THE CONFERENCE ON COMPUTERS IN PHYSICS INSTRUCTION

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PROCEEDINGS

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Preface

The computer is the dynamo of the information age. The raw computing power currently available in a desktop computer far outstrips what was commonly available on mainframes twenty-five years ago. The software now available to us is perhaps even more revolutionary than the raw power; it has led to fundamentally new ways to interact with the computer. Computers are revolutionizing activities ranging from accounting to composing rock music. Physics researchers, accustomed to being at the forefront of technology, have been deeply affected by the computer revolution. This effect has serious implications for both how we teach physics and what we teach.

The question is not whether the computer can be used to teach physics. It *is* being used to teach physics. Rather, the question is how the computer can be used to teach physics most effectively. The potential contributions of the computer to the teaching of physics—and to the understanding of physics—are immense. We must take this opportunity to think hard about what we really want our students to learn. The computer can let us rearrange the curriculum into units compelled by the logical progression of the material instead of by the computational limitations of our students or the physical limitations of our laboratory facilities.

But if we are to use the opportunity of the computer revolution to rethink the physics curriculum, we must be realistic and thorough. We must begin the task of curriculum reform by rethinking both content and delivery at all levels. Standard physics texts link courses from the high school to the graduate level, and these links are interdependent. The innovations in how we teach are now happening at all levels—from the elementary school to the graduate school. Thus our reform efforts will require the interaction of state-of-the-art researchers, college teachers interested in curriculum reform, high school physics teachers, education specialists, and experts in high technology.

There are many possibilities for using the computer to teach physics that are obvious and many more that we haven't yet thought of. A computer in the physics classroom can supplement lecture demonstrations. It can help students solve homework problems and provide drill and practice when they don't understand. It can help build their intuition either directly or in conjunction with lab work. It can help students take and analyze data in the lab, and it can let them begin independent research at a very early stage. Some of these computer uses will have strong positive impacts on student learning; some will have negative impacts. Our task as teachers is to classify uses according to effectiveness. We must purge uses that don't work, and test, refine, and retain uses that do.

The Conference on Computers in Physics Instruction

To allow physics teachers and software developers in physics education to come together and see the state of the art in using computers to teach physics, we organized a conference on Computers in Physics Instruction, held August 1-5, 1988, at the McKimmon Center on the campus of North Carolina State University in Raleigh, North Carolina. Nearly four 400 attended from all over the United States and a dozen foreign countries.

The idea for the conference evolved from conversations that took place among members of the physics community, particularly at the biannual meetings of the American Association of Physics Teachers and at a workshop of sixty of the country's leading practitioners in computer teaching held at Dickinson College in February 1986. That group specifically recommended that a large national meeting be held.

The conference on Computers in Physics Instruction included 39 invited lectures and 122 contributed presentations. The conference introduced a number of innovations in the hope of increasing interactions and stimulating future contacts. Besides the oral presentations, there were poster-demonstration sessions, one-hour mini-workshops, and "open" computers that were used to display, discuss, and exchange software. Upon arrival, all conference participants received a package of twenty-one diskettes with thirty-five software programs for five different kinds of computers. (To obtain a set of these diskettes, use the order form in the back of this book.)

The Proceedings

The invited talks and contributions in these proceedings reflect the great diversity of ways physicists use computers to teach physics.

One possibility is, of course, to use the computer in the laboratory to take data and to analyze and display the results quickly and easily. This can simplify some of the technical details of the laboratory and expand its power. The use of the computer for data acquisition and analysis is having a powerful impact on researchers and by implication on our training of graduate students. At the introductory, level the computer can help clarify the meaning of the data and lead to substantial improvement in the student's understanding of difficult physical laws and concepts.

A second major use of the computer is to build models and simulate experiments. Model building is the fundamental component of the theoretical side of physics, and having the computer available vastly expands both the class of problems we can consider and the kinds of models we can build. In some cases we can simulate real-world phenomena that we are prevented from studying in the laboratory by constraints of time, expense, danger, or feasibility. For example, planetary motion is too slow to permit extended observation in a single semester. But many orbits can be simulated and studied conveniently and quickly on the computer screen. Furthermore, our simulations can extend to "what if's." We can try models that do not occur in the real world to see what the implication would be. What would happen if we changed the gravitational-force law a little?

One of the most valuable uses of simulation is to allow students to visualize, through display and animation, concepts that they may find difficult to understand from looking at equations and a single static picture in a text. A number of papers in this volume present a variety of innovative examples of how to use simulations in this way.

In some areas of contemporary physics, computers are more than helpful; they are essential. Much of the work in modern-physics research involves extensive computation. For example, the fields of nonlinear dynamics and chaos. A number of papers in this volume discuss how one might approach introducing the concepts of chaos into the curriculum using the computer. The subject of computational physics is discussed extensively. The implications of modern computer developments for the research environment are discussed in articles on supercomputers and on *Mathematica*, a formidable program that combines calculation, symbolic manipulation, graphing, and text processing.

Papers in this volume also discuss a diverse variety of important issues, including cognitive issues, the role of contemporary physics, and the use of the laserdisc. Other papers deal with the use of the computer as an instructional assistant—or evaluation and recording student performance, and for keeping track of the day-by-day details of teaching, not only in physics, but in any discipline.

Another focus is the practical matter of producing physics courseware. Several papers deal with authoring tools and programming languages, focusing on their special applicability to physics. Specific computer utilities that allow physics applications are also evaluated and described.

For those who wish to explore the possibilities for incorporating computers into physics instruction and to explore programs already in place, there are descriptions of the many instructional physics projects now underway in the United States. These projects range from incorporating a physics curriculum into a fully coordinated local area network, through well-funded microcomputer-based laboratories, to individual efforts to incorporate a single simulation into a tradition curriculum.

Finally, some of the papers deal with the central problem of communicating with one another on the role of the computer in physics teaching. The conference on Computers in Physics Instruction is one such forum, but there are others. Papers in this volume discuss the preparation of educational software for publication, the criteria that will be used to evaluate it, and various publishing possibilities. There is, for example a discussion of *Physics Academic Software*, a joint project of the American Institute of Physics, the American Physical Society, and the American Association of Physics Teachers, which will serve as a new mode of simplifying access to high-quality academic software.

Communicating Teaching Innovations

The conference on Computers in Physics Instruction brought some of the best and most creative workers in many diverse groups together, both to further their interaction and to produce a volume that would have a broad impact.

Educational developments seem to have a much smaller "diffusion coefficient" than corresponding innovations in research. Researchers regularly publish their work, report on it at conferences, read the literature, and travel from university to university giving seminars on their latest work.

There is a great deal of activity in computer use in the classroom, but much of it fails to get published or disseminated beyond the local environment. The American Association of Physics Teachers publishes journals and resource volumes, and holds workshops that reach a significant number of the faithful, but the large majority of college physics teachers remain almost completely unaware of such efforts.

Even if they do become interested, the literature is highly diffuse. Important papers are reported in such journals as the *Journal of Research in Science Teaching* and *Computers in Education*, journals that may not be as familiar to the research physicist as *The Physical Review* or the *Review of Scientific Instruments*. Part of what we are trying to do with this volume is to give an overview of what is now happening and to provide a link (through references in the papers) to the rapidly growing relevant literature. We have assembled a smorgasbord of papers on a wide variety of topics relating to the role of the computer in physics education.

The computer has wrought great changes in the practice of the profession of physics. These changes have serious implications for physics teaching. We offer this proceedings to those who would accept both the changes and their implications and decide to involve themselves in the challenging and exciting subject of teaching physics with the computer.

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