Hardware and Software Preferences

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High-school teachers trained in using computers to teach physics, working in diverse settings, report success with the same small number of software and hardware packages. Their clear preferences emerged in the process of evaluating a pair of three-week workshops conducted by the Physics Courseware Evaluation Project (PCEP) during the summer of 1993 at North Carolina State University.

Project Overview

Applications for the PCEP Teacher Institute were solicited from a list of 3000 high-school teachers supplied by the American Association of Physics Teachers. All applicants had a strong interest in computer tools for teaching physics, but levels of previous experience varied greatly. The 24 teachers invited to participate in the Institute came from 17 states; experience in physics teaching ranged from 4 to 36 years. The same group returned a year later for a follow-up workshop.

For the 1993–94 school year, each teacher taught on average slightly fewer than four physics classes, with an average size of 21 students, for a total student population of 1800. Computers were used an average of 1.6 times per week, during which computer activities occupied 73% of the class period.

The typical classroom held between 6 and 7 computers, with the remainder housed in computer laboratories. There was considerable mixing of brands, with many teachers commenting that they used whatever they could find. Of the 24 teachers surveyed, 19 had Macintosh computers averaging 7 Macs per teacher; 17 of the 24 teachers had the older model Apple II computers, averaging 5 each; 13 of the 24 had an average of 4 PC computers. An average of 2.8 students were assigned to each station.

The PCEP workshop was structured into three one-week sessions. The first week centered around instructional software and simulations; the second dealt with microcomputer-based laboratories; the third was concerned with spreadsheet use in the physics classroom. After the workshop, each teacher ordered $2000 worth of equipment and software with NSF-supplied funding. The teachers had access to the PCEP courseware library consisting of approximately 300 simulation programs, 15 MBL interfaces, 50 probes with data-acquisition software, and 10 spreadsheets, 15 graphics programs and 15 mathematical tools. The 1994 follow-up workshops were held after the teachers had used their newly acquired materials (plus existing technology in their schools) for one year. These follow-up sessions lasted two weeks and mainly involved further development and sharing of classroom activities. Between the two workshops, teachers were expected to lead two workshops of their own. This worked exceedingly well, with nearly 1500 other teachers attending 53 PCEP teacher workshops. The 24 PCEP teachers had indeed become experts in applying technology to the teaching of physics.

During the academic year, seven members of the PCEP research staff made site visits to each teacher's school. The first visit, during the fall of 1993, was mostly for encouragement and to work out difficulties in equipment or software setup. The second visit, during the spring of 1994, was the primary data-gathering trip. A typical site visit lasted most of a day and allowed time for classroom observation, interviews with teachers and one or two administrators, and informal discussions with students. Occasionally videotapes of student projects that utilized technology were made available. For several visits interviewers went in pairs so they could

Table I. Computer tool needs of the PCEP teachers as of April, 1994.

Need	Frequency of Ranking (1 = top)								Weighted
	1	2	3	4	5	6	7	8	Average
More computers	9	7	1	1	3	0	0	0	4.00
More MBL interfaces	2	6	6	4	1	2	0	0	3.44
Computer screen projection	5	4	2	2	3	0	1	1	2.92
More instructional software	0	2	6	7	4	1	0	0	2.89
More copies of Excel	1	1	4	4	2	2	5	0	2.31
More assignments keyed to software	3	2	1	3	3	2	2	0	2.25
More space for computers	3	0	0	0	2	3	3	4	1.42
More assistance in using computers	0	1	1	0	1	5	3	4	1.17

Table II. MBL probes usage.

MBL Probe	Popularity Own	Popularity Use	Setting Demo	Setting Lab	Setting Indep. Study	Usage Often	Usage Occasional	Usage Seldom	Success 0 to 5
Motion (ultrasonic)	100	100	39	41	20	70	22	9	4.3
Photogates	97	92	38	49	14	58	26	16	4.4
Force	95	86	45	39	15	41	47	12	3.9
Smart Pulley	78	55	46	46	8	56	33	11	4.2
Temperature	88	51	50	50	0	22	44	33	4.4
Voltage, current	89	43	40	40	20	67	17	17	4.8
Light	96	35	25	50	25	17	50	33	4.0
Magnetic field	48	29	100	0	0	0	0	100	3.0
Pressure	42	28	0	50	50	-	-	-	-
Geiger counter	27	23	33	67	0	0	0	100	1.0
Microphone	-	-	38	33	29	33	42	25	4.4

compare notes and impressions. This was done to judge inter-rater reliability. No serious disagreements were noted.

Findings

The PCEP teachers were asked to prioritize the needs that remained after they had been using technology for physics teaching for at least one year after attending the workshop. Eight possibilities were listed and they were asked to rank them in importance. The results are listed in Table I. The weighted averages used to determine overall ranking were calculated by multiplying the number of top rank votes by 8, the number of second rank votes by 7, the number of third rank votes by 6, etc. Additional computers and MBL interfaces topped the list. Teachers not having computer screen projection noted that it was their top remaining need. The Excel query was included since a third of the PCEP workshop dealt specifically with spreadsheet use in the classroom using Excel. The self-reliance of this group of teachers (and possibly the effectiveness of their workshop experience) is evident in the relatively low priority given to software-specific student assignments and additional assistance in using and maintaining the technology. It is also important to remember that this list was compiled after $2000 had already been spent on software and MBL hardware for each of their classrooms. (One item missing from the list is the "need" to convert *single* copies of software to *site* licenses. The 1993 PCEP teachers were encouraged to acquire a wide range of software packages for evaluation and testing. Limited funding allowed them to purchase only a few site licenses. Discussions with the PCEP teachers during the summer of 1994 after they used single copies and after they used networks, if available to them, revealed a strong desire to make exemplary software available to all of their students at the same time, preferably on a network.)

Tables II through IV, reporting on utilization of the software, are sorted by the percentage of teachers that actually used each package. For a variety of reasons, not all teachers who owned a copy were able to use the software or equipment. The percentages listed under Setting are relative to the number of times the packages were used. The usage values indicate how often computer activities were a part of instruction during the relevant topical coverage. (In other words, both the setting and usage values add up to 100%.) Teachers rated their success on a scale with 0 referring to no success and 5 indicating great satisfaction with the educational impact of the package. In general they were quite happy with the effectiveness of technology.

Table II indicates that ultrasonic motion detectors proved to be universally popular and successful in a variety of settings. Photogate use was reported with nearly the same enthusiasm. Force probes complete the top three probe choices, although they were not used by as many of the teachers nor as effectively. We were a bit surprised at the reduced use of Smart Pulleys. Just over half the teachers took advantage of them, although more than three-quarters owned them. It should also be noted that voltage/current probes, although not used by as many of the teachers, had the highest

Table III. Spreadsheet usage.

Spreadsheet	Popularity Own	Popularity Use	Setting Demo	Setting Lab	Setting Indep. Study	Usage Often	Usage Occasional	Usage Seldom	Success
Excel	97	72	27	41	32	50	33	17	3.8
MS Works	73	53	20	60	20	25	25	50	3.5
ClarisWorks	67	52	25	75	0	67	0	33	4.5
AppleWorks (Apple II)	43	37	50	0	50	100	0	0	3.0
Quattro Pro (PC)	45	-	20	40	40	100	0	0	4.5
Lotus 1-2-3	0	-	-	-	-	-	-	-	-

success ranking of all MBL probes. Since most teachers own these devices, their use should be promoted.

Spreadsheet usage (Table III) is skewed because the PCEP workshop focused on Excel as a prototypical spreadsheet. In fact, nearly all the teachers ordered the package, as can be seen by its top ranking in the ownership column. But more than one-quarter of the teachers did not use the package in their classes, usually because of a limited number of copies. When it was used, it appeared to be fairly successful in all three settings: demonstrations, laboratory, and independent study. We do not have an explanation for the substantially higher success ratings of ClarisWorks and Quattro Pro spreadsheets. Perhaps the teachers had more experience with these packages because of their lower cost and wider availability within their own schools.

Table IV, the software usage chart, provides a quick way to check the effectiveness of the variety of software packages used by the PCEP teachers. Like the other tables, it is listed in order by usage.[2] Graphs & Tracks, owned by nearly all the teachers, was used most often and with great success.

Graphical Analysis, Electric Field Hockey, and Objects in Motion were the next most-used programs. Then there is a

Table IV. Software usage.*

Software[1] (Title, Publisher)	Popularity		Setting			Usage			Success
	Own	Use	Demo	Lab	Indep. Study	Often	Occasional	Seldom	
Graphs & Tracks, Physics Academic Software (PAS)	97	81	25	43	32	20	73	7	4.4
Graphical Analysis Vernier Software	86	77	23	64	14	42	58	0	4.5
Electric Field Hockey, PAS	90	76	22	43	35	38	62	0	4.5
Objects in Motion, PAS	79	71	35	55	10	23	62	15	3.9
Interactive Physics II, Knowledge Revolution	81	62	39	28	33	71	29	0	4.2
General Physics Series, Cross Educational Software	66	61	24	41	35	20	70	10	3.5
Physics (Mac), Broderbund Software	59	55	21	21	57	50	50	0	3.6
EM Field, PAS	79	46	44	44	11	43	57	0	4.8
The Essence of Physics, W.W. Norton	64	41	29	29	43	0	100	0	3.7
Guilty or Innocent? (Mac), AAPT	48	40	25	63	13	33	33	33	2.5
StudyWare for Physics, Cliffs Notes	41	35	17	33	50	25	75	0	2.5
Harmonic Motion Workshop (Apple II), High Technology Software	40	32	50	50	0	0	100	0	5.0
Optics Lab (Mac), Intellimation Library for the Macintosh	55	30	50	50	0	0	100	0	3.0
Physics Simulation Programs (PC), PAS	30	27	60	40	0	0	100	0	3.3
Electronics Workbench, Interactive Image Technologies	32	26	33	0	67	0	0	100	3.0
Spacetime, PAS	29	23	0	100	0	0	50	50	3.5
Circuit Tutor (Mac), Addison-Wesley	26	23	0	33	67	0	100	0	4.5
MacBreadboard (Mac), Yoeric Software	7	6	50	0	50	0	0	100	3.0
Projectile II (Apple II), Vernier Software	22	0	40	60	0	50	50	0	4.0
Cricket Graph (Mac), Computer Associates	17	0	0	50	50	0	100	0	3.5
Kinematics II (PC, Apple II), Vernier Software	10	0	0	100	0	0	100	0	4.0
KaleidaGraph (Mac), Synergy Software	9	0	0	50	50	0	100	0	3.0
RelLab (Mac), PAS	9	0	0	0	100	0	0	100	-

*Most of the popular MBL probes and interfaces and simulation software, as well as the Excel spreadsheet package, operate on both the Macintosh or PC computers. When a software title operates only on one platform, the computer (Mac, PC, Apple II) is indicated.

Table V. Effectiveness of technology in the classroom.

Issue	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Computers save time in teaching mechanics.	4	29	25	34	8
Computers do *not* allow for more depth of coverage.	0	4	0	38	58
Computers allow for needed repetition.	21	75	4	0	0
Computers do *not* aid in teaching graphing.	0	0	8	21	71
Computers allow for a higher level of analysis of graphing.	83	17	0	0	0
Computers do *not* hold student interest.	0	4	13	42	41
Computers engaged students in physics activities.	54	38	8	0	0
Computers do *not* remove the tedium from lab work.	0	8	8	67	17
Computers allow you to teach topics never taught before.	21	58	4	17	0
The immediate feedback of computers is *not* a useful teaching tool.	0	0	0	50	50
In-class demonstrations of software work well.	61	9	26	4	0
Independent student computer use does *not* work well.	0	4	9	70	17
Computers speed the pace of instruction.	4	25	38	33	0
Matching graphs of motion is a valuable exercise for students.	59	33	4	4	0
Having students make predictions before viewing computer simulations is *not* a valuable exercise.	4	0	4	62	30
Computers can help students understand physics concepts.	45	50	0	5	0

substantial drop in the usage table for the remaining packages. One package we did note as unusual was Harmonic Motion Workshop for the Apple II. Although used by only a third of the teachers, and even then only occasionally, it had the highest success ranking.

Based on answers to additional questions on our surveys, it appears that the PCEP teachers were willing and able to take the information they gathered during the workshops and make extensive use of it in their classes. That is, their high level of training is evident. Note that two-thirds of the PCEP teachers rated additional in-service training as a low priority. Even though all indicated that the PCEP workshops were very useful, they did not want additional instruction in applying technology to their teaching. In fact, the main obstacles to computer usage indicated were money and teacher preparation time. Teachers did not seem concerned with student computing skills, time for students to use technology, or the brand of computers.

To assess the teachers' perception of whether computers are effective in the classroom, they were asked if they agreed with a variety of statements on the use of technology. The results, in percentages, are shown in Table V. A large majority of either agree-strongly agree responses (or disagree-strongly disagree) is interpreted that the statement is basically true (or untrue).

In general, the PCEP teachers, after having been exposed to a wide variety of software teaching techniques, were in agreement that computers allow for more depth of coverage of physics concepts with some agreeing that new topics never taught before could be introduced and, at the same time, computers allowed students the opportunity for needed repetition. Responses were mixed as to whether the computer saves time in teaching mechanics or speeds the pace of instruction.

The teachers felt that computers help out in teaching graphing techniques and definitely allow students to analyze graphs at a higher level. Using the appropriate software and a sonic ranger and having the students match a position-vs-time or velocity-vs-time graph is a valuable exercise for the classes of these teachers, as was making predictions before viewing a computer simulation. Further, the PCEP group opined that computers hold the interest of students and engage them in physics activities. Independent student use works well, and the immediate feedback of computers is

Table VI. Teacher involvement with computers.

Issue	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
My use of computers to teach physics is influencing other physics teachers in my school.	19	53	6	12	12
I am in contact with other physics teachers through e-mail.	29	33	0	13	25
School support for my computer activities has *not* increased because of the PCEP Teacher Institute.	9	17	13	52	13
I have *not* looked at what others are doing with computers in physics instruction.	4	4	9	70	13
Other teachers at my school are using computers because of my computer activities.	20	53	11	11	5

important. Most telling is that the PCEP teachers believe computers can help students understand physics concepts.

Teachers who like to do demonstrations found the computer worked well, but many teachers no longer lecture and thus do not do demos. They have their students experiment on their own.

Related to the hardware and software preferences of these teachers is the issue of whether these chosen packages will be chosen by other teachers, and whether other teachers will have the resources to incorporate these methods into their high-school physics classrooms. Since the PCEP Teacher Institute was designed as a leadership workshop, we were interested in finding out what kind of influence the teachers had in their own schools. Table VI lists their responses in percentages. For those schools that had at least one other physics teacher, the teachers were making an impact, and even if there were no other physics teachers, many participants shared their new findings with other faculty in the science department. Much of the MBL equipment can be used in chemistry and biology with the addition of a few more probes. Most of the teachers were aware of new teaching techniques and were interested in learning what other teachers were doing.

Those teachers who used e-mail sent mail to other physics teachers, but many teachers are not connected to the Internet.

Most felt that the PCEP Teacher Institute helped them get support from their school. A few believed that it made a major difference. The commitment required of the school districts meant that long-promised hardware was now provided.

One of the teachers, when talking about approaching administrators, said that having attended the workshop "adds credibility." He is able to tell them "I'm not going to try it, I'm going to do it." He feels he can say this because of his experience with equipment and software and the opportunities he has had for talking with other teachers who are using technology to teach physics. This particular teacher's assistant superintendent said in a separate interview about school support for the teacher's use of technology, "I know there's not a risk there." Administrators were impressed with the fact that teachers attended the extended workshop and with the immediate application of what they learned. They commented that this was an unprecedented opportunity for teachers to look at software, and they wished the same was available for other disciplines.

Acknowledgments

We would like to thank Brook Henderson and Aaron Titus, graduate students in NCSU's Physics Education Research Group, and Scott Schultz, a graduate of the PERG program, for their help with this study. John Park, of the Department of Science and Math Education and an associate faculty member in the Physics Department, provided valuable assistance. We especially appreciate the support of the National Science Foundation's Teacher Enhancement Program grant TPE-9253343, which made the PCEP Teacher Institutes and this follow-up study possible.

References

1. For information on obtaining software see M.H. Gjertsen, *Comput. Physics* **5** (1), 71 (1991) and Wilkinson et al., *Comput. Physics* **9** (1), 1995.
2. Three of the four most popular programs are packages published by Physics Academic Software (PAS), a peer-reviewed, educational software publishing project of the American Institute of Physics in cooperation with the American Physical Society and the American Association of Physics Teachers (which is housed in the same building as some of the PCEP workshops). Did they enjoy an unfair advantage in their original presentation to the teachers? This possibility is a reasonable concern and one that we tried to avoid during workshop presentations. Teachers were encouraged to try many different packages from the huge selection available to them and share their findings with the other participants. Note that many introductory level titles from PAS were not selected by any teacher.

Physics Trick of the Month

Water Level Riddle

Float a small glass in a beaker filled with water, then add to the glass marbles, pebbles, or other small heavy objects, until the glass is close to sinking. Mark the water level on the beaker. Remove the glass, dump the marbles into the water, and refloat the empty glass. Will the water level rise or fall?

Few students will guess that the level will fall. It seems plausible that putting the marbles into the beaker would make the level rise. Explaining why the reverse is true is a good way to introduce your students to some elementary hydraulics.

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