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by Philip H. Winne

TECHNOLOGY AND EDUCATIONAL REFORM

Ce n'est pas en parachutant des logiciels de traitement de texte, des langages de programmation, des ordinateurs plus avancés ou des outils d'accès à l'Internet dans les classes qu'on va forcément améliorer la qualité de l'éducation, dit l'auteur. Si on n'est pas attentif à la façon dont les étudiants et leurs enseignants se servent des systèmes et aux principes fondamentaux de l'apprentissage qui doivent servir de base à l'efficacité des systèmes d'éducation, il est difficile de prédire les résultats de ces aventures technologiques entreprises au nom de la réforme. Certaines expériences peuvent être désastreuses. Et même si elles ne le sont pas, il faut se demander si elles sont rentables. Aussi bien du point de vue professionnel que du point de vue légal, les enseignants ont la responsabilité d'organiser l'enseignement de manière à faciliter l'acquisition des connaissances par les étudiants. La façon dont ils s'acquittent de cette responsabilité compte plus que ce qui apparaît sur les écrans d'ordinateur.

A few million years ago, an early human sought to teach by using a stick to draw images of animals or a crude map in the soil of Africa's plains. Modern educators continue to search for technologies that contribute to effective teaching. Today, several million years after the first technology-supported educational reform, many teachers use very special soil — silicon, phosphors, gold and other rare materials used in sophisticated computing hardware — to this end.

Because society's self-renewal through education is not merely important but very expensive and political, controversy abounds about how educational change should unfold. Must today's schools undertake wholesale reform? Are computer technologies critical to that process? Seymour Papert, for one, did not equivocate. In his 1980 book, *Mindstorms: Children, Computers, and Powerful Ideas*, he wrote: "We are at a point in the history of education when radical change is possible, and the possibility for that change is directly tied to the impact of the computer."[1]

To enthusiasts for educational reform, history offers a sober message. Based on his study of teaching practices across nine decades between 1890 and 1980, Larry Cuban observed: "There should be a page in the *Guinness Book of Records* on failed classroom reforms, for few ever seem to have been incorporated into teachers' repertoires."[2] We should ask: Will educational reform — whether it braves, is undergirded, or is led by computing technologies — be different? Will it be effective?

Academy Ex Machina

In 1986, the Apple Classrooms of Tomorrow (ACOT) project began an unprecedented study of change in education. Apple Computer poured computer resources into five schools in America, providing one computer in the classroom plus one to use at home[3] for every student and the teacher, as well as "printers, scanners, laser-disc and videotape players, modems, CD-ROM drives and a variety of software packages."[4] Accompanying this wealth of material resources, each teacher received "basic training" on topics such as telecommunications, how to fix simple hardware and software problems, and introductions to various software tools such as graphics applications and spreadsheets. Apple also supplied partial funding for a staff coordinator at each site to provide technical assistance and instructional guidance.

The objectives of the ACOT project were laudable. It was to work collaboratively with educators to:

• install and operate computer-saturated classrooms as living laboratories in every grade (K-12);

• integrate state-of-the-art technologies into the instructional fabric of schooling;

• bring about positive educational development and change;

• study and understand the impact of total computer access on students, teachers and instructional processes.[5]

At the outset, everyone acknowledged there was very little research on which to predict what might happen or from which to draw guidelines to avoid disaster. Under such conditions, schools' eagerness to participate might imply naiveté in undertaking as expansive and otherwise expensive an adventure as ACOT. Yet, the project was precisely the kind of social experiment oft called for by educational reformers.

The project expanded to involve ultimately a total of 32 classrooms in five schools spread over four states. Technological resources also advanced, prompting new adaptations to teaching and affording changing classroom experiences for both students and teachers. Throughout, Apple did one unequivocally right thing — it and, with its blessing and support, other researchers documented and researched what happened and what participants thought about it. For this, more than any other quality, the ACOT project is praiseworthy.

From this and too few other well-documented innovations, much has been learned about the potential for and the realities of computing technologies as levers for changing educational processes, personnel and outcomes. What are the highlights? Before describing findings from the ACOT project, let's begin at the beginning.

Integrated learning systems — wind them up and watch them ... shuffle?

In the 1960s, Patrick Suppes and colleagues at Stanford University developed drill-and-practice software that individualized instruction in mathematics for elementary pupils. This was the first in a line of successively more sophisticated integrated learning systems. In such systems, problems, exercises and feedback span at least a year's material, and selections from this curriculum are adapted by the software to match each student's individual progress through that curriculum. A special feature claimed for integrated learning systems is feedback they provide to students and to their teacher in detail that is practically difficult to gain otherwise.

Two decades later, Suppes reported that more than 400,000 American students used the software daily.[6] Though integrated learning systems are not much covered in today's media, they are in widespread use throughout the industrially developed countries, especially by students challenged with learning disabilities.[7]

Two main kinds of effects were predicted when students used integrated learning systems. First, by individualizing instruction, every student's achievement should be optimized relative to what a classroom teacher can achieve while accommodating a wide range of students' individual differences. In particular, students who start out with lower achievement should gain. Second, because students work solo, undesirable peer competition was expected to diminish, if not vanish.

Did it work? Hativa and Lesgold recently summarized their intensive studies on implementations of four integrated learning systems used in Israeli and American schools.[8] First, many students who used these systems stepped well beyond mere drill-and-practice of already known skills to learn new information. Usually, students who began with higher levels of achievement learned more than others. Second, effects on competition among students varied unpredictably. One system that was specifically designed to lessen social comparison actually increased it. In another setting using another system not specifically configured to address competition, it diminished. Third, the same integrated learning system could engender dramatically different effects depending on how the teacher incorporated it into the overall classroom context. A fourth finding has significant implications for uncounted testimonials about computing and education — participants unknowingly were biased in accounts of how technology affected them, often failing to notice unexpected processes and their effects.

Computer programming for problem solving

While integrated learning systems were quietly adopted by many schools, other transformations were afoot that received much more publicity. Spurred by critics who bemoaned "didactic" teaching and proclaimed unbearable declines in students' abilities to solve problems,[9] computer programming was offered as a path to success. The upshot was that students and their teachers struggled to mount arcane operating systems and write a few lines of Pascal or Basic code to solve challenging problems like computing areas of circles. Though implementations differed considerably from the rhetoric, the hypothesis was important — generalizable skills for framing and then solving problems could develop if children practiced them by writing computer programs.

Programming languages are complex and demanding, and few teachers ever mastered them to the degree necessary to teach them. Logo, co-invented by Papert, was supposed to change all that. An offspring of LISP, a "real" programming language used in research on artificial intelligence, Logo introduced children to a turtle who could navigate around the screen when issued simple commands. Children could explore what happened if they directed the turtle "forward 10" and they could play with basic geometric concepts like "left 90˚." It was predicted that working on novel problems such as "Can your turtle build a house?" would elevate motivation and almost coincidentally afford children occasion to fashion transferable skills of problem solving.

The idea swept much of education by (mind) storm. Not only did schools clamor for the hardware and software they needed, but extensions to the programming environment were invented, such as Lego-Logo which allowed Lego-built, motor-driven objects to be programmed to traverse fictional Martian and other landscapes. A valuable upshot was that many educational researchers were introduced to classrooms as they situated their work on basic theories of problem solving in contexts of classrooms using Logo.

Change and results were less than hoped for. Fifteen years and dozens of research studies yielded controversial and inconclusive results. Vigorous debates arose about the value of programming as a stepping stone to better skills in problem solving. Amidst this, there was one reasonably general effect: With lots of structure and extensive practice, a very few problem-solving skills may show modest development and limited transfer to other situations.[10] Unfortunately, neither the degree of structure nor the amount of practice was supposed to be necessary, and both were mildly antithetical to the values of these reformers. As with integrated learning systems, it mattered a lot how the teacher shaped students' classroom experiences and related programming to state-prescribed curricula.

Computer literacy for productivity

The most common software on schools' computers is probably the word processor. These are powerful tools for entering, formatting and editing text (and sometimes other forms of information). Students who avail themselves of such features might learn to write more effectively for at least two reasons. First, revising drafts of written work is a key feature in models of competent writing. Tools that invite revising and make it easier to do might lead students to do more revising. Second, skillful use of a word processor's features can format a composition efficiently. This may free the student's cognition to focus more on aspects of writing per se. Together, these potentials should foster written work of higher quality than would be produced using traditional paper-and-pencil media.

Table 1
How Hot Are Compositions Written with Word Porcessors?

Outcome	Difference from 17° average
Quality of writing: students in general	+1°
Quality of writing: students with previously low writing achievement	+2°
Length of composition	+2°
Correct usage of conventions	none
Revisions	none
Attitude toward writing	none

Bangert-Drowns reviewed research where students used word processors,[11] investigating whether they wrote better compositions than students who did not. He first carefully sifted studies to insure that groups received nearly identical writing instruction and that the research did not suffer serious methodological flaws. For the remaining studies, Bangert-Drowns recorded five kinds of effects using effect size statistics.

Because effect size statistics may be unfamiliar, I offer an analog. Suppose the daily high temperature in Vancouver ranges between -5˚ and 30˚ C over a year.[12] Also, assume daily highs would form a bell-shaped or normal curve on a graph where daily highs are sequenced from small to large along the horizontal axis, and a vertical axis marks the number of days for which a given high temperature was recorded. Finally, assume the average daily high for the year is 17˚. Under these assumptions, the daily high should range between 11˚ and 23˚ for approximately 2/3 of a year's 365 days.

How "hot" are classrooms where students use word processors compared to an "average" 17˚ class that uses traditional paper-and-pencil media? The table shows Bangert-Drowns' findings. In climatic terms, a difference of 1˚ or 2˚ is major. If a student is planning a day at one of Vancouver's beaches, however, it hardly makes a difference.

I can find no reviews like Bangert-Drowns' that survey research on students' uses of other productivity software — spreadsheets, databases, graphics applications and the like. Whether they might make a difference in educational reform is unknown. The case for using word processing to enhance education, however, seems clear — it does not matter.

Frontiers: Intelligent tutors and collaborations over the internet

Today's "buzz" about educational computing technologies is loudest and sometimes cacophonous when the topics are two newer innovations, intelligent tutoring systems and explorations using the internet. Tutoring systems are software that students use, mostly solo, to study subjects like geometry, algebra and LISP programming. Software for exploring the Internet may be email or conferencing tools, world wide web browsers, or databases that store and provide access to notes and reports on practically any subject that students and teachers want to exchange over a network. In different ways, each approach promises to reform learning and, on the coattails of that change, to reform teaching and the schools at large.

Intelligent tutoring systems, significant elaborations of integrated learning systems, first appeared in research labs in the early 1980s. Their developers hoped for actual educational effects, but the primary target they aimed for was creating models of learning minds. The work of Anderson and his colleagues[13] in this area stands out for its solid theoretical grounding plus extensive field testing.

In 1984, initial versions of systems for tutoring LISP and geometry were built and given small-scale trials. Results were encouraging, so the LISP tutor was refined. Its latest successor is used today to teach a course at Carnegie Mellon University.

The geometry tutor was set up in a Pittsburgh high school. A first evaluation in the 1986-87 school year marked a genuine success. Students who used the tutor to study geometry solo gained the equivalent of a letter grade on a year-end test. On the temperature scale I introduced before, this was a hot system. It boosted students' success to a very pleasant 23˚ over an average 17˚ classroom. In some classes, there were not enough computers for every student to work alone, so students doubled up. This cut the benefit, reducing it to 19˚, a bare 2˚ above average.

Further field tests of the geometry tutoring system uncovered side effects. First, students spent more time studying with the tutor than without it. And, their teachers reported having more time to work with students who wanted help. Second, contrary to some who worry that students would experience isolation, the opposite was observed. In computer labs, students engaged "in a constant banter of conversation"[14] sharing knowledge about geometry as well as how to "work" the system. Neither was the teacher isolated. He or she was actively engaged in providing guidance about both software and geometry. And students liked studying with the tutor.

Other findings describe how these powerful systems fit or do not fit into school routines. There is plenty of room for improvement. First, it is clear there needs to be a stronger articulation between the curriculum researchers install in a tutor and educators' senses of curriculum. A particular issue is how the section of a curriculum that students learn with the tutoring system can establish sturdier foundations for next year's studies. Second, the tutor's sophistication is a double-edged sword. Unlike other media for curricula, teachers can not adjust any of the tutor's features or align the content it presents to the broader classroom context. Third, teachers need extensive support, "about one year to become comfortable with the tutor" so that, in the following year, "teachers have students who show achievement gains with the tutor."[15]

Similar findings characterize innovations where students seek information and collaborate using the Internet. The technologies required for this work often are difficult to integrate with long-standing classroom practices, though this disruption is exactly what some reformers seek. Everyone needs initial support to use the technologies at all, and even more support is required to use them as intended. Significantly, "popular attention given to these Internet initiatives is rapidly becoming disproportional to the amount of substantive classroom research on learning derived from these projects … Much of the published work … has been anecdotal description … intuitive analyses of what works logistically and what doesn't."[16] Lacking the kinds of research that Bangert-Drowns reviewed or that Anderson and colleagues carried out, we just do not know whether Internet-savvy collaborations work.

Will computing technologies contribute to educational reform?

Newspaper articles and TV ads often portray rosy impressions that newer, faster and fancier computing technologies will reform education for the better. Little attention is given to the challenges associated with installing, using and maintaining those technologies. Conclusions from the ACOT experience warn otherwise:

First, even when classroom environments are drastically altered and teachers are willingly immersed in innovation, change is slow and sometimes includes temporary regression… Second, teacher commitment to an *innovation will not occur until they see positive benefits for themselves and their students … Third, the contextual supports necessary to promote teacher change are rarely in place when technology is added to schools.*[17]

The lessons taught by my brief and necessarily incomplete review of research affirm and elaborate these issues that need addressing if technologies are to be lighthouse beacons on the seas of educational reform. Quality education is not likely to be achieved by parachuting word processors, programming languages or the latest hardware and Internet tools into classrooms. Without careful attention to how students and their teachers are prepared to use systems, and to fundamental principles of learning that must underlie educationally effective systems, the results of adventures in technology-led reform are unpredictable. Some turn out quite badly. Among excursions that are harmless, one should ask whether they were cost effective. The answer is presently unknown.

Teachers are responsible, both professionally and legally, for organizing lessons to enhance student learning. What they do in this role matters more than what appears on computer screens.[18] Where will teachers find guidance about teaching and organizing classrooms to create effective technologically supported complements to current practices?

Unfortunately, knowledge available at the beginning of the ACOT project has not advanced very much. Too many one-off trials and too few carefully designed research studies have been done. If educational reform by or with technology bypasses this essential way station, it faces lottery-like odds of winning what society, teachers, and students all seek — quality and enjoyable education.[19]

A call for more research is staid, and travel along a prudent, research-based path may be too slow for reformers. But slow pace can be a boon where change "invariably creates new problems at the same time it may ameliorate others.[20] Rather than rocket fuel for reform, technology might better be viewed as a catalyst for change. High-quality research on educational technologies can provide teachers and their students with tools to accelerate educational progress. But a tool is a tool. What was true for the first teacher who used technology so many millions of years ago still applies today. A better stick, or a better computer, affords useful reform only to those who are skilled in its uses.

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