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Challenges from Alfred Bork: What has happened to computers in physics education?

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What has happened to computers in physics education?

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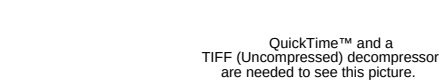
Abstract

In his 1978 Millikan lecture on Interactive Learning, Alfred Bork discussed eleven different modes of computer use in physics education. This paper converts Bork's modes into challenges to the computers in physics education community and evaluates our progress since 1978. It concludes with a brief discussion of future challenges.

Alfred Bork, professor of physics at the University of California Irvine, was the early guru of computers in physics education. Before many of us even had computer access on our campuses, Alfred was leading computer workshops at AAPT meetings. He connected a computer in a hotel room to his main frame back on the Univ. of California Irvine campus and led discussions about how computers might change the content of our physics courses. Professor Bork received the AAPT Millikan Award in the summer of 1978 – thirty years ago. Therefore, it seems appropriate to take stock of what has happened to computers in physics education since then and what challenges are before us.



Dr. Alfred Bork, Millikan Award winner and lecturer, summer, 1978

In Professor Bork's Millikan lecture[1] he laid out for us several different ways that computers could be used as a learning device. Bork presents these different modes as aspects of computer use in physics for discussion during his presentation. I am going to take the liberty to transform his ***modes*** into ***challenges*** for the physics education community of 2008. Furthermore, not all of the different ways to use computers in physics education seem to warrant the same level of discussion, so I have invented by own arbitrary grouping of Bork's modes of use. I will examine each of these groups and discuss what I think has happened since 1978 in the use of computers in physics education and extend Bork's work to challenge us for the future of computers in physics education.[2]

I want to do this for three reasons:

- Challenges can awaken us to new areas of work that need our attention.
- I learned about computers in physics at the feet of Alfred Bork and can bring more than 35 years of experience to this analysis.
- We need to be reminded of the pioneering work done and insights of Alfred Bork. Sadly, there will be people reading this article who have never heard of or read anything by Alfred Bork. At a national conference on computers in education in 2006 I met a faculty member from the University of California Irvine who did not even recognize the name Alfred Bork. Just as the NSTA created a Robert Karplus prize, perhaps the AAPT should create an Alfred Bork prize for the innovative use of computers in physics education.

Modes in which computers can be used as a learning device as described by Alfred Bork in 1978:

I have decided to group them into four categories: Learner controlled, teacher controlled, communication and personal factors, and in true professor tradition I am going to assign a grade for each category.

Learner Controlled:

• ***Student control of pacing –*** computers make individual pacing convenient and commercially practical.

• ***Student control over content –*** computers enable us to provide a great variety of interactive learning experiences and allow students flexibility in choosing them.

The flexible use of time that is permitted by computer use has not really been used much on a macroscale in physics education. In the 1970s there was a strong interest in self-paced instruction pioneered at MIT called the Keller Plan or PSI[14]. This style of instruction demonstrated improved student learning in a wide variety of courses[15], but has almost completely disappeared in college level physics courses now. The intensive use of computers would make this type of physics course much less labor intensive than it was more than 20 years ago, but any attraction of self-pacing for student learning has not been evident to university faculty except at web-based or distance education universities.

Of course, on the mircoscale, i.e. when to do my web-based homework, control can be given completely over to the student, although most teachers do impose some kind of time limit. For most courses it is not possible to do the homework for the first week of class during the last week of the term of instruction.

Student control over content has been even less influenced by computers than control over pacing. I think physics course content is more rigid now that it was in the heyday of the Keller Plan courses.

• ***Intellectual tool –*** students can use computers as learning tools to master concepts.

This is a mode of computer use in which we have excelled since 1978. Consider the power of the computer algebra systems such as Maple[10] and Mathematica[11] that are now available to our students. In physics laboratories we have Vernier[12] and PASCO[13] data collecting and analysis software that is superb. The power of these software packages and the new computers make the use of interactive digital video in our physics classrooms inexpensive and feasible. In addition our students have ready access to word processing, spreadsheet and presentation software. The intellectual tools available to our students today are fabulous. The challenge to us as teachers is to find a way to blend all of these tools into a coherent learning experience of physics concepts for our students.

Category Grade: When we consider the tremendous opportunities that computers give us to increase student learning and student motivation when we turn over more of the control of pacing and content to the learners we realize that we have only begun to stratch the surface of the category of using computers in physics education. On the other hand, the development of powerful computer tools for student learning is very impressive, so on balance I have to give us a grade of B in this category.

Teacher Controlled:

• ***Interactive learning –*** computers enable us to make learning interactive, with students constantly cast as *participants* in the process rather than as *spectators*.

This aspect of computer learning has indirectly had a substantial impact on physics teaching, I think. The peer interaction movement[3] and the use of personal response systems[4] in lecture courses have brought interactivity into the passive lecture setting. Bork, I think, envisioned whole classes interacting in a group setting at computers. This has happened on some campuses and there is some movement, as in project SCALE-UP,[5] in this direction. But most of the interactive learning is still left to Just in Time Teaching[6] style of homework activities. The broad use of adaptive feedback to students inputs is still largely lacking.

• ***Individualization –*** computers enable us to make the learning experience for each student unique, tailored to the needs, desires and moods of each student.

This is a facet of computer use that is largely unaddressed. A variety of computer-based learning activities are provided by some physics teachers but the learning goals of most physics courses are universalized. Every student in a particular course is expected to achieve pretty much the same end of course level. We have responded to the variety of student needs by offering different batches of physics content. It seems to me that this is a challenge that the computers in physics education community is not yet prepared to address.

One aspect of individualization that I think has been addressed is trying to cope with the great variation in student skill sets as they enter a physics course. This wide range in student skills is typical of nearly every introductory college-level physics class. A variety of remediation activities can be made available to students to aid them in becoming successful physics students even though they may have entered the course with very weak preparation.

• ***Experience –*** computers enable us to create worlds, realms of experiences, with the hope of enriching formal learning environments that follow.

Through the use of Physlets[7] and such programs as Interactive Physics[8] and interactive websites such as the Virtual Physics Laboratory[9] physics students today have access to a wide variety of enriching computer learning environments. Of course, many students will not use these learning resources unless the use of these resources are somehow integrated into the course grade. That remains an important challenge to physics teachers.

• ***Time and sequence control –*** computers enable the timing and sequence of material to be modified upon student request.

Those of us who used the Keller Plan in the 1970s frequently developed variable paths that students could use to wander through the content of a physics course. We created the various paths, primarily based upon our knowledge of the essential prerequisites for learning various physics concepts, but the students could decide which way to go. The students also had some control of which concepts they sought to master. Computers make this type of flexibility even easier to manage than it was back in the paper and pencil era of the Keller Plan. There has been considerable attention given to adaptive testing processes[16], but I have seen very little evidence of it becoming an important aspect of physics teaching.

• ***Testing as a learning mode –*** computers enable us to make testing an interactive learning experience by providing immediate and precisely formulated feedback, offering direct aid to students.

I think we are really doing well with this. The Just in Time Teaching movement along with such software programs as WebAssign[17] and eGrade[18] have made this mode of computer use accessible and useful. It is being adopted by a wide variety of faculty and institutions. It shows great promise for increasing student learning.

• ***Management –*** computers can maintain class records.

Again, this is a mode of computer use in physics education that has progressed very well since 1978. With Blackboard[19] and similar courseware management software packages the management of physics courses is much easier and more efficient than it used to be. In addition, the computer testing data retrieval systems can give an instructor much more detailed information about the study habits of the students than was possible years ago.

Category Grade: We have struggled with this category for 30 years. We have been helped tremendously by the personal computer revolution, compared to the time sharing main frame context of 1978. The domination of the personal computer environment with only a few different operating systems has made a variety of powerful courseware available to physics teachers. While there are several serious challenges left for teachers we have done pretty well for a grade of B+.

Communication:

• ***Communication –*** computers enable us to use electronic mail and the world wide web to communicate with students.

There are communication possibilities today that far exceed, I think, what Bork could have envisioned in his 1978 Millikan lecture. Physics teachers as a whole may not be taking full advantage of all of them, but there is wide spread use of both email and websites to enhance communication between the teacher and the students and among the students themselves. Now a teacher can encourage the development of e-based study groups and/or lab partners for the improvement of student learning. The ability to podcast physics content offers whole new areas of teacher-student interaction that are beginning to be explored. How do we deliver physics messages to iPods and iPhones?

Personal Factors:

• ***Personal factors –*** computers have no prejudices. Some students desire to deal with learning materials in an impersonal way.

This has been a very strong aspect of the use of computers in physics education from the beginning. It is relatively easy in physics to provide a wide variety of physics experiences and different questions to students and students can repeat them *ad nauseam* without penalty. Most student responses to physics questions are relatively easy to parse and partial credit for partial answers can be readily assigned.

Category Grades: I may be missing something here, but except for the challenge of figuring out how to use iPods and iPhones for more effective learning of physics, I think the physics education community is doing very well with computer-based communication and personal factors. I give this category an A grade.

Conclusions

Alfred Bork described a variety of modes of computer use in physics education in 1978, just at the beginning of the personal computer era. There remain challenges to us in both learner

and teacher controlled uses of computers. How can we use student control over pacing and content to improve student learning? How can we use adaptive feedback and testing more effectively in our physics courses? What are new ways that we can make physics courses more individualized? I would like to see us be able to make more use of interactive digital video of physics experiments. What about some version of YouTube[20] physics? In addition, the new wireless technologies and the ubiquitous iPods and iPhones present us with new challenges. But I hope we can expect to see the physics education community at the forefront in figuring out how to best use all technologies for the enhance of physics learning.

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[19] Blackboard™ now available from Blackboard Inc., 1899 L Street NW, 11th Floor, Washington, DC 20036. http://www.blackboard.com

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