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ABSTRACT

With support from the National Science Foundation and the University of California, the Physics Computer Development Project have produced in the last six years computer based material in a wide variety of modes. Among the major products are science learning dialogs, graphic additions to APL (A Programming Language), the underlying software, and the authoring system. The project has five major objectives: to produce examples of effective use of graphics in computer-based teaching materials; to explore the use of graphics in computer based teaching materials; to explore authoring modes; to introduce dialogs and other standard computer approaches into standard undergraduate environments; to seek a compatible software strategy. Future projects include an organized Research Unit in Educational Technology and a single timesharing computer for science teaching on all eight undergraduate campuses of the University of California. (SK)

CURRENT STATUS OF THE PHYSICS COMPUTER DEVELOPMENT PROJECT

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During the last six years, with support from the National Science Foundation and the University of California, the Physics Computer Development Project has been engaged in the development of computer-based teaching material in a wide variety of modes. This report reviews the work of the group and discusses the directions of present activities.

OBJECTIVES

The Project has five major objectives.

First, and foremost, the Project aims to produce compelling examples of effective use of the computer in learning situations, primarily in physics and the other sciences, at the undergraduate level. We did not begin with a restricted view of just how the computer was to be used, based on philosophical considerations; rather, we hoped to employ the computer in a wide variety of modes, appropriate to the pedagogical problems encountered. We have never intended to teach entire courses by means of computers, but to choose those uses most effective for the learning situations and the student; we assume that other teaching media will also be involved. This directive implies that we do not begin by asking "What program shall we write?"; to the contrary, we ask "What are the difficult but important learning problems in this area?" Another implication is that the interactive programs--dialogs--should not force students to adapt to the requirements of the program, but should allow students to behave in fashions more natural to them; the dialogs should be highly responsive to student needs and inputs.

A second major objective is to explore the use of graphics in computer-based teaching materials. Early computer use in education was seldom pictorial, because the input-output equipment, resembling typewriters, allowed only crude visual presentations. Visual information provides an alternative to alphanumeric information, and so provides unique learning advantages. A graphic sequence can by dynamically dependent on students' requests and responses, allowing possibilities not available in films. Discovery and development of effective visual dialogs was and is a major goal of this project. Further, these same graphic facilities are important for student problem solving.

The third major objective of the Physics Computer Development Project is to explore authoring modes. If sizable bodies of learning sequences on the computer are to be produced, many teachers should be involved. We can expect highly successful teachers to be more than usually effective in authoring student-computer dialogs. Many of these excellent teachers can see the learning potentials of the computer, but few are interested in taking the time to learn computer languages, techniques, and operating systems. So we raise three questions: How can these good teachers be persuaded to develop computer-based material? How can they be provided with the resources, facilities, and assistance to ease the task? What institutional structures will encourage dialog preparation, both organizational structures and reward structures?

The fourth objective is to introduce dialogs and other computer approaches into standard undergraduate environments. We wanted to work with large classes. The problems are partially political. Faculty members tend to be conservative with regard to new teaching techniques. The standard texts do not acknowledge the existence of computers; they are a powerful conservative force inhibiting computer use. New problems arise as the material is used in schools other than the original one, problems which are to only a small degree dependent on hardware differences.

Finally, the project sought a software strategy consistent with the above goals. The software approach needs to be highly flexible so that it can grow because of the pedagogical demands of good teachers serving as authors. It should allow full graphic capability. It should allow users all the resources of the computer. It should produce self-documented programs which are easy to read and to modify. It should store essential information for producing dialogs. As the major objective is the production of effective dialogs, software development is to be undertaken only when necessary. Existing software is to be used as far as possible.

It should be noted that the Physics Computer Development Project has not so far attempted to to develop any computer hardware. Rather we have worked with existing computers and terminals.

We have, however, attempted to influence vendors to modify their products to make them more useful in educational environments. Further, we have avoided developing operating systems or full languages.

PROGRESS AND PROBLEMS

The Project has made steady progress toward the goals outlined. The results will be outlined in the next section.

We received a small setback just before the grant was received. The initial proposal assumed computer equipment then available on the Irvine campus, but the University changed computing facilities. So the graphic software we planned on could not be employed. However, the new computer, a Xerox Sigma 7, has proven to be an excellent machine for our purposes. It has a full-scale efficient timesharing system, with good debugging facilities. A few software problems still exist, and we are working with Xerox to solve them.

Commercial development of inexpensive graphic terminals also proceeded more slowly than we would have preferred. Most terminal vendors are concerned primarily with the commercial market, so they are not always responsive to educational needs. But we have been able to work with several vendors, and the terminal situation has greatly improved. Tektronix has proven to be particularly amenable to advice from the educational community. The University now owns about thirty Tektronix 4013s allowing PCDP material to be widely used.

RESULTS

The principal products of the Physics Computer Development Project are the dialogs, the graphic additions to APL, the underlying software, and the authoring system.

Dialogs

Producing science teaching dialogs is the Project's major activity. Students are now using about thirty-five dialogs; many are currently under development. Brief descriptions of the dialogs are listed in Physics Dialogs for Student Use, available on request. Some dialogs have been discarded, as ineffective; an idea which seems good in advance will sometimes prove to be of little value to students. Early dialogs employ no visuals, as we initially had no graphic displays, but recent dialogs use graphics extensively. Many of the dialogs fit into a few distinctive pedagogical classes, areas where we believe the computer to be particularly effective.

One major learning problem is developing problem-solving abilities. Conventional teaching often is not effective in developing this skill, important in all areas of science. We have pursued several types of dialogs seeking to aid students in solving problems. Several dialogs (such as DOPPLER) are designed to assist with homework problems; each is devised for a specific problem that the student has not been able to solve, helping not only with that problem but teaching something of the heuristics of problem solving. Another type, the interactive proof dialog, (COUPOSC is an example) tries to make the major derivations of the text or lecture a more active experience for students. Instead of the typical passive experience, students attempt the critical decisions in the proof, receiving help where necessary. A third possibility, little explored but offering promise, gives an incompletely defined problem and obliges the student to request the missing information; help can also be offered in the process.

A second major objective in learning, also difficult to approach with conventional teaching methods, is developing insight; in physics we are more successful in teaching techniques than in developing intuition about the behavior of the physical world. Experience is essential in developing insight and intuition. A dialog such as MOTION creates an interactive world for students; they can move about freely, exploring the effects of the laws of mechanics in a variety of abstract spaces. We can give students a range of experiences unobtainable in everyday life or in the laboratory, and so aid in developing insight. Graphics, pictorial information, is vitally important in this process.

Forming useful concepts is another critical intellectual activity, related to the two just discussed. In a suitable structured computer environment students can grope toward key ideas, for which definitions might be "given" in a more traditional situation. Thus, in the dialog 3D students achieve the concepts of divergence, curl, and gradient by "seeing" them as generalizations of the concept of ordinary derivative. The <u>names</u> are introduced only after the <u>ideas</u> are understood.

Other dialogs are less easy to classify. LUNA and TERRA attempt to teach a critical idea, that of the nature of a scientific model. We have developed several game-like dialogs, useful for motivation; but we are only slowly learning how to write games which also provide a learning experience. Perhaps the best such dialog game is FERM, introducing the important idea of a minimal principle.

Two incomplete dialogs, QUANTUM and SPACE, explore new and interesting directions. Both allow considerable student control of the flow of the program, permitting the student to move to new areas and tasks, but both maintain and use full information on what students do. We are continuing their development; they are serving as models for future work.

These and other types of dialogs are reviewed in Effective Computer Use in Physics Education.

APL Graphics

In addition to preparing dialogs, we have also investigated problem solving by computer, with students writing programs, in standard programming languages in the course of homework assignments. About one-half of student usage in large courses is devoted to this mode of use. One major advance in using computers for problem solving has been to provide students, for their own use, the graphic capabilities present in dialogs. In the process of developing our graphic material we have been able to successfully influence the products of both a terminal vendor (Tektronix) and a main-frame vendor (Xerox).

After a review of languages, we decided that APL was a superior problem-solving language for undergraduates in science and engineering. So we added graphic capability to APL, in a manner natural to the language. This facility is now in widespread use not only at Irvine, but in many other locations with Xerox computers. We also developed very effective material, Ten Finger APL, for learning both the nongraphic and graphic capabilities of APL. The approach does not involve lectures, reading, or dialogs; the student enters APL and observes the behavior of the computer as specified statements are entered.

The graphic software is based on the powerful facilities available in APL for handling collections of numbers. We added a new output operator, quad zero. It produces, when assigned a data structure interpretable as graphic data, pictorial output. The system is further described in APL as a Language for Interactive Graphics.

Dialog Software

The software goals have been outlined. We chose to base development on assembly macros, writing new macros in response to pedagogical needs. These macros (in Metasymbol on the Xerox Sigma 7) have English names, and have only a few arguments, to aid in readability of source code and to make the task of computer entry easier for secretaries. The macros usually write only a few instructions in-line; much of the work is accomplished in subroutines, stored in a library. We write new macros when new teaching facilities are needed.

Programs also contain FORTRAN segments where needed, particularly for calculational purposes. We also make heavy use of the overlay facilities of the loader, as many of the dialogs are much too large to fit into the core available to a time-sharing user. Full documentation of the software is available.

Dialog Preparation

In addition to the useful dialogs that our Project has produced--teaching materials that we believe are as effective as any in wide student use developed anywhere in the world--we have made important innovations in the process of preparing such material.

The key person in the preparation of learning sequences is the competent teacher with experience and insight into the learning process. Hence, the first problem in producing computer-based teaching materials is to identify and to involve such teachers, even though they may have had little previous interest in this particular process. Many outstanding teachers from Irvine and elsewhere have been associated with us. Undergraduates who have shown insight into assisting others in learning have also produced some dialogs.

The teachers who have prepared our materials have very different teaching philosophies; it is no secret that good teachers disagree highly about just how to teach effectively. As a project we favor no single teaching style or philosophy. Different programs reflect different points of view, even in the same area. Only through additional research and testing of materials in the student "marketplace," with large numbers of students, can we decide the relative validities of varying approaches. Probably each dialog will work in some situations, given the diversity of learning strategies used by students.

Competent teachers may have little direct interest in the computer. They can be highly interested in the possibilities if they see a device which can assist learning, however. We must convince such a person that the computer has unique teaching capabilities, and then provide a mechanism whereby teachers can generate dialogs without becoming computer experts, or even computer novices. To stimulate interest in the computer as a learning medium, demonstration is very effective; it is useful to show teachers a variety of materials already developed, with a running discussion of the limitations of the medium and individual decisions on the part of the author. We offer many such demonstrations each year. These demonstrations need not be given at Irvine. The Project has often given talks and demonstrations on other college and university campuses, and so many instructors have viewed our dialogs through long distance phone conversations with the computer.

We have a very satisfactory mechanism which obviates instructors from learning computer languages and becoming computer experts. We do not require that dialog writers learn any one computer language or technique, or that they learn the particular details of our operating system. Instead they describe pedagogically how the sequence is to proceed, and we take responsibility for getting the program running. We encourage dialog writers to think freely about the possibilities; we may tell them if a program facility is technically unfeasible or too time consuming. But in most cases we can provide the computer facilities the authors require, even if we have not previously needed such a facility. Most of our authors write in a loose flowchart format.

The technique varies from author to author. An experienced Project member aids in early stages of preparing dialogs. An author can develop a complete pedagogical specification of a sizable chunk of material in a week, given the help of an experienced person for the first few hours. This method allows teachers to do what they can do best--teaching. It also precludes their spending weeks learning a programming language. But if an author is particularly interested in computer details, he or she can write programs directly.

The second stage in dialog preparation is entering the material, usually by a secretary or a student programmer. We teach the person to work at a terminal directly from the flowchart, using a simple editing system on the Xerox Sigma 7, and we also teach a few widely used dialog commands. The process of training the secretary takes only a few hours, with the person working more and more alone the last few hours, with only slight backup. We can train most competent secretaries. The process is no more difficult than operating an MTST, and secretaries see the job of entering computer material to be similar to using an MTST. Any area which cannot be handled is indicated by comment lines in the program. Secretaries also learn to make corrections and modifications.

The third stage involves programmers, often students, who know the full range of our software dialog facilities; they produce a working program. There may be problems with what the secretary typed, but the main task is to program parts too difficult for the secretary. Programmers write FORTRAN segments if needed, assemble dialog pieces, compile FORTRAN segments, and produce load modules. Graphic coding has presented numerous problems. In many of our recent dialogs, with heavy emphasis on visual presentations, graphic coding is about 75% of the total programming task.

Recently we have developed some interactive APL facilities to aid in the production of the graphic portions of dialogs. These facilities allow the author or programmer to "design" pictures, including associated alphanumeric information, directly at the terminal, using the graphic input crosshairs. The program then writes the graphic macros required, and puts them in a file. In some situations dramatic reductions in programming time are possible.

WORKING WITH OTHER SCHOOLS

We are also very interested in the process of transferring our materials to other campuses. The problems are great; they include not only the classical difficulties of transporting software, but also the issues always involved in educational innovation. Our emphasis is on the second group of problems, although we have worked with several groups interested in moving our software to other computers.

Some use of our dialogs is currently taking place, on a limited basis from many schools in our area, including Community Colleges and campuses of the California State University and Colleges; these schools access the Irvine computer through the phone system. Because of financial and other considerations, this use is still limited. We have also sent programs to other schools with Xerox computer equipment, and offered assistance in getting these programs operable.

Of particular interest to us is increasing cooperation within the University of California. With support from the University we directed a workshop in the summer of 1974 for four physics faculty members from four other University of California campuses (Riverside, Santa Cruz, Davis, and Santa Barbara). The grant also supported terminal acquisition and computer time. In addition to becoming familiar with existing material, each person prepared a new dialog. But no extensive student use is possible because the funds are not large.

Several new suggestions to the University will, we believe, lead to greatly increased use on other University of California campuses. One is the establishment of an Organized Research

Unit in Educational Technology. This center would serve to focus developmental activity and would provide a limited amount of continued support from the University. It might evolve into the type of larger center portrayed in The Carnegie Commission report, The Fourth Revolution - Instructional Technology in Higher Education.

Another suggestion directly addresses the availability of compu r facilities. It proposes to make available a single timesharing computer for science teaching on all eight undergraduate campuses of the University of California. This computer would not support research and administrative use, but would be devoted to education. The PCDP materials would be available throughout the University, and faculty members on other campuses would join us in the preparation of new materials, leading to an order of magnitude increase in the number of dialogs available. This model, too, works toward the ideas presented in the Carnegie Commission report.

NEW DIRECTIONS

Recent renewed support from the National Science Foundation allows us not only to pursue some of the programs already suggested, but also allows several new approaches.

In developing dialogs such as QUANTUM we have uncovered organizational strategies which allow greater student control over the flow of the program, strategies which are largely independent of the subject area. The work has been undertaken by the codirector of the project, Richard Ballard. The basic notion is a two-stage program for understanding student input; if the local testing (looking for response to a specific question) fails, the program goes to a higher level and tests to see if the student wants to change the topic, request a definition, or be given other assistance. We are working with this idea in several interdisciplinary areas, combining physics with math, chemistry, and fine arts.

Another new direction is the restructuring of beginning physics courses, with the hope of making these much more flexible from the student point of view. Existing and new dialogs will be employed. The new facilities will involve an interactive course management system, a database on student progress accessible by the student, by the instructor, and by computer dialogs. An evolutionary process over several years is contemplated. We hope that eventually the course can be adapted to the needs and interests of individual students, so that different students can follow different paths through beginning physics. In addition to the problems of software development, two challenging obstacles must be overcome before such a system is practical; the pedagogical problems of keeping students active in a relatively free environment, and the problems of convincing faculty that the resultant course is a desirable alternative to conventional courses.

RECOMMENDATIONS

Much additional experience is needed in developing computer-based learning material. As with any new teaching media, initial uses tend to be imitative, and so do not exploit the full capabi]ities of the media; thus, early computer use often resembled programmed instruction. This fact, that we are still learning, has important implications.

As we do not actually know how to use the computer fully effectively in learning, we must be careful not to rule out any possibilities. This suggests that at least some of the development work be done on full general-purpose computers, rather than on specialized hardware or software. A specially designed "CAI system" must make decisions which restrict what is possible, but in a full multipurpose system all the computer facilities are available.

A related suggestion is that some development should be discipline-oriented. The experience needed to improve our use of the media may be somewhat different from area to area. Cooperation between groups of institutions should also be encouraged, because such cooperation allows a greater concentration of faculty participation in each discipline.

Several hardware directions seem particularly worth pursuing at the moment. The extremely rapid development of microcomputer technology, and the accompanying decrease in price, suggests that stand-alone systems, each containing the necessary computer power, are a good bet for educational use in the near future; susch a system could connect to a larger computer for special purposes, but it would mostly operate alone. Without the restrictions imposed by communication lines, much faster displays with color and dynamic animation would be possible. Reliability could be improved, as failure would affect only one user. In spite of recent work, the combination of other media--audio, slides, video or film sequences--with computer dialogs still leaves much to be desired. It appears that the home videodisk system, such as that being developed by MCA, Phillips, and others, offers a good solution to this media problem, and these systems could also be the programming basis of stand-alone systems.

SELECTED PAPERS AND DOCUMENTS

Progress Reports

The Physics Computer Development Project - Alfred Bork and Richard Ballard, Journal of College Science Teaching, Vol. II, No. 4, April, 1973.

The Computer in a Responsive Learning Environment - Let a Thousand Flowers Bloom - Alfred M. Bork, Dartmouth Conference Proceedings, April 12, 1971.

Computer-Based Mechanics - Alfred M. Bork, Conference on Computers in Science Education (I.I.T., 1970).

Physics Dialogs for Student Use - Alfred M. Bork, September 24, 1973.

Graphic Dialogs

Inexpensive Timeshared Graphics on the Sigma 7 - Alfred M. Bork, September 29, 1971.

Computer Graphics and Physics Teaching - Alfred Bork and Richard Ballard, February 25, 1972, Third Conference on Computers in the Undergraduate Curriculum, Atlanta, 1972.

Model Programs - Great Expectations - Richard Ballard, Fourth Conference on Computers in the Undergraduate Curricula, Claremont, California, June 18, 1973.

Exploring New Worlds - Richard Ballard, Proceedings of the 13th Annual Convention of Association for Educational Data Systems, Virginia Beach, Virginia, May 29, 1975.

Authoring New Worlds - Richard Ballard, March, 1975.

APL Graphics

Graphic APL for the Sigma - Alfred M. Bork, Xerox User Group Proceedings, Vol. 1, December 7-8, 1972.

Ten Finger APL - An Introduction to APL from the Terminal - Alfred M. Bork, September 11, 1974.

APL as a Language for Interactive Graphics - Alfred M. Bork, January 22, 1974.

Nongraphic Dialogs

A Computer-Based Dialogue for Deriving Energy Conservation for Motion in One Dimension - Alfred Bork and Noah Sherman, American Journal of Physics, Vol. 3912, 137-143, 1971.

Computer Assistance in Student Problem Assignments - Mark Monroe, June, 1971. Second Conference on Computers in the Undergraduate Curriculum, Dartmouth College.

An Interactive Computer Teaching Dialog for Solving a System of Coupled Oscillators - Charles P. Munch, February, 1972.

A Computer Simulation for the Study of Waves - Alfred M. Bork and John Robson, American Journal of Physics, Vol. 40, 1288, September, 1972.

Dialog Software

Teaching Conversations with the Xerox Sigma 7:

System Description - Alfred Bork and Charles Mosmann, May 26, 1971.

System Users Manual, UTS Version - Charles Mosmann, Alfred Bork and Dobree Purdy, August 2, 1973.

Graphic Dialog Facilities - Alfred Bork, Estelle Warner, and John Collins, April 17, 1973.

System Maintenance Manual - Dobree Purdy and Alfred M. Bork, August 9, 1973.

Using PCDP Graphic Software at Irvine - Alfred Bork, December 19, 1973.

Using PCDP Materials Away from Irvine - Alfred Bork, August 30, 1972.

The Computer in Learning--Advice to Dialog Writers - Alfred M. Bork, J. of Educational Data Processing, Vol. 9, No. 3, 1972.

FORTRAN Graphics - Terry Moore and Alfred Bork, May 14, 1973.

Dialog X - Richard Ballard, November, 1974.

Computers and Teaching

Computers in the Physics Curriculum - Ronald Blum and Alfred M. Bork, American Journal of Physics, Vol. 38, No. 8, 959-970, August, 1970.

Science Education and the Future - Alfred M. Bork, September, 1971.

Computer Needs for Teaching Physics - Alfred M. Bork and Herbert Peckham, April, 1975.

The Computer in Physics Instruction - An Example from Today and Suggestions for the Future - Alfred M. Bork, New Trends in Physics Teaching, Vol. II. Paris, UNESCO, 1972.

Effective Computer Use in Physics Education - Alfred M. Bork, Am. J. Phys., Vol. 43, No. 1, January, 1975.

The Computer in Teaching - Ten Widely Believed Myths - Alfred Bork, ACM SIGCUE Bulletin, Vol. 7, No. 4, October, 1973. Reprinted in Points Northwest, No. 6, January, 1974 (American Society for Information Science); EDU #11, Spring, 1973.

The Computer in Learning - The Ordinary Mortal - Alfred Bork, National Computer Conference, 1973.

Limitations of APL as a Language for Student-Computer Dialogs - Alfred Bork, September 4, 1974.

Terminals

Terminals for Education - Alfred M. Bork, EDUCOM Bulletin, Vol. 7, No. 4, Winter, 1972.

SIGMA 7

An Informal Introduction to the UCI Sigma 7, Alfred M. Bork, September, 1974.

Miscellaneous

George Leonard's View of the Computer in Education - Alfred Bork, Creative Computing, November-December, 1974.

Learning, Computers, Pictures - Alfred Bork, The Journal, Vol. 1, No. 5, pp. 6-13, November, 1974.

Learning with Computers - Today and Tomorrow, Alfred Bork, January, 1975.