive.

Chonacky (1982), at Southern Connecticut State University, reported using the microcomputer to cultivate a high degree of participation by students in general physics experiments. The microcomputer enables students to do more realistic analyses of their experimental data, and subsequently to act upon their findings. In particular, students participate in the statistical analysis of data, correlation analysis (i.e., curve fitting), empirical investigation-hypothesis testing, and the sharing of experimental data for the purpose of cooperative analyses. A frequent application is to identify patterns in the data. Facile data manipulation rewards attempts by students to discover these underlying patterns. These goals are somewhat at variance with the more traditional goals that stress verification of physical laws and the elucidation of principles. Chonacky claims that not only are his goals better served by the computer than are traditional goals, but his goals are more worthwhile.

Studies of Computer Literacy in Physics Instruction

Two camps of computer literacy advocacy have emerged recently. The outspoken advocate of one of these positions is Arthur Luehrmann (1980), who argued that computer literacy must mean an ability to do something and not merely to recognize, identify, or be aware of facts which are alleged about computing. Advocates of a more comprehensive view include Moursund (1976), Rawitch (1978), Watt (1980) and Anderson, Klassen and Johnson (1980). In their view computer literacy involves more than doing. It also involves knowledge about computers that the layperson needs to function effectively in society, understanding how computers can be productively used, and understanding of computer-society issues. This view also involves an understanding of computers that enables one to evaluate computer applications as well as to do things with computers.

According to Bork (1978), the following complaint is often registered at doctoral examinations in physics: while some graduate students can carry out the mathematical manipulation, even for very advanced problems, they still have little intuition as to what is happening physically with the phenomena. Bork argued that such insight is critical for successful research, and so courses should consider how to assist students in this regard:

> An important aspect of education in the sciences is the development of intuition concerning phenomena predicted by fundamental theories. Science education today is primarily

> aimed at expanding theories and showing how to apply them. The computer can greatly aid students in building such intuition by providing a rich range of experiences not found in the everyday world or in the laboratory (Bork, 1978, p. 796).

Besides helping students develop intuitions about phenomena, computer literacy also can entail knowing how to use the computer as a method of experimentation. For example, Garmon (1981) argued that chemists should learn how to use computers in this way:

> The explosion of computer chemistry programs is due partly to laboratory economics. "Research is expensive," says computer chemist George T. S. Wolken Jr. . . . "Manipulation of computers instead of chemical molecules can save valuable time and remove the necessity for making and testing of materials of questionable value." Because computer costs decrease annually about 30 percent, and because days of computer-assisted planning can save weeks of expensive laboratory trial and error, more chemists are turning to computers to save research dollars. . . . But the computer's laboratory popularity is a consequence of more than dollars and cents; it also stems from the fact that computers can take chemists beyond the realm of bench-top experimentation (Garmon, 1981, p. 140).

Several courses offered at the college level to provide students of physics with computer literacy at a level expected of a professional scientist have been reported. Patterson (1981) reported about a course at the South Dakota School of Mines and Technology for a small class of advanced undergraduate students of physics. The course required the students to use the computer in a project. Patterson found that students gained valuable insight into the physics of their project. This level of insight would not have been gained without computer use. Furthermore, the research atmosphere of the course gave students a feeling for the real-world work of a physicist.

Hurd (1981) at Surrey University described a degree course designed to produce graduates with a thorough grounding in physics coupled with a working knowledge of microcomputers. This degree course offers students a highly stimulating and demanding course of study in which they develop fluent use of microcomputers over a four year period along with the more traditional studies in physics. Christiansen (1978) reported an altogether different approach to computer literacy for students of physics at the Technical University of Denmark. This approach involves students in their freshman year after they have completed elementary courses in mathematics, mechanics, and elementary computer science. The students take a special course for one week, eight hours per day. In this course students investigate the new tool offered by the computer in three projects. The first project demonstrates for the student that very accurate solutions to physical problems can be found using simple numerical methods. The second project involves the student in a physical problem closely related to some engineering problem met in practice and for which the possible solution cannot be obtained easily without the use of the computer. In the third project students look at numerical solutions to problems which have no analytical solution.

The applications of the computer to physics teaching are many and continually expanding, but the field is fractured and disorganized. The literature indicates that many people are pursuing their own interesting projects with idiosyncratic equipment and approaches that cannot be shared. If these resources are to be drawn together, a common set of computer literacy objectives for physics students will be needed.

Studies of General Computer Literacy

Curriculum development work in computer science has been a continuing effort of the Curriculum Committee on Computer Science of the Association for Computing Machinery. The latest effort of this group is titled Curriculum '78, which was published in the Communications of the ACM in March 1979. In preparing this set of recommendations, the writing group paid considerable attention to the developments reported in the literature and to informal comments received regarding ACM's earlier set of recommendations in Curriculum '68.

As part of the background work in preparation of Curriculum '78, an extensive survey of the literature of computer science education since Curriculum '68 was prepared and published. Also, a variety of individuals representing different types of institutions and different interests within computer science were brought to the Curriculum Committee on Computer Science's meetings and working sessions to present their ideas. A working draft of Curriculum '78 was prepared and published in the June 1977 SIGCSE Bulletin so that the material would receive as wide a distribution as possible, and so that an input from interested individuals could be obtained. Prior to the publication of the working paper, draft reports on specific areas were widely circulated and numerous panel and discussion sessions were held both to inform interested parties of the thinking of the committee and to allow for comments and suggestions on the work done to that point.

The wide circulation of the various drafts and working papers resulted in numerous suggestions and constructive criticisms, many of which are incorporated in the final draft of Curriculum '78.

The findings of the Curriculum Committee on Computer Science resulted in a set of objectives for undergraduate computer science majors. The objectives were stated at three levels: elementary, intermediate, and advanced. The elementary core objectives, which are fundamental and thus relevant to this study, are as follows:

1. be able to write programs in a reasonable amount of time that work correctly, are well documented, and are readable;
2. be able to determine whether or not they have written a reasonably efficient and well organized program;
3. know that general types of problems are amenable to computer solution, and the various tools necessary for solving such problems;
4. be able to assess the implications of work performed either as an individual or as a member of a team;
5. understand basic computer architectures;
6. be prepared to pursue in-depth training in one or more application areas or further education in computer science (Austing, 1979).

Another effort to define a set of computer literacy objective was the work of Neill (1977). He compiled a list of forty-three computer literacy topics from textbooks, computer science journals, and computer education journals. He then submitted this list to six computer educators for criticism. This resulted in a revised list of forty-seven topics. Neill next identified four different types of skills that are relevant to some computer literacy topics. They are:

a. using operating computer equipment or computer products
b. designing components, programs, or systems associated with computers
c. constructing computer devices or systems
d. maintaining computer hardware or software (Neill, 1977, p. 41).

He then examined the list of 47 topics and derived appropriate objectives for all topics where knowledge, attitudes, or one of the four types of skills listed above could be identified. Using these objectives, he developed an instrument which used three scales (attitude, knowledge and skill) to determine the relevance of the objective to a high school computer literacy curriculum. An example of the type of item developed by Neill to represent the 47 topics is as follows:

> Topic 18
> Information retrieval and file management applications are computer programs which store, organize, update, search, and retrieve information such as customer accounts, library circulation data, or school enrollment data.

X = I do not have sufficient understanding to rate the objectives for this topic						X
knowledge of information retrieval applications	0	1	2	3	4	5
skill in using information retrieval applications	0	1	2	3	4	5
skill in designing information retrieval applications	0	1	2	3	4	5
attitude toward information retrieval applications	0	1	2	3	4	5

> (Neill, 1977, p. 104).

Based on the results of his study, Neill defined a computer literate high school graduate as one who:

> [W]ill have developed knowledge and attitudes about the impact of computer technology on society and will understand the use of computers in the problem-solving process (Neill, 1977, p. 87).

The Minnesota Education Computing Consortium (MECC) compiled a list of seven domains of computer literacy. This taxonomy of domains was the result of both the Minnesota assessment of computer literacy conducted in 1978 and the National Assessment conducted in 1980.

An important initial phase of the MECC study was to search and synthesize the available literature into a coherent set of instructional objectives that reflects what is implied by the phrase "computer literacy." The initial list of objectives was subjected to many revisions and then circulated to twelve "outside experts" representing the professional societies, industry, and education, for reaction and validation. On the basis of feedback from these individuals the objectives were categorized into a taxonomy having seven domains:

1. programming and algorithm skills
2. skills in computer usage
3. hardware and software principles
4. major uses and applications principles
5. limitations of computers
6. personal and social impacts
7. relevant values and attitudes
   (Anderson, 1981), p. 689).

This taxonomy places strong emphasis on experiential aspects of computing as well as on those aspects traditionally called computer awareness. While each domain may not be given equal weight, a comprehensive approach to establishing a universe of computer literacy objectives requires that all these domains be included.

It seems likely that future endeavors to produce computer literate students in the general physics sequence will have elements from each of these domains. Assuming agreement, however, many questions remain unanswered: Are there domains missing from this list which are important to physics educators? How much knowledge is necessary in each domain? How many skills are implied by each statement? At what level must the knowledge and skills be satisfactorily demonstrated in each domain? These are questions addressed in the present study.

Use of Needs Assessment Technology to Define Computer Literacy

Borg and Gall (1979) described the educational research and development cycle used by the Far West Laboratory for Educational Research and Development, which is part of a national network of centers for improving education through research and development technology. The first step of the cycle includes needs assessment, which is a technique for identifying the most important objectives to be accomplished in an instructional program or curriculum. Popham (1971) defined educational need as the difference between a student's current status and her desired status.

The model of curriculum development created by Tyler (1950) has been widely used since the early 1950s. The Tyler model requires the curriculum developer to address these questions:

1. What educational purposes should the school seek to attain?
2. What educational experiences can be provided that are likely to attain these purposes?
3. How can these educational experiences be effectively organized?
4. How can we determine whether these purposes are being attained?

Tyler's questions are frequently credited with providing the impetus for the behavioral objectives movement of recent years. Leaders of this movement argue that instructional goals should be stated in behavioral terms, with built-in criteria for measurement of outcomes. Selections are then made from alternative activities to help the student attain the desired behavioral objectives. The activities are organized into a scope and sequence, and evaluation is conducted to determine how well the activities have helped students achieve the objectives.

Popham and Baker (1970) stated that an instructional objective should include a performance criterion to guide direct classroom instruction. However, they indicate that such specificity is not appropriate in the needs assessment phase of curriculum design. This study is an assessment of needs and hence the elements of computer literacy used in this study will be defined by instructional objectives stated without a performance criterion, as in this example:

> the student will understand the general system architecture of a computer.

A model for assessing curricular needs was developed by the Committee on Assessing the Progress of Education (CAPE). Their model is concerned with providing information about "what students know, what skills they have developed, and what their attitudes are" (Womer, 1970, p. 1). In order to achieve this task, the committee developed objectives for each of ten subject areas. The objectives were sifted through subject matter specialists and panels of "thoughtful lay adults" until the objectives were accepted as relevant to public education. These objectives then served as the basis for exercises which were designed to test students' mastery of the objectives. The information which resulted from the testing phase then served as a basis for making curricular decisions.

The initial stage of this process (that is, the development of objectives) is most relevant to this study. The elements of computer literacy for students completing the general physics sequence were identified and defined as a set of curricular objectives. These objectives were then submitted to physics educators. The final list of objectives reflect a degree of consensus regarding the content of computer literacy for those students completing the general physics sequence.

CHAPTER III

METHODOLOGY

Introduction

The present study was descriptive in intent. The two major purposes of the study were: (1) to describe the possible range of computer literacy objectives for general physics; and (2) to describe the views of college and university physics educators about the level of computer mastery and the most important objectives from the possible range for students completing the general physics sequence.

Research Design

Phase I: Identifying the Universe of Computer Literacy Objectives

The study was conducted in three phases. The goal of phase I was to create a universe of computer topics that students who complete the general physics sequence might have studied. The achievement of this goal involved two tasks. The first task was to construct an interview schedule (see Appendix One). This interview schedule was structured around the seven domains of computer literacy defined by the Minnesota Educational Computer Consortium. The domains are:

1. programming and algorithm skills
2. skills in computer usage

3. hardware and software principles
4. major uses and applications principles
5. limitations of computers
6. personal and social aspects
7. relevant values and attitudes.

Henerson (1978) advised that probes are a necessary part of any interview. Probes are questions that elicit additional information in the case of incomplete or vague answers. A list of standard probes used in this phase of the study are included in Appendix Two.

The second task of this phase of the study was to interview five physics professors who have expertise in the use of computers in physics by virtue of their recent, in-depth involvement with computers in teaching physics courses, or in doing physics research. All of these professors have been teaching college-level physics for more than ten years, and are currently involved in courses in which computer use is part of the curriculum. Three of the five professors were, at the time of the interview, teaching general physics courses in which students were required to use the computer. The other two professors were teaching upper-division courses in which the students were required to use the computer. As a group these professors had published eleven recent articles or literature reviews concerning computer usage.

A direct interview approach was utilized; that is, each respondent was contacted by telephone, an interview was requested, the purpose of the interview was explained, and a copy of the interview schedule was sent to the respondent at least one week prior to the interview.

Interviews of at least one and one-half hours duration took place in the winter of 1983. The interviews took place on the respondent's campus, one each located in Sacramento and Palo Alto, California, Ashland, Oregon and two in the metropolitan Portland, Oregon area.

Phase II: Developing an Interview Schedule to Determine Computer Literacy

The goal of phase II was to generate an interview schedule having more structure and closed format than the interview schedule of phase I. The schedule included the universe of objectives obtained in phase I and further refined by this phase of the study. This interview schedule was designed to be used in phase III of the study. The achievement of this goal involved three tasks. Each of these tasks was designed to determine whether the objectives obtained in phase I omitted important categories of objectives, whether objectives were combined that should be separate, and whether some objectives were redundant, ambiguous, or meaningless.

The first of these tasks was to compare the list of objectives obtained in phase I with the objectives of Curriculum '78.

The second task of this phase of the study was to compare the phase I list of objectives with the list of topics and objectives determined by Neill (1977).

The final task of this phase was to compare the list of objectives that resulted following task two with the list of objectives compiled by the researchers at MECC (Johnson, 1980).

The following examples illustrate the process of refinement in developing the interview schedule of phase III from the responses to the interview schedule of phase I. Responses to the phase I interview schedule question, "What sorts of hardware principles should these students learn?" included:

1. understand analog-to-digital interfacing circuitry
2. understand digital-to-analog interfacing circuitry
3. understand transducer concepts
4. understand digital logic circuitry.

In each case the objective was concerned with data acquisition and process control techniques. No particular level of understanding was stated or given with any of these objectives. A comparison of these responses with the elementary objectives of Curriculum '78 revealed that the expectation for computer science majors in these areas, prior to upper-division, are only at the most rudimentary level. Therefore, the four objectives were combined into two general questions regarding data acquisition and process control. The first of these questions, question 20 (see Appendix Three), was designed to elicit the opinion of the respondent with regard to the appropriateness of these topics in the general physics sequence. The second question, question 21 (see Appendix Three), was designed to determine a level of understanding appropriate for general physics.

None of the experts interviewed during phase I felt that personal or social aspects of computing or computer usage should be taught in general physics. However, comparisons of Neill's and MECC's lists of topics and objectives include nine different computer literacy objectives associated with personal or social aspects of computing. Therefore, a general question on the appropriateness of these issues in the general physics sequence was included in the phase III interview schedule (see Question 29, Appendix Three).

Another example of "level of understanding" refinement resulted from comparison of phase I responses in the programming and algorithm domain with the MECC objectives. During phase I no level of understanding was specified by the experts with regard to the algorithms that those experts felt were useful and/or appropriate for general physics. The MECC objectives imply various levels of understanding in the domain of programming and algorithms. For example,

> Follow and give correct output for a simple algorithm.
> Given a simple algorithm, explain what it accomplishes (i.e., interpret and generalize).
> Modify a simple algorithm to accomplish a new, but related task.
> Detect logic errors in an algorithm
> (Johnson, 1980, p. 93).

As a result of reviewing these objectives, the four levels of understanding associated with questions five through eleven of the phase III interview schedule were generated.

The interview schedule resulting from these tasks and the list of standard probes are presented in Appendix Three and Appendix Four, respectively.

Phase III: Selecting and Interviewing a Sample of Physics Educators to Determine Computer Literacy

The goal of phase III was to identify a subset of instructional objectives that define computer literacy for students who have completed the general physics sequence. To achieve this goal the instrument developed in phase II was used to interview a random sample of twenty-one west-coast physics educators, seven each at the university, four year, and two-year college levels.

The population of physics educators from which the sample was drawn was defined as professors of physics at two- and four-year west coast colleges and universities who belong to the American Association of Physics Teachers (AAPT). To assure adequate representation of the three levels of institutions (two- and four-year colleges and universities), the names of seven professors of physics at each level of institution were selected randomly using the most current (1980) AAPT membership directory.

Due to financial constraints the study was confined to west coast colleges and universities. It was felt that the differences in financing and educational mission of each of the types of institutions may affect the thinking of professors with regard to computer literacy. However, it was felt that the methods of financing and the educational mission of the types of universities are consistent across the country and therefore geographical location was unlikely to cause bias.

Data Analysis

In general, the design of the phase III interview schedule made the quantification of the results of the interviews easy. However, an occasional respondent chose a level of understanding for the algorithms of questions five through eleven that did not exist. For example, one respondent set an appropriate level of student understanding for some of these algorithms at level two and one-half. When such responses were given, the level was lowered to the next whole number response for quantification purposes.

Questions that asked for suggestions from the respondent often elicited lengthy descriptive suggestions. These descriptions were generally quantified under the topic of general physics to which they were associated. For example, various kinds of projectile motion and trajectory simulation were described in depth, but were included under projectile simulations for quantification purposes.

Some respondents chose several programming languages and some respondents ranked several choices of language as being appropriate. All choices of language were included in the quantification process. Likewise, some respondents chose various versions of a particular language, for example, FORTRAN 77 or FORTRAN IV. All such choices were included under the heading FORTRAN for quantification purposes.

CHAPTER IV

RESULTS

Introduction

Results of the study are organized by computer literacy domain. For the first two domains, the results are presented in three tables. The first table contains the list of the universe of objectives determined in phase I of the study. The second table for a domain contains the universe of objectives listed in rank order by the percentage of the phase III sample indicating that the objective would be useful and/or appropriate for the general physics sequence. Also included in this table is the percentage of each stratum (two-year college, four-year college, or university professor) agreeing that the objective is useful and/or appropriate for the general physics sequence. The third table for a domain, when appropriate, indicates percentage of the phase III sample indicating whether the objective should be learned as a prerequisite, as a corequisite, or as part of the sequence.

These three tables address the first four research questions specified in Chapter I:

1. What is the universe of objectives which define computer education for students completing the college-level general physics sequence?

2. Which of these objectives define a minimum subset of objectives that constitute computer literacy for students completing a general physics sequence?
3. Is the rating of computer literacy objectives by physics educators affected by the type of institution in which they teach (i.e., two-year, four-year, or university)?
4. Do physics educators perceive that this level of computer literacy should be achieved as a prerequisite or as part of the sequence?

There are no tables for Domain 6 from phase I. During the first phase the only objective that was mentioned for the domain of social and personal aspects of computing was the concern of two professors for students who become enamored with playing with the computer. Thus, a question asking for suggested objectives in this domain was included in the interview schedule for phase III.

Additional tables of results are given for some domains. These contain ancillary information gathered with regard to computer literacy objectives for general physics.

Domain 1

Table 1 contains the universe of objectives for the domain of programming and algorithm skills. The objectives are presented in rank order by the number of experts that identified the objective as useful or appropriate. There were fifteen objectives recommended with a majority of the panel recommending the first five of these objectives.

Table 2 contains the results of phase III of the study for the domain of programming and algorithm skills. During phase II of the study two of the objectives recommended in phase I were combined in the domain. The fourteen objectives are present in rank order by the percentage of the total sample that indicated that the objective would be useful for general physics. The table also includes the percentage of each stratum (two-year college, four-year college, and university) that indicated the objective would be useful. A majority of the respondents felt that the first four objectives would be useful.

Table 3 contains information about whether students should learn these skills of domain 1 as a prerequisite, corequisite, or as part of the sequence. The largest percentage, although not a majority, of the respondents felt that these skills should be taught as part of the sequence.

Table 4 contains information regarding the level of understanding of the algorithms that the respondent felt was appropriate for students of general physics. These levels include:

Level 1 = Intuitive understanding of the algorithm supplied by instructor.
Level 2 = Write a program for the algorithm supplied by the instructor.
Level 3 = Be able to derive the algorithm.
Level 4 = Be able to derive the algorithm and write a program.
Level 5 = Considered inappropriate by respondent.

The majority of respondents felt that either level 1 or level 2 was the appropriate level of understanding for algorithms involving numerical methods for finding derivatives, evaluating integrals, curve fitting, and function approximation. A majority of the respondents felt that algorithms for determining numerical solutions to differential equations were inappropriate for general physics. A majority of the four-year college respondents felt that all of the algorithms were inappropriate for general physics except algorithms for curve fitting.

Table 5 is a list of reasons given by the panel of experts for the various programming languages that they felt were most appropriate. Table 6 is a list of reasons for the choice of language given by the sample of phase III. This list is ranked by the number of respondents choosing the language. The majority of the respondents chose BASIC as the language most appropriate for general physics and the most frequent reason given for this choice was ease of learning and relearning for students.

TABLE 1. Domain 1--Universe of Programming and Algorithm Skills

---

In the domain of programming and algorithm skills students completing the general physics sequence should be able to:

1. obtain derivatives numerically by a variety of methods of the finite difference calculus. (5)
2. evaluate integrals numerically by a variety of methods. (5)
3. use the BASIC programming language. (4)
5. use matrix methods to solve systems of equations. (3)
6. use an assembler language. (2)
7. use the FORTRAN programming language. (2)
8. use the Pascal programming language. (2)
9. determine numerically the roots of equations by a variety of methods. (2)
10. determine the solution to systems of simultaneous linear algebraic equations. (2)
11. determine numerically the solutions to ordinary differential equations. (2)
12. use the ALGOL programming language. (1)
13. use the APL programming language. (1)
14. use the PL/1 programming language. (1)
15. generally approximate continuous functions. (1)

NOTE: The numbers in parentheses indicate the number of respondents from the panel of five experts who indicated that this objective was important for computer literacy for students of general physics.

TABLE 2. Domain 1--Determination of a Subset of the Universe of Programming and Algorithm Skills

Computer Literacy Objectives	Percentage of Sample Indicating Objective Would be Useful			
	Total N = 21	2 yr. N = 7	4 yr. N = 7	Univ. N = 7
fit data by least-squares methods and approximate continuous functions.	86	100	100	57
use the BASIC programming language at a useful tool level.	81	71	86	86
evaluate integrals numerically by a variety of methods.	73	86	57	86
obtain derivatives numerically by a variety of methods of the finite difference calculus.	71	86	43	86
determine the solution to systems of simultaneous algebraic equations, particularly via matrix methods.	43	71	29	29
use the Pascal programming languge at a useful tool level.	38	43	14	57
determine numerically the roots of equations by a variety of methods.	38	57	29	29
use the FORTRAN programming language at a useful tool level.	33	43	29	29
determine numerically the solutions to ordinary differential equations.	33	30	30	43
use the APL programming language at a useful tool level.	10	14	0	14
use an assembler language at a useful tool level.	5	14	0	0

TABLE 2 continued

	Total N = 21	2 yr. N = 7	4 yr. N = 7	Univ. N = 7
use the ALGOL programming language at a useful tool level.	0	0	0	0
use the PL/1 programming language at a useful tool level.	0	0	0	0

TABLE 3. Domain 1—Timing of Learning of Algorithm Skills with Respect to Timing of General Physics

Percentage of Sample Recommending Algorithm Learning as a:	Total N = 21	2 yr. N = 7	4 yr. N = 7	Univ. N = 7
Part of sequence	48	29	43	71
Prerequisite	33	29	57	14
Corequisite	14	43	0	0

TABLE 4. Level of Understanding of Algorithms by Students Completing General Physics

Interview Question Concerning Algorithms[a]	5	6	7	8	9	10
Level of Understanding	Percentage of Sample Considering Level Appropriate for the Algorithm					
Intuitive understanding of the algorithm supplied by instructor						
Total (N = 21)	29	29	15	29	71	14
2 year (N = 7)	43	43	29	43	71	14
4 year (N = 7)	29	29	14	29	100	29
University (N = 7)	14	14	0	14	43	0

TABLE 4 continued

	5	6	7	8	9	10
Write a program for the algorithm supplied by the instructor.						
Total (N = 21)	24	24	19	14	14	14
2 year (N = 7)	29	29	29	29	29	14
4 year (N = 7)	14	14	14	0	0	0
University (N = 7)	29	29	14	14	14	29
Be able to derive the algorithm.						
Total (N = 21)	5	5	0	0	0	0
2 year (N = 7)	14	14	0	0	0	0
4 year (N = 7)	0	0	0	0	0	0
University (N = 7)	0	0	0	0	0	0
Be able to derive the algorithm and write a program.						
Total (N = 21)	10	10	5	0	0	0
2 year (N = 7)	0	0	0	0	0	0
4 year (N = 7)	0	0	0	0	0	0
University (N = 7)	29	29	14	0	0	0
Considered inappropriate by respondent.						
Total (N = 21)	33	33	62	57	14	71
2 year (N = 7)	14	14	43	29	0	71
4 year (N = 7)	57	57	71	71	0	71
University (N = 7)	29	29	71	71	43	71

[a] 5. algorithms for obtaining derivatives numerically.

6. algorithms for evaluating integrals numerically.

7. algorithms for numerically evaluating the roots of equations.

8. algorithms for determining the solutions to simultaneous linear algebraic equations, particularly using matrix methods.

9. algorithms for determining least-square curve fitting and functional approximations.

10. algorithms for determining the numerical solution to ordinary differential equations.

TABLE 5. Domain 1--Universe of Programming Languages

Language Choice of Panelists	Reason for this Choice
ALGOL	1. Solution of numeric and scientific problems. 2. Underlying structure and discipline.
APL	1. Dynamic power in terms of array manipulation, i.e., ability to expand, compress and reshape arrays at will. 2. Intended for interactive use, i.e., commands are interpreted and executed when specified by terminal user rather than compiled for later execution.
Assembler	1. Hardware cognizant, allows user to get at "nuts & bolts"; i.e., demystify the machine. 2. Do not require much hardware or softward support.
BASIC	1. Ease of learning for students. 2. Is available on most personal computers. 3. Can address hardware.
FORTRAN	1. Solution of numeric and scientific problems. 2. Produces efficient machine language code. 3. There are valuable libraries of FORTRAN subroutines available.
Pascal	1. Easy to write bug-free programs that are easily read and maintained. 2. Has all the power of FORTRAN or PL/1, but much greater structure, only slightly more difficult to learn than BASIC. 3. Ease of manipulation of sets, records, and linked lists. 4. Several structured looping commands.
PL/1	1. Very general-purpose language. 2. Adequate for many types of applications.

TABLE 6. Domain 1--Subset of Programming Languages[a]

Language Choice of Members of Sample		Reasons for this Choice
BASIC	1.	Ease of learning and relearning for students. (14)
	2.	Available on most microcomputers. (8)
Pascal	1.	Structure, modularity, and data structures. (7)
	2.	Computer Science Department has chosen as core language. (2)
FORTRAN	1.	Scientific problem solving strengths. (6)
	2.	Largely independent of machine. (1)
APL	1.	Matrix manipulation capabilities via arrays. (2)
Assembler	1.	Demystifies the machine by allowing the programmer to get at the "nuts and bolts" of the machine. (1)
Other		
a. FORTH	1.	Forces students to generate an overall strategy to solve a problem. (1)
b. C	1.	Hardware cognizance. (1)
None	1.	Students of general physics are already overwhelmed with work. (1)

[a] Numbers in parentheses indicate number of respondents giving this reason. Some respondents chose more than one language.

Domain 2

The universe of skills in computer usage that students completing the general physics sequence might acquire is shown in Table 7. While the universe of these objectives is small, it is very general and there was a high degree of consensus among the experts. A majority of the phase I respondents mentioned each of the objectives of the universe as being useful for students of general physics.

Even though specific simulations were not requested in the interviews of the panel of experts, several specific simulations to extend laboratory experiments in which the topic is difficult for students to grasp fully using standard laboratory equipment were given as examples. These include: projectile motion, impulse and momentum, and Gauss' law. These suggestions prompted the inclusion of a request for such suggestions during phase III.

The opinions of the sample with regard to appropriate skills in computer usage are presented in Table 8. These skills are presented in rank order by the percentage of the sample agreeing that the objective is appropriate for general physics. Most of the sample agreed that using the computer in the laboratory for graph plotting, curve fitting, and repetitive calculations is a useful and appropriate computer literacy objective for the general physics sequence. A majority of the sample indicated that using the computer to extend laboratory experiments by simulation is an appropriate objective.

Table 9 includes information regarding the timing for learning these skills in computer usage, that is, as a prerequisite, corequisite, or a part of the sequence. Of those respondents that indicated that these skills in computer usage are appropriate, most felt that the skills should be learned as part of the sequence.

Responses to the request for suggested simulations that would allow students to experience experimental behavior that lies outside the physical constraints of the laboratory are presented in Table 10. These data are presented in rank order by the number of respondents suggesting the simulation. The largest number of suggested simulation topics were in the areas of projectile motion and field theory.

TABLE 7. Domain 2--Universe of Skills in Computer Usage

In the domain of skills in computer usage students completing the general physics sequence should:

1. Be able to use computers for simulations which extend laboratory experiments. (5)
2. Be able to input data to a computer for graphing, repetitive calculations, and curve-fitting in the laboratory. (5)
3. Be able to use word processors to do reports, etc. (4)
4. Be able to operate computers interactively to solve assigned physics problems. (3)

NOTE: Numbers in parentheses indicate number of respondents from panel of experts considering the objective appropriate.

TABLE 8. Domain 2--Determination of Subset of Objectives for Skills in Computer Usage

Computer Literacy Objectives	Percentage of Sample Agreeing with Objective.			
	Total N = 21	2 yr. N = 7	4 yr. N = 7	Univ. N = 7
Be able to use the computer in the laboratory to plot graphs, do repetitive calculations, and curve fitting.	90	100	71	100
Be able to use computers in extending laboratory experiments by simulation.	62	86	29	71
Be able to operate computer interactively to solve assigned physics problems.	48	43	14	86
Be able to use word processors to write laboratory reports, term papers, etc.	43	14	43	71

TABLE 9. Domain 2--Timing of Learning of Skills in Computer Usage with Respect to Timing of General Physics

Percentage of Sample Recommending Learning Skills in Computer Usage to:	Total N = 21	2 yr. N = 7	4 yr. N = 7	Univ. N = 7
Plot Graphs, Do Repetitive Calculations, Fit Curves				
Part of sequence	62	86	29	71
Prerequisite	0	0	0	0
Corequisite	0	0	0	0
Extend Experiments by Simulation				
Part of sequence	90	100	71	100
Prerequisite	0	0	0	0
Corequisite	0	0	0	0
Solve Problems Interactively				
Part of sequence	43	14	43	71
Prerequisite	0	0	0	0
Corequisite	0	0	0	0
Write Reports				
Part of sequence	14	29	14	0
Prerequisite	48	29	29	86
Corequisite	0	0	0	0

NOTE: The four skills are the subset listed in Table 8.

TABLE 10. Domain 2--Simulations Suggested by Sample of Physics Educators During Phase III

Simulation Suggested	Percentage of Sample Suggesting.			
	Total N = 21	2 yr. N = 7	4 yr. N = 7	Univ. N = 7
Projectile motion	33	57	14	29
Electric and magnetic fields	24	29	14	29
Optics (Ray tracing) (Thin film interference)	19	29	14	14
Collisions (Impulse and momentum)	10	29	0	0
Mechanical traveling waves (Reflection from various boundaries, superposition)	10	14	0	14
Statistical phenomena (Radioactive decay, Brownian motion)	19	29	14	14
Orbital mechanics	19	14	14	29
Friction forces	5	14	0	0
Particle-wave duality (scattering)	5	0	0	14
Oscillatory motion (large amplitude pendula)	5	0	0	14
Rotational motion	5	0	0	14

Domain 3

The universe of objectives for the domain of hardware and software principles is shown in Table 11. There was a general consensus of opinion by the panel of experts about these principles. The principles endorsed as useful and/or appropriate all dealt with microcomputer-controlled data acquisition and process control.

Table 12 presents in rank order the percentage of the sample finding each objective useful and/or appropriate. A majority of the sample found all four of the objectives useful and/or appropriate.

The responses to a question concerning the level of understanding of these principles are presented in Table 13. A majority of the respondents indicated that students of general physics should understand these objectives at a rudimentary level. That is, students should use the principles as "black boxes" requiring only intuitive knowledge.

TABLE 11. Domain 3--Universe of Hardware and Software Principles

In the domain of hardware and software principles the student completing the general physics sequence should:

1. Learn the computer hardware concepts associated with microcomputer laboratory instrumentation. (5)
2. Learn the software concepts associated with microcomputer laboratory instrumentation. (5)
3. Learn the interfacing concepts associated with microcomputer laboratory instrumentation. (3)
4. Learn the transducer concepts associated with microcomputer laboratory instrmentation. (2)

NOTE: The numbers in parentheses indicate how many members of the expert panel considered the objective appropriate.

TABLE 12. Domain 3--Determination of Subset of Objectives for Skills in Hardware and Software Principles

Computer Literacy Objectives	Percentage of Sample Agreeing with Objective			
	Total N = 21	2 yr. N = 7	4 yr. N = 7	Univ. N = 7
Learn the computer hardware concepts associated with microcomputer laboratory instrumentation.[a]	76	100	71	57
Learn the interfacing concepts associated with microcomputer laboratory instrumentation.	76	100	71	57
Learn the transducer concepts associated with microcomputer laboratory instrumentation.	76	100	71	57
Learn the software concepts associated with microcomputer laboratory instrumentation.	62	86	43	57

[a] Learn in this table means exposure at almost any level. Level is more precisely defined in Table 13.

TABLE 13. Domain 3--Level of Understanding of Hardware and Software Principles

Hardware or Software Principle[a]	1	2	3	4
Level of Understanding	Percentage of Sample Considering Level Appropriate			
Students should have intuitive knowledge, that is, know the principle as a "black box."				
Total (N = 21)	71	57	71	71
2 year (N = 7)	100	86	100	100
4 year (N = 7)	71	43	71	71
University (N = 7)	43	43	43	43
Student should learn the principle at a level higher than as a black box.				
Total (N = 21)	5	5	5	5
2 year (N = 7)	0	0	0	0
4 year (N = 7)	0	0	0	0
University (N = 7)	14	14	14	14
Principle considered inappropriate by respondent.				
Total (N = 21)	24	38	24	24
2 year (N = 7)	0	14	0	0
4 year (N = 7)	29	57	29	29
University (N = 7)	43	43	43	43

[a] 1. Computer hardware principles for microcomputer instrumentation.
2. Software principles for microcomputer instrumentation.
3. Interfacing principles for microcomputer instrumentation.
4. Transducer principles for microcomputer instrumentation.

Domain 4

The domain of major uses and applications principles proved to be difficult to differentiate from the domain of computer usage skills. The results indicate a great deal of overlap in the domain of computer usage skills. The respondents indicated that the student should be able to "use" the computer to achieve the objectives, while in the domain of uses and applications principles the respondents indicated that the student should "know" that programs exist to achieve the objective.

Table 14 presents the universe of objectives for this domain. Table 15 presents in rank order the percentage of the sample agreeing that the objective is useful for general physics.

TABLE 14. Domain 4--Universe of Uses and Applications Principles

---

In the domain of uses and applications principles the student completing the general physics sequence should:

1. Know that the computer can be used to simulate physics concepts that are not easily observed in the general physics laboratory. (5)
2. Know that program and subroutine libraries exist that will allow the machine to do repetitive calculations, graphing and curve fitting. (5)
3. Know that the computer can be used for data acquisition and process control. (4)

NOTE: The numbers in parentheses indicate how many members of the expert panel considered the objective appropriate.

TABLE 15. Domain 4--Determination of a Subset of the Universe of Uses and Applications

Objective	Percentage of Sample Indicating Objective Would be Useful			
	Total N = 21	2 yr. N = 7	4 yr. N = 7	Univ. N = 7
Know that program and subroutine libraries exist that will allow the computer to do repetitive calculations, graphing, and curve-fitting.	95	100	86	100
Know that the computer can be used to simulate physics concepts that are not easily observed in the general physics laboratory.	76	86	57	86
Know that the computer can be used for data acquisition and process control.	67	100	57	43

Domain 5

The universe of objectives for limitations of the computer is presented in Table 16. The majority of the panel of experts indicated that the difficulties of mathematical modelling and the shortcomings of numerical methods were the most essential objectives in the domain of limitations of the computer.

The responses of the phase III sample for this domain are presented in Table 17. The majority of the sample indicated that the most important limitation of the computer to be taught in general physics is that the computer is only a tool that can be used after a problem is fully understood.

Suggestions for specific objectives in this domain were requested of the phase III sample. A summary of these suggestions is presented in Table 18.

TABLE 16. Domain 5--Universe of Objectives for Limitations of the Computer

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In the domain of limitations of the computer the student completing the general physics sequence should:

1. Understand that there are many difficulties in simulating a complex situation by a mathematical model. (4)
2. Understand that there are shortcomings of numerical methods. (4)
3. Understand that one does not "just put a problem on the computer." The computer is a tool and on some occasions can make problems more easily solvable, but only after the problem is understood. (3)
4. Understand the limitations of computer interfacing when computers are used in instrumentation. (2)

NOTE: The numbers in parentheses indicate how many members of the expert panel thought the objective was appropriate.

TABLE 17. Domain 5--Determination of a Subset of the Universe of Objectives for Limitations of the Computer

Computer Literacy Objective	Percentage of Sample Indicating Objective Would be Appropriate.			
	Total N = 21	2 yr. N = 7	4 yr. N = 7	Univ. N = 7
Understand that one does not "just put a problem on the computer." The computer is a tool and on some occasions can make problems more easily solvable, but only after the problem is understood.	86	86	71	100
Understand that there are many difficulties in simulating a complex situation by a mathematical model.	57	71	43	57
Understand that there are shortcomings of numerical methods.	57	57	29	86
Understand the limitations of computer interfacing when computers are used in instrumentation.	43	57	29	43

TABLE 18. Domain 5--Suggested Objectives in the Domain of Limitations of the Computer to be Taught in Physics

Objective Suggested	Percentage of Sample Suggesting			
Students should be taught to:	Total N = 21	2 yr. N = 7	4 yr. N = 7	Univ. N = 7
Question whether the program is doing what it is proclaimed to do.	14	0	29	14
Look at the significant figures, accuracy, and precision of calculations performed by the computer.	10	0	29	0
Understand that not all problems can be solved by the computer or by someone else using the computer.	5	0	0	14
Be concerned about the increased dependence of people in physics on the computer.	5	0	0	14
Understand that the use of the computer to solve problems may take more time than not using the machine.	5	0	0	14

Domain 6

As mentioned at the beginning of this chapter, there was only one concern expressed in this domain during phase I. This was the concern of two professors about students who catch what one of these professors called "the computer disease." This label refers to students who become so enamored with playing with the computer they disregard everything else.

A general question regarding this domain was included in the phase III interview schedule. Responses of the sample to this question are presented in Table 19. A low percentage of the sample felt that ethical and social issues relating to the computer should be treated in the general physics sequence.

TABLE 19. Domain 6--Ethical and Social Issues Concerning the Computer to be Discussed in General Physics Suggested by Sample Respondents

Issue	Percentage of Sample Indicating the Issue Should be Discussed			
	Total N = 21	2 yr. N = 7	4 yr. N = 7	Univ. N = 7
Problems of becoming involved in the computer to the exclusion of everything else.	19	14	0	43
What computers can do, what they cannot do, and what they should not be used to do.	14	0	0	43
Ethics of good science and engineering.	10	14	0	14
Computer privacy--the ethics of snooping through another party's computer files.	10	0	29	0

Domain 7

A majority of the panel of experts indicated only two objectives with regard to relevant values and attitudes toward computer use or the computer. The attitudes are presented in Table 20. As shown in Table 21, most of the sample agreed that both of these objectives would be useful for the general physics sequence.

TABLE 20. Domain 7--Universe of Relevant Values and Attitudes

In the domain of relevant values and attitudes students completing the general physics sequence should:

1. Understand that the computer is a tool. (4)
2. Have no fear of using computers. (3)

NOTE: The numbers in parentheses indicate how many members of the expert panel considered the objective useful.

TABLE 21. Domain 7--Determination of a Subset of the Universe of Relevant Values and Attitudes

Objective	Percentage of Sample Indicating Objective Would be Useful			
	Total N = 21	2 yr. N = 7	4 yr. N = 7	Univ. N = 7
Understand that the computer is only a tool to facilitate and expedite the work of physicists.	95	100	86	100
Have no fear of using the computer.	90	100	71	100

Methods for Introducing the Computer in the General Physics Sequence

One of the research questions in this study was stated as follows:

> What are the methods that physics educators can use to introduce the computer into the general physics sequence?

During phase I of the study the experts were asked to suggest methods or strategies by which the specific objectives of most of the domains could be taught or learned. The responses to these queries were generally timing responses, for example, "as part of the lecture," or "as part of the laboratory," rather than a specific strategy or method. Thus, a question requesting suggestions for a general method to introduce the computer into the general physics sequence was included in the phase III interview schedule (see Question 28 in Appendix Three). The responses to this question are presented in Table 22.

During phase I one of the experts recommended a prerequisite course similar to a course that is required of all physics majors in upper-division or early graduate school, Mathematical Methods in Physics. This expert's recommendation was that a course be developed that is at an elementary level but that includes material from each of the domains and prepares students to use the computer as a tool in the general physics sequence. Thus a probe seeking the respondents' attitude toward such a course was included as part of the question mentioned above (see Appendix Four).

Table 23 presents the responses of the sample to this probe. While a majority of the respondents agreed with the concept of such a course in the freshman year, those agreeing were divided between making the course a recommended or required course.

TABLE 22. Suggested General Methods for Physics Educators to Introduce the Computer as a Tool of Engineering and Science

Suggested Method	Percentage of Sample Suggesting			
	Total N = 21	2 yr. N = 7	4 yr. N = 7	Univ. N = 7
As part of the general physics sequence as well as part of all required mathematics and science courses.	29	43	14	29
More computer instruction at the high school level.	29	29	0	43
Suggested courses in computer science prior to general physics.	19	14	0	43
Low key prerequisite course.	14	14	14	14
Require all students to have a personal computer	10	0	29	0

TABLE 23. Freshman Year Computer Methods in Science Course

	Percentage of Respondents Agree with a Low-Level, Freshman Year Course in Computer Methods in Science			
	Total N = 21	2 yr. N = 7	4 yr. N = 7	Univ. N = 7
Recommended Course	10	14	14	0
Required Course	48	57	29	57
Percentage Disagreeing with the Idea	43	29	57	43

Supplementary Findings

To assure that important areas of computer use for the general physics sequence were not overlooked, a general question asking for areas overlooked and general comments was included in the phase III interview schedule (see Question 30, Appendix Three). Nineteen percent of the respondents indicated that it is important for physics educators to remember that the tool should not become more important than the topic. That is, physics curriculum should not be designed around computing equipment.

Another nineteen percent indicated that the computer can be used effectively as a classroom demonstration device. This use of the computer would save blackboard calculation time and thereby allow time for more demonstrations in class.

Fourteen percent of the respondents indicated that the computer can be used for evaluation of mastery learning more efficiently than any other device. These respondents felt that physics educators should be using the computer for this type of evaluation.

One respondent indicated that "gadget-like" programs do not make a significant input, while another stated that non-interactive computer use in general physics is not of much value.

CHAPTER V

DISCUSSION

The most important research question addressed in the study concerned identifying a subset of objectives that constitute computer literacy for students completing a general physics sequence.

Relatively clear findings were obtained about what students should know about computers after completing the sequence. According to professors, students should be knowledgeable about the use of the computer as a tool of scientists and engineers. Areas of computer literacy emphasized by these physicists include: programming and numerical algorithm skills in the fundamental mathematical skill areas that have long been the tools of physics; the ability to use the computer to do repetitive calculations, graphing, curve fitting, and simulations; and knowledge of microcomputer-based laboratory instrumentation.

The results of the study indicate that professors are in touch with the state of the art in their profession and they do expect students to begin to learn the state of the art early in their training. Whether this is reflected in their teaching cannot be determined from this study, but at the level of intent these professors seem clearly to be aware of the many innovations that are being implemented in physics and engineering, and they seek to include these innovations in the general physics sequence.

The physics educators expressed little concern for including personal and social aspects of computing in physics courses. It seems typical for scientists and science educators to ignore these issues in doing their work. However, there is some question about the advisability of ignoring these issues considering the nuclear and genetic conventions that have been adopted recently. The scientists of this study did express concern about the social and personal aspects of computing but felt that these topics should be taught in another discipline, for example, philosophy or sociology. It seems that the attitude of these respondents can be summarized in the words of one respondent, "We don't teach students not to steal in physics."

It appears that the sample took their task seriously in that they did make selections from the universe of objectives. The respondents did not endorse all of the objectives of the universe.

How much should students know about the objectives endorsed by the sample? The level of complexity of computer programs that physics educators would expect of students can be inferred to be rather simple from the types of algorithms that the professors would expect students to be able to program. While this type of information was not solicited in the study, several professors indicated that simple programs having a coding length of about twenty lines would be appropriate for the implementation of algorithms that they would expect their students to understand.

In the domain of hardware and software principles the majority of the sample indicated that they would expect students of general physics to understand hardware and software principles for microcomputer data acquisition and analysis at a black box level where the student would only be concerned with inputs and outputs. These instructors indicated that more in-depth understanding should be required in upper-division courses.

What has been endorsed is a low-level of understanding of computers. The primary concern of these educators is physics and the use of computers is a secondary objective. That is, these physicists want students to know how to use the computer as a tool of physics. Students should be able to use simulations to develop intuitive understanding of physical concepts which are beyond their mathematical abilities. Further, students should be able to save time and frustration in doing mathematical analysis by acquiring and analyzing experimental data, thereby gaining more time to consider physical concepts.

Another important question asked in this study concerned whether computer literacy objectives should be achieved as prerequisites, corequisites, or as part of the general physics sequence. Most of the physics educators indicated that students should learn a programming language as a prerequisite. A majority of the sample indicated that the endorsed objectives should be learned as part of the sequence. Given that opinion, it is understandable that they would expect a low-level of understanding since these professors see as their primary goal the teaching of physics principles.

Thus, there appears to be a curriculum conflict. Professors want students to learn about computers, and they see this as their responsibility, yet they feel that they cannot teach these computer skills at a high-level since they have legitimate concerns about overloading students. Therefore, a concern that physics educators will have to resolve is where else in the curriculum some of these computer concepts can be taught.

At Reed College in Portland, Oregon the general physics sequence is taught over a two-year period as opposed to the typical one-year sequence. Many of the computer literacy objectives endorsed by physics educators in this study are already incorporated in the general physics sequence at Reed. This approach seems a good solution to the problem of helping engineering and physics students become computer literate in the general physics sequence without overloading them. Another approach to attaining these objectives is the low-level, freshman course in computer methods of science endorsed by a majority of the professors of this sample. Finally, the problem of developing computer literacy in physics and engineering students may become alleviated simply if the computer becomes more fully integrated into the high school curriculum.

One of the research questions involved methods for introducing the computer into the general physics sequence. No clear findings were obtained. One explanation is that physics professors are more concerned with content than method of presentation (like most professors are reputed to do). Another explanation for the lack of clear findings is that these professors may not be doing much instruction with or about the computer literacy objectives endorsed in this study and so they do not have clear and specific ideas for teaching about the computer and introducing it into the sequence. The review of the literature is not informative in this respect. While isolated instances of users of the computer in the general physics sequence have been reported, we lack knowledge about how general these practices are. For example, how prevalent is the Reed College approach?

An interesting question raised by the results of the study concerns the extent to which the computer literacy objectives identified in this study currently are being taught. The literature reports isolated instances but nothing about how general the phenomena are.

An examination of textbook content provides an indirect way of answering the question. Few widely circulated curriculum materials now exist for teaching the computer literacy concepts identified here as important. Christman (1981) published a supplement to Halliday and Resnick's (1981) Fundamentals of Physics, a text used frequently in general physics. The supplement incorporates problems to be programmed from topics in mechanics and electromagnetism, but this book is primarily aimed at programmable calculators.

The Eisberg and Lerner (1981) text, Physics: Foundations and Applications, focuses attention on computer-related topics such as: numerical differentiation and integration; assistance in curve plotting; numerical solution of differential equations; simulation of statistical experiments; and multiplication of several two by two matrices. But they focus on these numerical procedures by providing a separate section of problems; which they label numerical, at the end of a chapter. These procedures are provided with fourteen of thirty-one chapters. Explanations and examples relating to this textbook are given in a supplement by Eisberg and Peckham (1981). Again, however, the primary focus is on the use of programmable calculators. No laboratory manual encompassing the topics found to be appropriate in this study accompany either of these texts. These textbooks and their supplements include material which will satisfy some of the objectives considered useful and/or appropriate by the respondents in this study. However, much more computer-related work will have to be included in curriculum materials to meet all of the objectives endorsed by these respondents.

One of the research questions was whether differences would be found on the basis of institution type (two-year, or four-year college, or university) at which the respondent teaches. The sample's responses to items about the programming and algorithms domain, the hardware and software principles domain, and methods for introducing the computer into the sequence are pertinent to the question of respondent differences by institution. The respondent had the opportunity to register disagreement with the objective or method about which he was being queried. The four-year college professors expressed the highest percentage of disagreement in seven of the eleven responses elicited and recorded for these questions.

Additionally, in three of the four skills in computer usage (Table 8) the percentage of four-year college professors agreeing with the skill was the lowest percentage. In all three of the responses regarding uses and applications principles (Table 15), the percentage of four-year college professors agreeing that the computer literacy objective would be useful was the lowest percentage of the three strata. Likewise, the percentage of four-year college professors finding the objectives for limitations of the computer appropriate (Table 17) was the lowest percentage for each of the questions asked.

Furthermore, one of these four-year college respondents either registered disagreement with each objective or considered it inappropriate for general physics. The reasons given for his strong objections to the use of the computer in general physics seemed to center on two issues:

1. The use of the computer in general physics focuses attention on the computer and programming it and distracts students from learning of physical concepts.
2. These objectives would require too much time to teach and there is not presently enough time to cover the topics of general physics.

One explanation for this pattern of responses from the four-year college professors is a sampling fluke due to the small number of respondents in the sample. Another explanation is that four-year colleges may lack resources. Another explanation is that four-year college professors have a different perspective. Two-year college professors, as part of their job requirement, train people for current jobs. University professors do research which keeps them current. The four-year college professors may not feel the pressure of either the constraint of research or teaching current, job-related topics and therefore may not be in touch with the state of the art in physics education.

The universe of objectives that was obtained was not a primary goal. It was the means to an end. However, this universe of objectives may be useful for other reasons than the present study. The universe could be helpful to professors, textbook writers, and others involved in curriculum planning who do not want to be bound by an empirically derived subset of objectives determined by a sample of professors, however representative.

Limitations of the Study

During and after the study several limitations were noted. The sample of physics educators interviewed was small (N = 21) and all are teaching at west-coast colleges and universities. However, at this point there is no reason to believe that the sample is not more widely representative.

Several instances of unclear wording in the phase III interview schedule were noted that could be corrected with further revision. An example should have been used to illustrate the author's meaning of each of the levels used to characterize the word "understand" in the phase III interview schedule, since one cannot be sure how the respondents interpreted these levels.

In trying to ascertain the appropriateness or usefulness of simulations for general physics, there is a failure in the interview schedule to distinguish between student interaction with simulations to extend laboratory experiment concepts and professor use of simulations in lecture as an audio-visual device to demonstrate difficult concepts. A revision of the phase III interview schedule could also seek information regarding the length and complexity of programs that physics educators would expect of their students.

Except for statistics obtained by type of institution, and highest degree attained, this project did not attempt to determine the attributes of respondents that may have contributed to the types of responses given. For example, statistics regarding the extent of a respondent's use of computers in his or her research, teaching, and training may have given helpful insights into the pattern of responses received.

Recommendations

It is unusual for this type of study to be done on undergraduate physics education. There is a value in it, however, for the profession. At most professional association meetings the talks, papers, and workshops address a specific topic in the general physics sequence. These may include lecture demonstration techniques for a specific topic or new laboratory equipment for demonstrating a given topic. However, the author has not attended a professional meeting where the results of a study about changing, updating, or introducing new methods for the entire curriculum were presented.

The results of the study indicate that curriculum materials should be developed for general physics which incorporate computer literacy materials that:

1. Utilize the BASIC programming language.
2. Require the traditional mathematics tools of physics to be translated to the computer as a time and frustration saver.
3. Demonstrate and utilize elementary computer controlled data acquisition techniques.
4. Include computer simulations both as extensions of laboratory experiments and as lecture demonstrations.

More studies of this type may indicate other areas of the general physics sequence that could be improved and updated.

APPENDIX ONE

PHYSICS EDUCATOR INTERVIEW SCHEDULE

(PHASE I)

PHYSICAL EDUCATOR INTERVIEW SCHEDULE
(PHASE I)

While it is fairly well established that the computer has become an indispensable tool of science and engineering, physicists such as: Bork, Tinker, Peckham and Hubin have stated that the field of applications of the computer to physics teaching is fractured and disorganized.

We are attempting to establish a set of computer literacy instructional objectives to be achieved by students completing the general physics sequence.

In 1981 Anderson and Klassen of the Minnesota Educational Computer Consortium (MECC) working on a project funded by NSF proposed seven domains that they believe computer literacy must encompass. These domains are:

1. Programming and algorithms
2. Skills in computer usage
3. Hardware and software principles
4. Major uses and applications principles
5. Limitations of the computer
6. Personal and social aspects
7. Relevant values and attitudes

Since you have been identified as someone having expertise in the applications of the computer to physics education we are asking that you help by identifying specific objectives in each of these domains that are important for students to have attained upon completing the general physics sequence.

Additionally, if you feel that domains which are important have been omitted please identify them. Or, if you feel that there are domains among the seven named which are unimportant or irrelevant for students completing the general physics sequence please state so.

1. Name of Interviewee ______________________________

2. Name and type of Institution of the interviewee

   Name ____________________ Type ____________________

3. Highest degree earned by the interviewee ____________________

4. Recent publications or papers

   <u>Title</u> <u>Date</u>

5. Person recommended by interviewee who has expertise in use of

computers in physics who may possibly think differently than the interviewee.

Name of recommendee ______________________________

Institution ______________________________

I. The first of these domains is programming and algorithm skills. What sorts of programming and algorithm skills, if any, do you believe that a student completing the general physics sequence should have?

How should these skills be obtained, as part of the sequence or as a prerequisite or corequisite?

Can you suggest methods by which they should be taught or learned?

II. The second domain is skills in computer usage. This domain would encompass such skills as using "canned" programs in addition to, or rather than, designing algorithms and programs. What sorts of skills in computer usage would you like to see students who have completed the general physics sequence have?

Which of these skills do you believe must be learned as part of the sequence and which as prerequisites or corequisites?

Can you suggest specific strategies for teaching or learning these tasks?

III. The third domain is software and hardware principles. While it is perhaps difficult to differentiate between software principles and the domain of programming and algorithms, the sorts of items that this domain may include are:

1. Designing a data structure for a given application.

or

2. Explaining the differences in compilers, translators or assemblers.

What sorts of software principles do you believe that students completing the general physics sequence should learn?

Should these principles be learned as part of the sequence or as prerequisites or corequisites?

What sorts of hardware principles should these students learn?

How much of this should be learned as part of the sequence and how much as a prerequisite or corequisite?

IV. The fourth domain is major uses and applications principles. This domain, while perhaps difficult to differentiate from the domain of skills in computer usage, could focus more specifically on the concept of designing and developing a computer-supported application that would be personally useful in a general physics sequence.

What sorts of major uses and applications principles do you believe that students completing the general physics sequence should have learned?

In what ways would you recommend that the student learn these skills, or how should they be taught?

V. The fifth domain is limitations of the computer. What do you consider the important limitations of the computer for students of the general physics sequence to understand?

Which of these limitations should be learned as part of the sequence and which as prerequisites or corequisites?

Can you suggest methods by which these limitations can be learned or taught?

IV. The sixth domain is personal and social aspects. What do you consider as important personal and social aspects of computing or computer usage for students of general physics to obtain?

How would you teach these social considerations to students of general physics?

VII. The seventh domain is relevant values and attitudes. What relevant values and attitudes about computers and computing should be instilled in students of general physics?

How would you teach these attitudes and values?

VIII. Are there domains of computer literacy that we have overlooked?

IX. Have we included domains that you believe should not be considered in the general physics sequence? If so, would you please explain why?

APPENDIX TWO

LIST OF STANDARD PROBES USED WITH PHASE I INTERVIEW SCHEDULE

LIST OF STANDARD PROBES USED WITH PHASE I INTERVIEW SCHEDULE

Domain I

1. What language(s) do you believe is (are) appropriate for these students?

2. Why this (these) language(s)?

Domain II

1. Do you feel that these students should be able to use program documentation to select and run library programs for specific tasks such as:

   a. generating graphs
   b. simulation
   c. data analysis
   d. data bank searches for reports?

Domain III

1. These principles could run from such general topics as knowing the components of a computer, that is, general architecture, to recognizing the characteristics of secondary storage systems including magnetic tapes, floppy disks, etc.

2. Should these students understand how to determine accuracy in going from analog to digital?

3. Should these students understand the difficulties associated with sampling rates?

Domain IV

1. Is it important for students of general physics to be aware that programs exist which will allow them to extend laboratory experiments by simulation?

2. Is it important for these students to be aware of other library programs?

Domain V

1. Consider precision and significant figures. Should these students understand how the concepts of precision and significant figures can be applied to a particular language in order to get the job done, that is, how much should they know about precision and double-precision numbers?

2. Should the students be required to sit down at a computer and have it do what appears to be a fairly complicated problem and will cause the computer to have to "think" for a while to demonstrate that the computer is fast, but not infinitely fast?

Domain VI

1. Quite often students of scientific disciplines are considered "ivory towerists" or sociopaths lacking in social grace. The computer seems to aggravate and accentuate this opinion. In fact, so much so that the term "computer nerd" has become a common epithet used for those who spend much time at computers. Should this phenomenon cause concern for physics educators?

Domain VII

1. Some students who use the computer believe that if they persevere long enough they can solve all the problems of their universe. The real world is not like this. How can we show this to students?

APPENDIX THREE

PHYSICS EDUCATOR INTERVIEW SCHEDULE

(PHASE III)

PHYSICS EDUCATOR INTERVIEW SCHEDULE
(PHASE III)

While it is well established that the computer has become an indispensable tool of science and engineering, physicists such as Bork, Tinker, Peckham, and Hubin have stated that the field of applications of the computer to physics teaching is fractured and disorganized.

We are attempting to determine what minimum set of computer literacy instructional objectives should be achieved by students completing the general physics sequence, if any.

In 1981 Anderson and Klassen of the Minnesota Educational Computer Consortium (MECC) working on a project funded by NSF proposed seven domains that they believe computer literacy must encompass. These domains are:

1. Programming and algorithms
2. Skills in computer usage
3. Hardware and software principles
4. Major uses and applications principles
5. Limitations of the computer
6. Personal and social aspects
7. Relevant values and attitudes

Since the content of some or all of these domains may not be appropriate for instruction in general physics we are asking that you help by giving your opinion about objectives supplied in this instrument. Further, in some cases, we are asking that you identify specific objectives that you feel are important for students to have attained upon completing the general physics sequence, if any.

Additionally, if you feel that domains which are important have been omitted please identify them. Or, if you feel that there are domains among the seven named which are unimportant or irrelevant for students completing the general physics sequence please state so.

1. Name of Interviewee ______________________________

2. Name and type of institution of the interviewee ______________

Name ____________________ two year college ____________
four year college ____________
university ____________

3. Highest degree earned by the interviewee ________________

1. Which of the following languages should be learned at useful tool level by students completing the general physics sequence? (Check all that apply.)

    ALGOL ____________________
    APL ____________________
    Assembler ________________
    BASIC ____________________
    FORTRAN __________________
    Pascal ___________________
    PL-1 _____________________
    Other ____________________
    None _____________________

2. Why this (these) language(s)?

3. It has been suggested that students should be required to have programming skills, on entering the general physics sequence, just as they are required to have certain mathematical skills. This would allow the physics instructor to assign problems requiring programming or computer use to solve. Do you feel that this approach is appropriate?

4. It has been suggested that students of general physics would comprehend more physical concepts from understanding how to obtain numerical solutions to problems, ala the Feynman Lectures on Physics, rather than from solving problems strictly analytically, particularly if such problem solving is computer-based. Peckham has suggested that it is not only possible but perhaps desirable to introduce numerical topics on the computer. He argued that this can result in a "feeling" for physics concepts that will lead to a fuller understanding of the analytical approach. Can you suggest topics in general physics where your experience would lead you to believe such an approach would be beneficial for students of general physics?

    While considering the following questions regarding algorithms it may be helpful to characterize "understand" by one of the following four levels: (But it is not necessary to restrict yourself to any one or all of these levels.)

    1. Intuitive understanding of the algorithm supplied by the instructor
    2. Write a program of the algorithm supplied by the instructor
    3. Be able to derive the algorithm
    4. Be able to derive the algorithm and write a program.

5. Since we are often interested in calculations which involve continua of one type or another in general physics, should we require

students to understand algorithms for obtaining derivatives numerically? Such algorithms might include methods of the finite difference calculus such as: forward and backward differences, higher order forward and backward differences, central differences, and Taylor series expansions.

6. Likewise, would you consider it appropriate for students of general physics to understand algorithms for evaluating integrals numerically, such as rectangular, trapezoidal and parabolic approximations?

7. Would you consider it appropriate for students of general physics to understand algorithms for numerically evaluating the roots of equations such as interval bisection, secant and Newton's methods?

8. Would you consider it appropriate for students of general physics to understand algorithms for determining the solutions to simultaneous linear algebraic equations, particularly matrix methods?

9. Would you consider it appropriate for students of general physics to understand algorithms for determining least-square curve fitting and functional approximation?

10. Would you consider it appropriate for students of general physics to understand algorithms for determining the numerical solution to ordinary differential equations?

11. Are there algorithms other than those mentioned above you feel should be understood by students of general physics?

12. Should the student learn any or all of these algorithm skills as part of the sequence, or as a prerequisite, or corequisite?

13. Can you suggest methods by which the algorithm skills should be taught or learned?

14. A very natural and common use of the processing power of a computer is data analysis. It has been suggested that the value of doing least-square fits, repetitive calculation, and graphing is questionable <u>after the first few iterations</u>. The use of the computer for accomplishing such tasks could free students to concentrate on

the physics of the laboratory. What are your views regarding this statement?

15. Do you feel that general physics laboratories should be equipped with computer terminals or microcomputers which would allow students to accomplish the tasks listed above?

16. A relatively unused capability of the computer for laboratory support is simulation. Would you use computer facilities in the general physics laboratory to simulate or extend experiments so that students could investigate experimental behavior that lies outside the physical constraints of the lab?

17. Can you suggest any such extensions?

18. Bork has suggested that faculty members and highly motivated students may become entranced with using simulations but average students need motivation. Can you suggest methods by which average students can be persuaded to employ computer-based simulations designed to increase experiences?

19. Would you like to see word processors made available to students of general physics for completing final drafts of laboratory exercises, experiments, and projects?

20. It has been suggested that by the time today's students of general physics are employed, those that use labs in their work will find microcomputer instrumentation there. Yet the use of microcomputers with associated transducers and interfaces in the general physics lab is a cause of concern to some physics educators. They claim that this sort of instrumentation requires mastering sophisticated hardware, software and operating concepts that deter from the learning of physics concepts. What are your views concerning this issue?

21. How much should the student of general physics be required to know about the computer, the interfacing, and transducers? Should these devices be considered only as "black boxes," from and to which the student only cares about inputs and outputs?

22. How much should the student be required to know about the software for such instrumentation?

23. Can you suggest uses of such instrumentation that you believe would improve student perception and comprehension of physical concepts as compared to present methods of experimentation?

24. Some physics educators believe that it is the view of many scientists and engineers, that if a problem cannot be solved in any other way, all one needs to do is "put it on the computer." What are your views with respect to this issue?

25. Can you suggest methods, within the scope of the general physics sequence, by which we could demonstrate the following limitations of the computer?

    a. The difficulties of simulating a complex situation by a mathematical model.

    b. The shortcomings of numerical methods, that is, no numerical method is completely error free or no numerical method is optimal for all situations.

26. Is it appropriate for students of general physics to be required to understand limitations of computer interfacing such as sampling rate problems or are these types of hardware and software intricacies beyond the scope of general physics?

27. Are there other limitations of computer usage that should be taught in the general physics sequence?

28. Can you suggest a general method or methods by which we as physics educators could introduce the computer as a tool of science and engineering at or prior to the general physics sequence given the present curricular restraints of time and content?

29. Are there ethical or social issues concerning the computer that should be discussed in the general physics sequence?

30. Are there areas regarding the use of computers in general physics that we have not covered or comments that you would like to make?

APPENDIX FOUR

LIST OF STANDARD PROBES USED WITH PHASE III INTERVIEW SCHEDULE

LIST OF STANDARD PROBES USED WITH PHASE III INTERVIEW SCHEDULE

Question 14

1. Should we teach students of the general physics sequence that the computer is a tool which will save time and energy?

Question 18

1. How can we get students to overcome fear of computers, or should we be concerned about this attitude of fear of the computer?

Question 24

1. Is it appropriate at the general physics level to demonstrate that the computer is a tool that on occasion makes problems more easily solvable after the problem is understood?

Question 25a

1. Is this appropriate at the general physics level?

Question 35b

1. Is this appropriate at the general physics level?

Question 28

1. Physics majors take a course in mathematical methods in physics in late upper-division or early graduate school. Would you consider a course, in computer methods in science, which would cover the topics that we have discussed, required in the freshman year, appropriate for students who are going to take the general physics sequence?

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