Historical Perspectives on Technology and Music

By Peter Webster

Through the years, advances in technology have led to changes in how music is performed and taught.

In the opening paragraph of a 1926 article on the use of radio in music instruction, William Fisher stated, "We live in a period of rapid and surprising changes. From our age-long bondage to time and space we are fast being released, and no thinking man dares set the bounds for tomorrow's discoveries."[1] This article was titled "The Radio and Music," and it was published in this journal, which was then called the *Music Supervisors' Journal*.

Children entering formal education today are unaware of a world without computers, personal digital assistants, portable CD and MPG3 players, digital keyboards, and the Internet with its connection to vast amounts of information. Music is everywhere in these media, and music teachers are continually inspired to use these computer-based technologies in their work. This connection between the fundamental goals of our profession and the opportunities that technology presents is hardly new. Computer-based technology is far more complex today than ever before, and music—and its worldwide presence in our society—has never been richer; thus, our fascination with technology and its role in teaching and learning continues to grow.

The word "technology" itself comes from Greek roots that relate to art/skill and discourse/communication. From the medieval


Photo by Mark Regan.

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days of the famous music teacher Guido of Arezzo, who used his hand to teach music intervals and modes, to the present day, when a teacher may use an Internet site with Flash technology to reinforce the very same thing, we have celebrated the use of applied science to improve student understanding of our very complex art form. This article places some of the landmarks in computer-based technology into historical perspective. I have chosen to organize developments into those that relate first to hardware, then software, and finally to a philosophy of use. The Technology Time Line sidebar provides an overview of hardware and software development. The Selected Readings sidebar and the sources listed in the notes offer resources for deeper understanding of this topic.

Hardware Advances

Developments in music technology owe much to the imaginations and achievements of not only musicians, but also physicists, engineers, inventors, and mathematicians interested in music. Their achievements have been most directly related to the hardware aspect of music and technology and are noted here in five phases.[2]

Phase 1 (1600s to mid-1800s): Gears and Levers. This is the age of music boxes, player pianos, calliopes, and other music machines that used pneumatic and spring-driven power. Many of these early mechanical devices can be seen and heard today in museums dedicated to preserving such traditions.[3] Their sound quality and craftsmanship of design are impressive. Dramatic advances in traditional acoustic instruments were made during this time, including improvements in string, wind, and percussion instruments that have come to define these instruments today. In the world of mathematical calculations, Charles Babbage designed calculating machines that automated the preparation of navigation tables and solved mathematical problems. Our understanding of the physics of sound accompanied these hardware achievements. For example, during this time period, Joseph Sauveur's acoustical research led to more precise rendering of the over-

Selected Readings on Music Technology

Berz, William L., and Judith Bowman. *Applications of Research in Music Technology.* Reston, VA: MENC, 1994. An excellent source for results of research on music technology.

Chadabe, Joel. *Electric Sound: The Past and Promise of Electronic Music.* Upper Saddle River, NJ: Prentice Hall, 1997. One of the most comprehensive sources on electronic music history.

Reblitz, Arthur A., and Q. David Bowers. *Treasures of Mechanical Music.* Vestal, NY: Vestal Press, 1981. One of the most comprehensive sources of information on mechanical instruments.

Williams, David Brian, and Peter Richard Webster. *Experiencing Music Technology.* 2nd ed. New York: Schirmer/Wadsworth, 1999. Contains a number of time lines that document significant music technology events.

Technology Time Line

1600s to mid-1800s

- Music boxes, player pianos, calliopes, and other machines use pneumatic and spring-driven power to make music.
- Advances in traditional acoustic instruments are made.
- Charles Babbage designs calculating machines.
- Joseph Sauveur's acoustical research leads to more precise rendering of the overtone series.
- Jean Fourier develops a method of sound synthesis.
- Hermann von Helmholtz begins his pioneering work in acoustics.

Mid-1800s to early 1900s

- Alexander Graham Bell invents the telephone.
- Thomas Edison invents the phonograph.
- Herman Hollerith develops a system of coding data on punched cards.
- Thaddeus Cahill builds the Telharmonium.

Early 1900s to mid-1950s

- Early computers such as the ABC, UNIVAC, and the ENIAC are built.
- The vacuum-tube oscillator leads to the development of amplifiers, new phonographs, tape recorders, jukeboxes, and electric guitars.
- Electronic performance instruments such as the Hammond organ, Theremin, and Ondes Martenot are created.

Mid-1950s to late 1970s

- Large mainframe computers become more common and affordable, while smaller minicomputers are developed.
- Computer-assisted instruction from mainframe systems is found on university campuses.
- Robert Moog and Donald Buchla develop commercially successful music synthesizers.
- Wolfgang Kuhn and Reynold Allvin use a pitch extraction device and a mainframe computer for judging the pitch accuracy of melodic patterns.

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- Ned Deihl works with a large computer on ear training for instrumentalists.
- Don Bitzer develops the PLATO system. G. David Peters and Robert Placek use PLATO for college music instruction, and Fred Hofstetter uses it to develop the GUIDO ear-training curriculum.
- The National Consortium for Computer-Based Musical Instruction (NCCBMI) is established.

Late 1970s to 1984

- The Apple IIe personal computer is developed, followed by personal computers from IBM, Atari, Radio Shack, and other companies.
- Micro Music introduces the first commercial library of computer-assisted instruction (CAI) software.
- Computer technology becomes affordable enough for purchase by school systems.
- Computer languages such as BASIC and LOGO allow students and educators to design custom software.

1985 to 1994

- The sixteen-bit Macintosh platform with built-in sound emerges, and new IBM machines follow.
- Advances in hard disk and removable storage allow more educators to experiment with their own computer programs.
- The MIDI (Music Instrument Digital Interface) protocol is introduced.
- Laser-driven CD-ROM drives that can play audio CDs are developed.
- Interactive music teaching software programs *Music Mouse, Band-in-a-Box,* and *Practica Musica* become available.
- The *Deluxe Music Construction Set,* ENIGMA (which later became *Finale*), *MusicPrinter Plus,* and *Nightingale* use MIDI support and laser-printing technology for music notation.
- Programs such as *Digital Performer, Musicshop,* and *Vision* help musicians and students experiment with music production.
- Robert Winter uses Apple's *HyperCard* to design an interactive program on Beethoven's Symphony no. 9.

1995 to the present

- Enhanced CDs are readily available for many forms of music.
- *Making Music* and *Making More Music,* as well as *Music Ace* and *Music Ace 2,* offer guided interactive instruction in music composition and theory.
- *SmartMusic* and *Intonation Trainer* provide accompaniment support and help in the teaching of intonation.
- Educators use programs such as *Peak* and *Sound Forge* to record and process sound.
- Teaching materials, recorded music, and published music become available on the Internet.

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tone series. Jean Fourier developed a method of sound synthesis that we still teach today, and Hermann von Helmholtz began his pioneering work in acoustics.

Phase 2 (mid-1800s to early 1900s): Electricity. The mechanical achievements of Phase 1 were given new life and refinement with the development of electrical power. The invention of the telephone by Alexander Graham Bell and the phonograph by Thomas Edison changed our expectations for communications and the delivery of music instruction.[4] During this time, Herman Hollerith developed the first system of coding data on punched cards, and his Tabulating Machine Company later became what is now IBM. Thaddeus Cahill successfully financed and built the Telharmonium, a two-hundred-ton machine that employed rotating wheels passing near magnets to produce sounds that were sent through telephone lines. Cahill's hope for this venture in 1906 was to sell music delivered as a service to clients at distant sites—an interesting foreshadowing of the Internet.

Phase 3 (early 1900s to mid-1950s): The Vacuum Tube. This phase of hardware development saw an extraordinary development of new devices. Edison's vacuum-tube technology, together with electromagnetic relay switches, provided the basis for some of the most impressive early computers, such as the ABC, the UNIVAC, and the ENIAC, which filled a room the size of a city block. The development of new musical instruments during this period had considerable impact on electronic music and music education. The vacuum-tube oscillator was a great boon to music because it led to the development of amplifiers, new phonographs, tape recorders, jukeboxes, and even early electric guitars. Electronic performance instruments such as the Hammond organ, Theremin, and Ondes Martenot were created and played in public to some level of success. Electronic music was born during this period and was seen as a natural step for composers such as Hindemith, Milhaud, Honegger, Ibert, Messiaen, Varèse, and Stockhausen—all of whom used electronic instruments in their scores.

Phase 4 (mid-1950s to late 1970s): Transistors. Computing machines and music machines were further transformed in this postwar period by the invention and development of the transistor and the semiconductor. Large mainframe computers like the IBM 360 and CDC 6000 became more common and affordable, while smaller minicomputers, such as Digital Equipment Corporation's PDP-8, were developed. Computer-assisted instruction from mainframe systems was used on such campuses as the University of Illinois and Florida State University. Robert Moog and Donald Buchla developed some of the first commercially successful music synthesizers. Schools and individuals could purchase devices like the ARP 2600 and experiment with sound synthesis. In fact, during this time period, music educators began to experiment with principles of electronic music.

Work with analog tape to create new compositions was common. Sound synthesis was stressed in many music classes, and "music concrete"—music created from recordings of real-life sounds—was seen as a fascinating way to encourage creative thinking in music.[5]

Phase 5 (late 1970s to the present): Integrated Circuits. During this period, we witness the growth of small, but powerful, personal computer systems. Because of the effectiveness of the integrated circuit and the computer chip, computing machines and electronic instruments have gotten smaller while increasing their ability to process digital information. The popular Apple IIe personal computer was developed in the late 1970s, and add-on, digital-to-analog circuit cards gave the computer four-voice polyphony. The IBM corporation soon followed with its own personal computer, which was emulated by many computer manufacturers in the coming years. In the mid-1980s, the Macintosh platform with built-in sound emerged to replace the Apple IIe, and new IBM machines followed. New versions of both Macintosh and IBM-type machines have become the dominant computers for music performance and education. Advances in hard disk and removable storage made it possible for more and more educators to experiment with their own computer programs. Development of laser-driven CD-ROM drives (in the late 1980s) that can play audio CDs has allowed these personal computers to be easily adapted to the music classroom.

As computer technology developed in this modern era, so did electronic music instruments. The MIDI (Music Instrument Digital Interface) protocol was developed in the mid-1980s and allowed music devices to transmit codes that described sound. The sound resources inside these devices have improved dramatically in recent years, as sampling technology captured in chips has allowed the internal sounds of MIDI hardware to rival some of the best acoustic instruments. Since the beginning of the 1990s, music educators have used these MIDI-based devices to assist in music composition, performance, and listening—building on the tradition of the Moog and Buchla machines of the past. The Yamaha Disklavier piano, with its built-in recording technology, has offered an interesting addition to the performance options of musicians and has continued the long tradition of player pianos that began in the nineteenth century.

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The Importance of Software Content

These developments in hardware mean very little to music educators without software development. From the earliest music boxes to the recent handheld computer, there must be something of worth inside to communicate to others if this technology is to be useful. The first three phases of music technology development (1600s to the mid-1950s) focused on hardware development, with little or no attention to software design for music pedagogy. Music reproduction was featured with little interest in the actual teaching of music. This changed in Phase 4 of hardware development (late 1950s, 1960s, and early 1970s) when mainframe computers began to interest those in academic circles.

Software Development in the Mainframe Era (mid-1950s to mid-1970s). Several forces converged to make some of the very first computer-based music teaching software. In addition to the development of the phonograph, tape recorder, sound reproduction devices, and computer hardware, high-level programming languages began to be created to help run the mainframe systems. Musicians and educators on major university campuses gained access to hardware resources and began to experiment with writing software. For example, in 1967, Wolfgang Kuhn and Reynold Allvin of Stanford University used a pitch extraction device and a mainframe computer to help judge the pitch accuracy of melodic patterns. At the Pennsylvania State University in 1969, Ned Deihl did early work with a large computer on ear training for instrumentalists.

Perhaps some of the most significant work done at this time was at the University of Illinois with the PLATO system, first developed by Don Bitzer. The PLATO system used a large computer, touch-sensitive screens, and a programming language called TUTOR. G. David Peters and Robert Placek did experiments in music teaching, and the PLATO system came into regular use for college music instruction in 1973. Fred Hofstetter used a PLATO system at the University of Delaware in 1975 to develop ear-training materials. His curriculum, called GUIDO, continued to be developed, and its effectiveness was extensively documented.

These efforts are historically important and marked the true beginning of computer-based music teaching software development. Much of the effort was federally funded, restricted to students at large universities, and had a limited effect on music teaching in the primary and secondary schools. One by-product of these years was the 1975 establishment of the National Consortium for Computer-Based Musical Instruction (NCCBMI), which is now the Association for Technology in Music Instruction (ATMI). This group was, and continues to be, a major force in the application of technology at all levels of instruction.[6]

Software Development in the Age of the Personal Computer (mid-1970s to present). The hardware advances in personal computing, MIDI, and laser technology have completely changed the nature of music instruction; however, this time period is equally impressive for its major advances in music software. During this time, music production software for music printing, sequencing, and digital audio emerged. The drill-and-practice software that dominated the past era continued, but new music software that uses guided instruction, games, simulation, and creative exploration has become dominant. Internet-based delivery of instruction has become a recent development.

During 1978 to 1984, often referred to as the "eight-bit" period in honor of the first personal computers (such as those created by Apple, Atari, and Radio Shack), David Williams and David Shrader (and their *Micro Music* company) developed the first commercial library of computer-assisted instruction (CAI) software for use with these "microcomputers." The library included software to support melodic, rhythmic, and harmonic dictation; error detection; and music composition. This period was important for primary and secondary school education because school systems could, for the first time, afford computer technology in addition to tape recorders and music synthesizers. Computer languages such as BASIC and LOGO were designed to run on these home computers and became important creative tools for students and music educators in the design of custom software.[7]

From 1984 to 1994, the software aspect of music technology exploded in ways unparalleled in history. The development of the MIDI protocol and production of "sixteen-bit" computers, such as the Apple Macintosh and the newer versions of the IBM computer and its clones, allowed the creation of more sophisticated music instruction programs. Laurie Spiegel's *Music Mouse* program became the first improvisation-based software that turned the computer itself into a musical instrument. *Band-in-a-Box* from PG Music became the first commercial software to provide automated accompaniments for improvisation. *Practica Musica* from Ars Nova was one of the first music theory/aural skills programs to incorporate options for students and teachers—creating a kind of "flexible-practice" software that could be adapted to individual learning needs. Each of these programs used the MIDI protocol to help the computer use external synthesizers as sound sources as well as interactive partners in the learning process.

In addition to these CAI titles, the first programs for music notation were published. The *Deluxe Music Construction Set*, created by Geoff Brown, was the first popular music-printing program, followed soon by the development of the *ENIGMA* notation engine, which became Coda Music Technology's *Finale* program. Jack Jarrett's *MusicPrinter Plus* and Donald Byrd's *Nightingale* also emerged around this time. Each of these music-printing programs was aided greatly by MIDI support and by the development of laser-printing technology, which was also causing major advances in desktop publishing outside of music. Software for music sequencing was developing at the same time, allowing arrangers and composers to develop scores for commercial music, television, and film more effectively. Programs such as *Performer* from Mark of the Unicorn and *Musicshop* and *Vision* from Opcode were soon used by commercial musicians and music educators wishing to help students experiment with music production.

With today's affordable personal computers, even the youngest children can play along with the computer, make increasingly complex decisions about the composition of the music, or listen to music in new and exciting ways.

It was also during this ten-year period that the audio CD greatly influenced the development of multimedia software production. In 1989, the term "hypermedia" was coined by Ted Nelson, building on a much earlier idea of interrelated text sources. Nelson's idea was to create a learning environment that allowed software to connect graphics, sound, and text into an integrated whole. In this same year, Robert Winter designed the first commercial product in music to use this idea—an interactive program on Beethoven's Symphony no. 9, using a CD recording controlled by a software program. The software program was Apple's HyperCard, a tool kit for the development of hypermedia programs, written by Bill Atkinson. HyperCard was a conceptual breakthrough for music software production because it allowed music educators without significant computer programming experience to create high-quality interactive software that used audio recordings on CD. This, together with Apple Computer's development of QuickTime technology, which allowed the capture and playback of digital video as part of computer software, inspired a number of professionally created interactive CD-ROMs devoted to music.[8]

The period from 1995 to the present has seen continued development of hypermedia titles, referred to as "multimedia" experiences. For example, "enhanced CDs"—audio CDs with multimedia content that can be viewed using a CD-ROM drive—are readily available for many forms of music. In addition, software for music pedagogy has included new titles that encourage simulation and guided instruction. *Making Music* and *Making More Music* by Morton Subotnick provide support for music composition; these programs assume no knowledge of music notation and allow the student to discover musical structures by using a drawing metaphor. The role of a composer is simulated in ways that help teach the processes of composition. Harmonic Vision's *Music Ace* and *Music Ace 2* use guided instruction to help students understand music theory and aural skills in an interactive environment using animation. Children are guided in their discovery of important music facts, and opportunities are provided to test mastery with games and a composing space. These programs can be tailored to meet the needs of students and teachers and use the latest in computer-based technology, including software-based sound synthesis.

Music technology support for the music studio has significantly increased in recent years. Software such as *SmartMusic* and *Intonation Trainer* from Coda have provided accompaniment support for instrumentalists and vocalists and helped in the teaching of intonation. The quality of modern personal computer digital audio recording capabilities has also increased, allowing educators to take advantage of software that records performances directly to disc. Software such as *Peak* from Bias and *Sound Forge* from Sonic Foundry can be used to record and process sound with an impressive array of special effects. Music can now be easily recorded, processed, and "burned" onto an audio CD in one's home.

Perhaps the most important recent trend for software has been the rise of Internet-based materials for music teaching and learning.[9] As more music teachers gain skills in the development of Web sites and as more schools gain access to the Internet, music teaching materials provided online at any time of day or night have begun to transform both content and delivery strategies. Individuals and companies now routinely distribute recorded music on the Internet in the form of MPG3 files. Music notation software companies such as Coda and Sibelius recently announced procedures for purchasing published music directly from an Internet site.

Changes in Philosophy

A review of developments in hardware and software is incomplete without attention to the underlying shifts in how technology is used. The world truly is a more complex place today than it was thirty, twenty, or even ten years ago. Multiple cultures and value systems flourish, knowledge is growing at exponential rates, and change occurs faster and with more profound consequences than at any other time in history. Content is becoming more complex, and what we know about how children learn is a major consideration. Rote learning, memorization, and convergent thinking are more likely to be augmented or even replaced with discovery learning, problem solving, and divergent thinking. Cooperative learning, peer teaching, and project-centered learning with the teacher as a facilitator or monitor are becoming more valued than teacher-dominated interaction.

In the last ten years, music educators have used technology in a more "constructionist" context. Students are encouraged to "construct" their understanding of music through their experiments while being expertly guided by teachers.[10] The traditional drill-and-practice techniques that dominated the use of technology until the mid-1980s have been complemented by much more powerful software that uses problem-solving and role-playing techniques. Video, animation, text, and sound can unite to support a symbolically constructed world that represents reality in interesting and meaningful ways for children. With today's affordable personal computers, even the youngest children can play along with the computer, make increasingly complex decisions about the composition of the music, or listen to music in new and exciting ways. It is not just the multiple media that are significant, but their use in allowing children to think and feel musically.

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The Future

The ratio of cost-to-hardware capability has never been more favorable for music educators. Computers costing less than a thousand dollars have processing power, memory, and storage capacity that rival room-size mainframe computers of only a few decades ago. Digital video displays (DVD) will soon be commonplace in schools, replacing projectors and large tube screens. DVD drives are now standard on most computers, allowing access to several times more space than the average CD-ROM. At this time, DVDs have not been produced for music education with the kind of content that is really needed. This, however, will surely change as the production of such software resources becomes more economically feasible. There is also potential for the development of virtual-reality devices that allow children to explore music creation in powerful ways, interact with music while listening, and perform in new ways with instruments not imagined currently.[11]

Perhaps the most compelling current development is the trend for hardware devices to become smaller and to communicate without wires. Laptop computers and small personal digital assistants (PDAs) may soon be as ubiquitous in schools as lunch boxes and backpacks. It is not uncommon today to find these devices trading information by using infrared, satellite, or other wireless technologies. Personal recording devices like the MPG3 player are becoming quite affordable and can be programmed to contain compressed versions of hundreds of recordings from standard CDs or the Internet.

It seems clear from these trends that information in the form of text, graphics, video, and sound will be (1) moving to a digital format, (2) rendered with smaller and more powerful machines, and (3) used extensively by music teachers to assist children in understanding music by having them create music more interactively. The words of William Fisher that opened this article were published seventy-six years ago, but they could have been written yesterday. It has never been a more exciting time to be a music teacher.

Notes

1. William Fisher, "The Radio and Music," *Music Supervisors' Journal* 12, no. 3 (1926): 8.

2. The time periods presented in this article are, by nature, estimates and should not be taken too literally.

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Cultural Transformation

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States," *Harvard Educational Review* 57, no. 4 (1988): 421–44.

5. Terese M. Volk, *Music, Education, and Multiculturalism* (New York: Oxford University Press, 1988); Patricia Shehan Campbell, "Music, Education, and Community in a Multicultural Society," in *Cross Currents,* ed. Marie McCarthy (College Park, MD: University of Maryland, 1996); Marie McCarthy, "The Birth of Internationalism in Music Education, 1899–1938," *International Journal of Music Education* 21 (1993): 3–15.

6. Robert A. Choate, ed., *Documentary Report of the Tanglewood Symposium* (Washington, DC: Music Educators National Conference, 1968).

7. Michael L. Mark, "MENC: From Tanglewood to the Present," in *Vision 2020: The Housewright Symposium on the Future of Music Education,* ed. Clifford K. Madsen (Reston, VA: MENC, 2000).

8. "Music in World Cultures," special focus issue of the *Music Educators Journal* 59, no. 2 (1972).

9. James A. Standifer and Barbara Reeder, *Source Book of African and Afro-American Materials for Music Educators* (Washington, DC: Contemporary Music Project, 1972).

10. See Standifer and Reeder, *Source Book;* William M. Anderson, *Teaching Asian Musics in Elementary and Secondary Schools* (Dallas: Taylor Publishing Company, 1975); and Sally Monsour, *Songs of the Middle East* (Miami: Warner Bros. Publications, 1995).

11. William M. Anderson and Patricia Shehan Campbell, eds., *Multicultural Perspectives in Music Education* (Reston, VA: Music Educators National Conference, 1989). A second edition was published in 1996.

12. These articles are compiled in Patricia Shehan Campbell, *Music in Cultural Context: Eight Views on World Music Education* (Reston, VA: Music Educators National Conference, 1996).

13. Patricia Shehan Campbell, "Musica Exotica, Multiculturalism, and School Music," *The Quarterly Journal of Music Teaching and Learning* 5, no. 2 (1994): 65–75. ■

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3. A Web site for exploring virtual museum sites is: www.musicamecanica.org/musica_mecanica/a/index.html. This location provides links to hundreds of museums internationally.

4. Reviews of the very first issues of the *Music Supervisors' Journal* reveal advertisements for different models of the Victor Talking Machine victrola and for a series of recordings from the firm that would become the RCA recording company of today. See Cynthia A. Hoover, *The History of Music Machines* (New York: Drake Publishers, 1975).

5. For more information on how this phase affected music teaching, see *Music Educators Journal* 57, no. 5 (1971). This first special focus issue on music technology features articles on synthesizer use, programmed instruction, films, and computer-assisted instruction.

6. An excellent review of these software developments with large mainframe systems can be found in John M. Eddins, "A Brief History of Computer-Assisted Instruction in Music," *College Music Symposium* 21, no. 2 (1981): 7–14.

7. For more information on this period, see *Music Educators Journal* 69, no. 5 (1983). This is the *MEJ*'s second special focus issue devoted to technology, and it features articles on the microcomputer, synthesizers, and music technology pedagogy.

8. For a summary of some of these developments, see *Music Educators Journal* 79, no. 3 (1992). This is the *MEJ*'s third special focus issue devoted to technology.

9. See Bill Waters, "Ideas for Effective Web-Based Instruction," *Music Educators Journal* 85, no. 4 (1999): 13–17.

10. An excellent source on the emergence of constructionism as a modern philosophy for learning is: Yasmin Kafai and Mitchell Resnick, eds., *Constructionism in Practice: Designing, Thinking, and Learning in a Digital World* (Mahwah, NJ: Lawrence Erlbaum, 1996).

11. For a glimpse into how this might occur, read about the work of Tod Machover and others at the MIT Media Lab, where new "hyperinstruments" are being created and used in interesting ways. See: www.media.mit.edu/~tod/ ■