IMPLEMENTING TECHNOLOGY-RICH CURRICULAR MATERIALS: FINDINGS FROM THE *EXPLORING LIFE* PROJECT

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Abstract

Eighteen high school biology teachers from a stratified sample of thirteen distinct geographical United States regions participated in evaluating first-year prototypes of *Biology: Exploring Life* that incorporate a print textbook; accompanying Web activities to explain and reinforce the text and promote active, hands-on learning; and wet-lab investigations. This article discusses how we chose our teacher participants, compares our participant sample with the characteristics of early adopters of innovation, and details what we learned from our year-long investigation about implementing a technology-rich science product in real classrooms. The article concludes with recommendations for adopting technology-rich science learning products in schools.

Twenty-one years ago, Bunderson (1981) predicted that technology (at that time, the videodisc) would become a dominant source of instruction within the decade, largely replacing the teacher. Ten years later, Heinich (1991) was still arguing for “certified resources,” technology-based products that would displace teachers, an argument strongly supported by Perelman in *School’s Out* (1992). A survey of classrooms today would reveal, however, that teachers–while perhaps playing a slightly different role—still dominate the educational landscape.

A brief survey of the literature over the past 20 years shows early adopters—in typical technology champion style—have prophesied that the best was yet to come for teaching and learning using technology (see for example, Bork, 1985; Dennis & Kansky, 1984; Freeman, 1987; Jacobsen, 1998; Norman, 1997; and Sharp, 1993). Unfortunately, the extent to which technology has effected radical change in teaching and learning falls a bit short of the prophecy (Cuban, 2001). The major concerns about integration of technology in school settings in the last two decades’ literature seem to focus on **(a)** availability of suitable technology (hardware), **(b)** access to well-designed educational software, **(c)** adequate teacher training in technology use, and **(d)** support for teachers in using technology with students. In the words of Baker (1981), computer-based instructional products and applications will only succeed if they can be integrated “into the enduring fabric of the educational system” (p.23). This article examines how implementing technology-rich materials today reflects the same concerns expressed 20 years ago and attempts to illuminate some of the strands of that fabric.

Data from the National Center for Educational Statistics (1999) and the *State-of-the-States Survey* (2001) suggest that many schools have advanced beyond the first level of adopting technology:

purchasing hardware and software, preparing school facilities, and wiring schools for Internet access. Many schools have also completed the second level of adoption: preparing teachers to operate computers. As a general rule, successful completion of the first and second levels makes record-keeping easier, improves the quality of presentations, and increases professional communication among teachers.

Despite the apparent readiness of school systems to advance to the next level of technology integration and the presence of better computer facilities than a few years ago, technology-rich curricular materials do not appear to have yet been implemented on a large scale. According to the *State-of-the-States Survey*, 90% of the responding state-level directors of technology reported that they either require or recommend integration of computers into the curriculum. However, state directors of technology also reported that they would rate only 80% of their state's teachers as "average" in proficiency in integrating technology (Solmon, 1999). Further, these state directors suggested that only 62% of their teachers used technology to enhance teaching, while fewer than 45% pursued higher level thinking activities with their students. Similarly, the directors rated only 11% of their teachers as above average in using project-based learning or cooperative groups.

Lemke and Coughlin (1998) studied factors that determine whether schools will be successful in raising the level of student use of computers for learning. Their study produced a list of key factors that mirrors the factors identified in the past twenty years' literature. Missing from their list, however, was a well-developed, comprehensive curriculum that can be used for an entire course of study. Such year-long curricula that integrate technology may be crucial to helping teachers bring about the kind of systemic change that technology integration may demand (*CEO Forum*, 1997; Mann, 1998; Sherman, 1998). There appears to be much support for the desire for such curricula (Bailey, 1997; Dockstader, 1999; Ediger, 1997; Fine 1999; Gunter & Wiens, 1998; Hall & Mantz, 2000). This support is further reinforced by the fact that 22% of the state-level directors of technology, when asked why computers are not used in schools, responded that schools needed to revise the curriculum.

To address just this need, the present project integrated technology into the full-year curriculum. The product uses a 4 E's learning cycle model, a modification of the 5 E's instructional model (Biological Sciences Curriculum Study, 1993) that integrates computer media throughout. The

E's represent various phases of the constructivist learning cycle (***e**ngage, **e**xplore, **e**xplain, **e**valuate*). The product, whose prototyping was funded by the National Science Foundation, integrates a shorter (800-page), concept-oriented textbook, a collection of inquiry-based lab and field activities, and an extensive World Wide Web site that provides an interactive learning environment for students. These components are designed to work together to help teachers provide a more interactive classroom in which computers support and enhance delivery of the curriculum. Unlike textbooks "published" (posted) on the Web largely as Acrobat PDF files or other forms of documents and worksheets, *Biology: Exploring Life* materials go beyond simple reading, teacher lesson plans, and activity worksheets. Web activities explain and reinforce the text and promote active, hands-on learning. They encourage students to explore, analyze, draw conclusions, and share their findings.

Hoover and Abhaya (1995) argued, however, that many "educational" sites are not well suited to classroom use because (a) they lack strong instructional (pedagogical) design and (b) scientists (content specialists) have difficulty collaborating with educators and Web site designers to produce the most efficacious sites. In addition, a number of authors argue that teachers need professional development to help them learn how to integrate technology into teaching and learning and that we need newer models for such development activities (see for example, Black, 1998 and Smith-Gratto & Fisher, 1999).

In order to develop a useful and adoptable product, we needed to explore how melding a print textbook with online activities influenced what teachers in real school settings could do. The developers produced prototype materials and then asked a sample of teachers to implement them in real classrooms under a wide range of technological configurations. The major questions we, as evaluators, sought to answer through our study were,

1. How ready are biology teachers who are early adopters of technology to employ a curriculum that requires students to use computers on a regular or even daily basis?
2. What motivation, additional education, hardware, or skills do teachers require in order to integrate almost-daily computer use into the curriculum?
3. Do high schools have the adequate technology facilities to implement a curricular program that incorporates students using computers on an almost-daily basis?

4. How might existing schools change to support a technology-based curricular program?

Participants

Three evaluation workshops were conducted at different developmental stages during the first year of our project. To attract participants, we posted calls for participation on national and state educational listservs and bulletin boards. Biology teachers who were interested in participating in the *Biology: Exploring Life* evaluation completed a 44-item computer experience questionnaire. This questionnaire allowed us to identify participants' varied demographics and background characteristics, including geographical area, socioeconomic level of the school, years using the Internet for teacher planning/preparation, perceived preparation to use the computer and Internet in classroom activities, training to integrate instructional technologies into curricula, number of computers in the classroom and school, student-to-computer ratio, and reported technology use in the classroom.

Forty-two high school biology teachers, one pre-service biology teacher, and one science supervisor were selected from a stratified sample of 13 distinct geographical regions that included Alaska and Hawaii. These 44 people participated in the evaluation of the first-year prototypes, reviewing the materials in various stages of development at one of the three evaluation workshops (August 2000, October 2000, and March 2001). Although the 42 teachers had volunteered to implement the materials in their classrooms, only 18 were able to do so during the 2000-2001 school year. They pilot-tested the *Biology: Exploring Life* materials with 783 students. The loss of 24 teachers was due primarily to scheduling problems and the timing of the workshops in relation to when the content in the prototypes was covered in their classrooms. For this reason, some of these teachers agreed to participate in the second year's field test instead. In addition, five classrooms were chosen for field observations based on arbitrary volunteer selection.

Data Collection

As noted earlier, we collected data on teachers' past practices, teaching experience, use of computers, and professional development. At the three workshops, teacher participants evaluated how well prototype materials met national and local teaching standards and assessed the cognitive and interest level of students. In addition, they appraised the quality of prototype use of the interactive qualities of computers and the Web. To determine the use of the materials in the classroom, the evaluation team conducted five classroom field observations during the school year. Students completed measures of biology content knowledge and concept understanding before and after using chapter materials, and each teacher submitted a questionnaire and a journal with open-ended responses after using each chapter. To collect a richer and more detailed set of teacher impressions, a member of the evaluation team conducted follow-up phone interviews with teacher participants who completed two or more units. To obtain a richer pool of student reactions to the prototypes, we selected two volunteer teachers and examined their students' submitted journals.

Findings

Findings are discussed below in terms of the teachers' self-report data prior to implementing the materials in the school setting and then what we learned about their actual use of the materials in the pilot. Although student knowledge of biology, as measured by all four pre-to-post pilot measures, increased significantly [$t(477)=18.64$; $t(212)=15.11$; $t(85)=9.94$; $t(77)=4.79$; all findings $p=.001$] and student reported strong favorable reactions to the prototype materials, this paper focuses on the teacher's experience. Thus, we discuss student findings only in relation to how they might affect teacher actions and decisions in implementing such a technology-rich product.

Participant Self-Report Data Before the Pilot

This section is divided into four main parts: *participants as early adopters, reduced planning time, computer facilities and support,* and *participant use of technology.*

Participants as Early Adopters

According to Rogers (1986), adopters of technology fall into fairly clearly defined categories. Innovators and early adopters lead the way, early majority folks hold the middle ground, while late majority adopters and laggards wait longest. Given that we used the Web and email as principal means of soliciting a volunteer sample, we assumed our participants might well fall on the leading edge of Rogers' adoption-of-innovation curve (as applied to educational technology use). Teachers' reported use data offered some support for this assumption.

Our teachers reported that they used computers for preparation and planning once a week or more (97%) and rated themselves as well or very well prepared to use technology (83%). The vast majority of our participating teachers (88.1%) reported they had used computers for three or more years in teacher planning and preparation and had completed professional development in the past three years related to technology use or implementation. Similarly, all participants (100%) reported that they had assigned their students Web-based research tasks, while 92.9% reported they had assigned students data-analysis and problem-solving tasks using computers or the Web. Those same respondents reported that they felt ready to use computers for their own professional use, as well as with their students. Participants reported notable levels of participation in professional development activities; 76.2% said they had completed nine or more hours in the past 3 years, while one-third reported taking more than 32 hours in that same period. Despite such training, most in our sample identified their own independent learning (97.6%) and interactions among colleagues (83.3%) as main sources of their knowledge about technology and its use. This contrasts with 35.7% who reported that at least a moderate extent of their training came from college courses.

Reduced Planning Time

Participants noted on their questionnaires during the first workshop that additional planning time would be needed to infuse technology into their biology curriculum. This is consistent with the assertions of writers who have suggested technology implementations increase the demand on teacher planning time and restrictions in available time may act as a limiting factor (Cummings, 1998; Heck &Wallace, 1999; Schnackenberg, Asuncion, & Rosler, 1999).

However, during focus groups prior to the field test, the teachers espoused the belief that the prototype materials would actually save planning time. Because these materials included interactive activities that enhanced the text, offered links that were kept up to date, and because the publishers were responsible for keeping information updated, participants opined that they would spend less time searching and more time teaching. Because the program offered activities at various cognitive levels, participants also thought the prototype materials might save time adjusting materials for different class levels and interests.

Computer Facilities and Support

Many teachers in our study (73.8%) reported that they expected adequate support for a technology-integrative curriculum from their administrators. Most (54.8%) rated the number of computers in their school as sufficient to use a Web-based curriculum. Similarly, most respondents (61%) reported that their districts had a computer training requirement.

Participating teachers reported differential access to computers in their instructional settings. Twenty-five percent of the participants responded that they had what we would call a "classroom set"; that is, 10 or more computers in the classroom. Forty-nine percent of the teachers reported having two to nine computers and only 26% reported just one computer in the classroom. Almost all of the teachers (97.6%) reported, however, that they also had access to a computer lab.

Participant Use of Technology

At the same time that we saw evidence that our sample might be more active in using technology in schools, we were surprised at the ways teachers reported actually using computers in schools. The three most reported activities—searching for possible activities to use with students, communicating with colleagues, and word processing—were uses supporting **teaching**, not uses involving **students** in the classroom directly. When we looked at how students in their classrooms used computers, most of the reported activities were data collection and reporting.

A majority of the teachers (66.7%) responded that they did not use computers for classroom multimedia presentations at all, or did so infrequently. This finding seems consonant with McDermott and Murray's (2000) contention that the use of computers still remains teacher-centered as opposed to learner-centered. The finding seems particularly important here, however, because our prototype materials were student-centered and required teachers to have students use computers in the classroom almost daily.

Pilot Results

This section is organized around four headings. The first three parallel the previous discussions: *planning time not reduced, inconsistent computer facilities issues,* and *teacher use of technology*. The fourth heading, *findings related to specific learners,* relates to how specific populations of students interacted with the prototypes.

Planning Time Not Reduced

Despite teachers' prediction of reduced planning time requirements, once the field test was underway, the majority of teachers reported that they spent **additional** time planning and preparing to teach. Most of that extra time was spent dealing with the technical requirements: arranging computers, adjusting schedules around labs times, and installing software and Web browser plug-ins. Many teachers reported spending planning time developing supplemental worksheets to be used as accountability measures when students completed online tutorials. As anticipated, teachers did feel that the program reduced the amount of time they spent searching for support materials, and respondents suggested that they would be able to spend less time planning if their school computers were properly configured and if the publisher developed worksheets to be used with materials.

Inconsistent Computer Facilities and Support

Once they were using the prototype materials on a regular basis, a number of our pilot teachers discovered their school buildings did not have an adequate support system for implementing such technology-intensive curricular materials. As we talked to teachers, we found that there was little consistency in schools' student computer facilities. Some distributed computers so that every room had a computer, while other schools centralized all computers for student use in computer labs. We observed that some teachers who valued technology were unwilling to wait for their school budgets to equip individual classrooms with computers. Instead, they had acquired computers for their classrooms through grants and private funds. This meant that, within the very same school, some teachers had technology-rich classrooms while others had almost no classroom technology. Ironically, this produced a "digital divide" within a school wider than the difference between that school and others.

Many of the teachers had planned to use their school's computer lab to do the activities. However, teachers often discovered they were not able to access their computer lab or that lab availability was restricted with little scheduling flexibility. Sometimes this meant our teachers were left having to adjust a week or even a month of lessons in order to get lab time. Such availability might determine whether the materials got used at all: One teacher was called out of town and her class missed the computer lab day. When she returned, she was unable to reserve another day right away. Unfortunately, she had used up the time that was allotted by her core curriculum to the concept covered by the prototype's Web-based activities and had to move on to other materials.

Most biology classrooms are not designed to accommodate a large number of computers. Often there are not enough electrical outlets and few (or no) Internet connections. Some schools lined computers up in neat rows that left little room for students to work in pairs or even work independently because of the crowded linear layout. Our observations indicated that wireless computers offered greater classroom arrangement flexibility than using a computer lab, permitting more collaboration and small group work. However, even with wireless computers, difficulties occurred. In one classroom, students had to walk around the room, holding their computers like divining rods to find the service area of their wireless computer hub. Their room was, by the pernicious nature of the technology gods, located in an area that received three separate signals from disparate ends of the school.

Facilities were only part of the problem, however. Most reported difficulties related to preparing computers to use the program. The computers required minimum system requirements of 64 MB of RAM, Internet Explorer 5 or higher as the Web browser, 350 MHz CPU speed, at least 56K connection speed, and installation of Flash 5 and QuickTime 4 plug-ins to the Web browser. Every school had a unique network system configuration, requiring knowledge of how addresses needed to be configured for network access. Most teachers required computer support persons to help them confirm that their computers met the minimum requirements and were properly configured. This included help with downloading and installing the Web browser and necessary plug-ins. When adequate technical support was not available, teachers needed to be "technologically savvy" in order to prepare available computers to implement the curriculum.

Communication between teacher and computer support persons varied greatly from school to school, as did responsiveness. Some teachers were able to call system administrators, who quickly came to configure computers, while others had system administrators who responded slowly or didn't show at all. One teacher had computers in her room for six months before they sent a technician in to set them up and to connect them to the Internet. The knowledge level of the system support people in different schools also varied greatly. In one case, a teacher checked with the system administrator and was assured that the school's computers would be able to run the program. When she began the pilot test, she found that the computers were woefully inadequate.

School system technology policies also created problems. Some systems had blocking software that inhibited learners from accessing externally linked Web sites that were linked to prototype activities. Some systems restricted teachers from downloading necessary plug-ins or upgrading their version of Internet Explorer. Two teachers had problems with their systems not connecting to the Web site. Because of computers with less memory, one teacher had to download plug-ins each morning and then take them off at night. Often, school Internet connections were slow, frustrating both students and teachers.

Regardless of how much technical support teachers had in their schools, all teachers became emergency technicians while pilot testing the prototype materials, troubleshooting problems as necessary during class. Many teachers had to learn to download software, reboot computers, and set up audio capabilities on their computers. The amount of time and type of problem were usually minor annoyances. However, for almost 43% of our pilot teachers (18 teachers out of the 42) it constituted enough of a hardship that pilot testing was aborted.

Teacher Use of Technology

As we observed teachers in the classroom, it was apparent that being an innovator was not always fun or easy. Few teachers had complete availability or the perfect arrangement of computers. Many teachers had difficulties thinking of ways in which they could adapt use of computers to facilitate their teaching. As previously mentioned, most of the teachers had not used computers with the students on a regular basis or as a critical component for teaching. In order to implement the prototype materials, many teachers had to adjust their normal styles of teaching.

There was no one pattern to how teachers used the prototype materials. Teachers spent from two to 20 days implementing the chapters. How teachers used materials and which materials teachers selected for use appeared to be influenced by their comfort level in working with technology, as well as their need to meet local standards and core curriculum requirements. Teachers also selected different components based on the ability levels of their students and the sorts of instructional activities best supported by the arrangement and location of available computers.

It appears that many biology teachers in our sample did not know how to make the most of available computers in their classrooms. Of those teachers who had multiple computers in their classrooms, few reported using them as learning stations. Likewise, few teachers said they used an LCD projector to project visualizations on a screen or a television monitor to call attention to biological concepts presented in the materials. One teacher, who did not know she had the ability to connect her computer to her classroom television monitor, decided to print out an animation screen to illustrate the biological concepts that were presented in the animation. Another teacher, despite having enough computers in her classroom for the students to work in groups, took her students to the library computer lab to do the activities, since she believed the only way to work with prototype materials was individually (one computer per student). Similarly, many teachers were unaware of new products just coming out, like wireless computers, hand-held computers, and SmartBoards that would offer more ways to present interactive segments of the prototype materials.

Many teachers customized the instructional design of materials to accommodate their pedagogical styles. The materials are designed so that teachers can selectively choose different components to meet the diverse needs of their students. For example, one teacher chose to use the Web components to enhance her lecture material. In contrast, after implementing the wet lab, another teacher had students use the computer activities to check their understanding of concepts presented in the lab and to reinforce that learning.

Most teachers did not implement all computer-based activities in a chapter. When teachers had limited time, wet labs were the first activities to be omitted, and teachers tended to use the WebQuests at the beginning of the chapters as an introduction to the chapter’s content. Interactive tutorials were next most likely to be used by teachers to illustrate concepts or to reinforce vocabulary.

Teachers experienced management issues when using the prototype materials in a computer lab. In computer labs, eye contact was a problem with students seated behind computer monitors or with their backs to the teacher. Computer audio could also be a problem: As an extreme example, the students in one lab were completing an activity in which a bear burps after he has eaten an apple. They decided to devote time to trying to get all computers to play the bear’s burp in unison and the teacher had trouble getting them back on task.

It is difficult for a teacher to be the center of activity in a computer lab. Teachers who were accustomed to using a teacher-centered approach expressed some uncertainty, therefore, about what role to play when using computer activities. One teacher commented that she felt a bit useless and didn't quite know what to do when the students became focused on the computers and busy with the activities. Student data suggested that teachers were not the only ones aware of the change: Several students noted in their journals that their learning became more intrinsic and relied less on the teacher's direct instruction. Many students said they enjoyed the shift in emphasis to a more student-centered atmosphere. However, not all students preferred learning autonomously with computers. In two schools, higher level biology students reported that they preferred a more traditional textbook-centered curriculum over the prototype materials.

We deemed a successful implementation of the prototype materials to be one in which classroom students were able to use the prototype materials assigned by the teacher and learned biology. A variety of factors contributed to successful implementation. In the most successful classrooms, the teachers appeared to have a pedagogical style that permitted them to incorporate the materials without radically changing their approach to teaching. Such a style usually was one that permitted a combination of teacher-centered and student-centered learning, with easy transitions between the two. Structuring the classroom environment for students to work in small groups proved to be a most advantageous way to implement the materials. Teachers circulated among groups, guiding activities and assisting the students, while students often discussed concepts among themselves to derive responses to questions in the tutorials. Teachers who had multiple ways to use computers and multiple types of related technology also appeared to have more success. For instance, teachers who used a combination of projected computer animations for whole-group guided discussion and stand-alone computers for small group activities also reported success implementing the materials. Similarly, five to seven computers spread out to allow students to work in small groups and wireless connections where students could form their own work groups dynamically seemed good ways to configure for student-centered activities.

Findings Related to Specific Learners

Some student findings had implications for teachers implementing such a technology-rich product. In particular, we saw some evidence that this approach might have had unanticipated effects on specific populations of learners. For instance, one teacher noted that the academic performance of her students with Individual Education Plans (IEPs) for learning disabilities improved while implementing the program. The most dramatic observation was a student whose average mark improved from a D to a B. In an unfortunate confirmation of the learner's preference for the prototype approach, the student's mark slipped back to a D when the textbook-centered curriculum was reinstated at the end of the pilot test. In the same class, grades for two English-as-a-second-language students also improved while using the prototype materials. During study hall, they were able to access the Web site and complete activities at their own pace. While novelty may play some role in these findings, it is worth noting that the implementation covered a period of one to three weeks per chapter for each of the three chapter prototypes.

In contrast, analysis of student journals indicated that low-proficiency readers had more difficulty reading text on a computer monitor than from a textbook. These learners also became disorientated with activities that launched more than one browser window. For instance, some of the WebQuests required learners to navigate across Web sites, opening several concurrent windows. As a result, such students appeared to have trouble staying focused and on task, jumping instead between and among Web sites.

Recommendations

As a result of the first year's pilot test, we are able to make a few recommendations that we have already implemented in the second year's field test. They may well also apply to implementing other kinds of technology-rich science materials.

1. Technology-rich products still demand more technological sophistication than many teachers currently possess and more technical support than many schools currently provide.

Cutting-edge really means early implementers bleed so that later users may have fewer problems. As we saw in our pilot, present levels of technology call for a lot of troubleshooting. Until things become simpler, teachers need to be adept troubleshooters if they wish to use technology-rich materials in their classrooms. Given the troubles that some of our teachers had with technical support in their buildings, administrations who wish to see their teachers use such materials may well need to make certain the necessary level of technical support–and responsiveness—is there for teachers. In addition, teachers need to be made aware of the sorts of teaching technologies that exist, from large monitor connections to data projectors, to SmartBoards and amplified speaker connections. Not only should schools help their teachers understand what these technologies are and how to use them in teaching, but technology-rich materials produced for use in schools settings should include good instructions on how to use those materials in a wide range of delivery techniques.

2. Teachers wishing to implement technology-rich materials may need to rely on a more diverse set of computer configurations than just using the computer lab.

Our teachers certainly encountered a number of problems in working with computer labs. Availability and scheduling problems made it difficult to complete activities where they fell in the curriculum. If teachers want to stay on schedule, they may need to think in terms of a combination of approaches, only some of which might occur in a computer lab. And any activities in the computer lab need to be scheduled well in advance. Further, for technology-rich learning products to succeed, schools need to recognize the importance of instructional uses of computer labs, not simply use of such facilities for word processing and other activities calling for the use of tool/productivity programs. Similarly, schools need to plan for classroom Internet access.

Technology continues to advance. Wireless computers certainly appeared to help those teachers who had them to implement our prototypes in more flexible ways. Unfortunately, once a technology solution finds its way into a school, competition for that resource becomes greater. For instance, a teacher in our sample had received a grant to purchase wireless laptop computers for her school's biology department. At the beginning of the school year, she was the only teacher using the equipment. However, as more and more teachers began using her wireless laptop computers, she had more and more trouble scheduling them for her own use with our prototypes.

3. Technology-rich materials may change the nature of teacher planning for instruction.

While our teachers did not achieve the anticipated saving in planning time, the way in which they used their planning time did change a bit. It may be that having such rich materials means that teachers spend their advance time planning which parts of the product to implement when; how to prepare students for their interactions with the materials; which things to cover in whole-class settings, which in small groups, and which individually; how to match materials and activities to one's individual teaching style and philosophy; and how to assess student learning after using the materials. Of course, another use of planning time will continue for the present to be setting up the technology and preparing the setting for its use.

4. Professional development may need to focus more on helping teachers and administrators understand how best to implement learner-centered approaches.

Our findings suggest that many teachers (and perhaps administrators) may not have as broad an understanding of learner-centered approaches to teaching biology as they might. It is worth noting that high school science teachers may be more likely to have a science degree than a science education or education degree and may not have received training in incorporating technology into instructional contexts (*National Center for Education Statistics,* 1999). If such teachers are to employ more learner-centered approaches as recommended in the *National Center for Education Statistics* report, professional development focused on acquiring a diverse repertoire of pedagogical approaches may prove useful.

5. While it might seem logical to delay adoption of technology-based curricular materials until lots of high-powered computer equipment is widely distributed in schools, it may make more sense to start using products like this and let curricular demand dictate acquisition of more computer technology.

There's an old saying in the computer industry: *Software sells hardware (not the reverse).* Technology-using teachers do not seem to wait for the perfect hardware before they find strong technology-based curriculum materials. Instead, they acquire and adopt strong curricular materials and then use the technological demands of those materials to justify acquiring more computer technology.

Notes:

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