

# Preparing for the Changing Role of Instructional Technologies in Medical Education

Bernard R. Robin, PhD, Sara G. McNeil, EdD, David A. Cook, MD, MHPE, Kathryn L. Agarwal, MD, and Geeta R. Singhal, MD, MED

## Abstract

As part of an international faculty development conference in February 2010, a working group of medical educators and physicians discussed the changing role of instructional technologies and made recommendations for supporting faculty in using these technologies in medical education. The resulting discussion highlighted ways technology is transforming the entire process of medical education and identified several converging trends that have implications for how medical educators might prepare for the next decade. These trends include the explosion

of new information; all information, including both health knowledge and medical records, becoming digital; a new generation of learners; the emergence of new instructional technologies; and the accelerating rate of change, especially related to technology. The working group developed five recommendations that academic health leaders and policy makers may use as a starting point for dealing with the instructional technology challenges facing medical education over the next decade. These recommendations are (1) using technology to provide/support experiences for learners that are not

otherwise possible—not as a replacement for, but as a supplement to, face-to-face experiences, (2) focusing on fundamental principles of teaching and learning rather than learning specific technologies in isolation, (3) allocating a variety of resources to support the appropriate use of instructional technologies, (4) supporting faculty members as they adopt new technologies, and (5) providing funding and leadership to enhance electronic infrastructure to facilitate sharing of resources and instructional ideas.

**A**s institutions of higher education evolve, it is obvious that they, like many other organizations and systems, need to undergo radical changes to deal with the converging trends that are affecting how we live, learn, and solve problems in health care and beyond. As Christensen<sup>1</sup>

notes in the Forum for the Future of Higher Education, schools must completely rethink and restructure the way they deliver educational content: “The rebuilding task demands a team comprising experts who don’t represent their departments or divisions and who can think outside the current organizational structure.” This transformation will occur in many ways; much of it will involve new technologies, both as the object of instruction and for the purpose of facilitating and assessing learning.

With this kind of transformation in mind, a conference, “A 2020 Vision of Faculty Development Across the Medical Education Continuum,”<sup>2</sup> was convened in February 2010. There, a working group of medical educators and physicians discussed the changing role of instructional technologies in medical education, as well as several converging trends and challenges that have implications for how medical educators might prepare for the next decade. They subsequently developed five recommendations for supporting faculty in using instructional technologies in medical education. Those recommendations, and the discussion that shaped them, are the focus of this article.

## The Challenge in Predicting the Future

In 1936, H.G. Wells<sup>3</sup> suggested that the solution to “all the scattered and ineffective mental wealth of the world” was what he called a “World Encyclopaedia” for the common man. The World Encyclopaedia would be assembled by authorities in each subject area and would be “a concentration, a clarification, and a synthesis” designed to “hold the world together mentally.” Wells’ World Encyclopaedia sounds remarkably like today’s Wikipedia, a multilingual, Web-based, free-content encyclopedia project based on an editable, collaborative model begun in 2001 by Jimmy Wales and Larry Sanger.<sup>4</sup> In 1945, Vannevar Bush<sup>5</sup> described the difficulty in managing and disseminating the results of research to the scientific community. He proposed the *memex*, a device in which “an individual stores all of his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility.” The *memex* sounds surprisingly like today’s handheld computers and Internet-connected smartphones. Yet not all predictions of the future are this accurate. John Eric Erichsen,<sup>6</sup> appointed Surgeon Extraordinary to Queen Victoria, stated

**Dr. Robin** is associate professor of instructional technology, Department of Curriculum and Instruction, and director, Master’s of Education in Teaching Program With an Emphasis in the Health Sciences, College of Education, University of Houston, Houston, Texas.

**Dr. McNeil** is associate professor and program director of instructional technology, Department of Curriculum and Instruction, College of Education, University of Houston, Houston, Texas.

**Dr. Cook** is professor of medicine and director, Office of Education Research, Mayo Clinic College of Medicine, Rochester, Minnesota.

**Dr. Agarwal** is assistant professor of medicine, Section of Geriatrics, Baylor College of Medicine, Houston, Texas.

**Dr. Singhal** is assistant professor of pediatrics, Section of Emergency Medicine, Baylor College of Medicine, Houston, Texas.

Correspondence should be addressed to Dr. Robin, 256 Farish Hall, University of Houston, Houston, TX 77204-5027; telephone: (713) 743-4952; e-mail: brobin@uh.edu.

Acad Med. 2011;86:435–439.  
First published online February 21, 2011  
doi: 10.1097/ACM.0b013e31820dbbee4

in 1873: “There cannot always be fresh fields for conquest by the knife. There must be portions of the human frame that will ever remain sacred from its intrusion—at least, in the surgeon’s hand.” William Thomson (Lord Kelvin), an English physicist and inventor, stated in 1899 that “X-rays will prove to be a hoax.”<sup>7</sup> Acknowledging Kanter’s<sup>8</sup> caution that predicting the future is best left to fortune tellers, we need to do our best to predict future opportunities to improve medical education, or worse, be left behind as the world moves on without us.

We face two important tasks: first, to adapt to change early enough to influence outcomes; and second, to harness change to enhance education. Although it is impossible to predict the future with full certainty, understanding and interpreting the transformation that is occurring may serve as a guide in preparing for the evolving role of instructional technologies in medical education. We thus offer a view of several converging trends that have implications for how medical educators might prepare for the next decade and the new challenges they will encounter in medical education by 2020.

## Converging Trends in Technology That Are Affecting Medical Education

### Trend 1: The explosion of new information

The rate of growth of the world’s collective body of knowledge has been accelerating at an extraordinary pace. The world’s body of knowledge doubled between 1800 and 1900, by 1940 the doubling rate was every 20 years,<sup>9</sup> and Cornall<sup>10</sup> has postulated that by 2015, the body of knowledge in the world will double every 35 days.

The amount of new medical information has undergone a similarly explosive trajectory: Some futurists suggest that at the beginning of the 21st century, the amount of new medical information was doubling every three years.<sup>11</sup> Further, as new information becomes available and old becomes obsolete or less than complete, the formal knowledge base of health care professionals loses its relevance over time and must be supplemented with new training and opportunities for continued learning. Rather than having their education end at

the completion of medical school, internship, and residency, new physicians face a lifelong task of processing, understanding, and using a dizzying amount of new medical information.

### Trend 2: The digitization of all information

Many futurists have suggested that the next generation of computer users will be able to access any information at any time and from any place. However, we don’t need to wait for the future to see this change occur—for many types of information this transition has already taken place. Because of concerns about legal, ethical, and privacy concerns, health information has thus far been limited in this regard, but that is changing. Google Health (<https://www.google.com/health>) now allows people who create an account to collect their medical records, prescriptions, and other health data and share them with family members, health care practitioners, and others online. This venture may forecast whether patients are willing to trust their health information to large personal health record providers, and it will provide a glimpse at how making patients “stewards of their own medical data” will impact medical care in the future.<sup>12</sup> By making it easy for patients to manage and share their own records, online personal health records have the potential to bring about a tremendous increase in the fluidity of health data—not unlike the information accessibility model that Vannevar Bush proposed in 1945. Yet this growth of hyperconnectivity to the Internet and the Web prompts medical educators and policy makers to ask serious questions about a broad range of social, personal, and ethical issues that will almost certainly provoke tension among users, parents, policy makers, and educators.

Technology itself is playing a role in this explosion of digital information. In his classic book *The Innovator’s Dilemma*, Christensen<sup>13</sup> explores how some innovations disrupt the traditional way of performing tasks by breaking with the past and creating new functionality not found in the original process or object. One of the significant characteristics of disruptive technologies is that they turn the power over to the user rather than maintaining centralized, predetermined use/control. Traditional film photography and printing were disrupted by

inexpensive, easy-to-use digital cameras and printers that allow anyone to be a “photographer.” Phonograph records, cassettes, and audio CDs were disrupted by MP3 files and players that allowed users to compile and play “on demand” playlists of their choosing instead of a predetermined “show.” Broadcasting has, in part, been co-opted by users who upload original and almost instantaneously current YouTube videos with inexpensive digital cameras, camcorders, and cell-phone cameras. As learners gain access to and control over increasing amounts of digital information, successful educators must take advantage of the disruptive effects this information creates. In Bonk’s<sup>14</sup> view, “institutions will need to create new mechanisms for the way knowledge is created, supported, disseminated, and consumed.”

### Trend 3: New generations of learners

Most medical educators today fall into one of three categories: “digital immigrants,” “digital settlers,” or “traditionalists.” “Digital immigrants,” a term coined by Prensky,<sup>15</sup> describes those who learned to use technology after finishing a formal education without continuous access to computers. Most of these people now use digital technologies, but they do so “with an accent,” typical of someone who learned a new language as an adult. A smaller number of adults, including many educators and health care professionals, are “digital settlers,” described by Palfrey and Gasser<sup>16</sup> as those who were not “born digital” but who “live digital” nonetheless. These adults feel comfortable using many technologies for professional and personal productivity, and their accent is decidedly less pronounced than that of their digital immigrant cousins. Another group, the “traditionalists,” grew up without technology and have not embraced it as a core part of their teaching.

Educators such as Norris and Soloway<sup>17</sup> suggest that change in educational practices should focus on innovative instructional strategies to reach and engage those students whom Prensky described as “digital natives.” These young people were born into a digital world and speak the language of technology fluently, as a native tongue. They grew up using Google, easily read text on a computer screen or mobile device, and freely share details of their

private lives on publicly accessible Web sites such as Facebook. Their use of and attitudes toward technology are dramatically different from those of their parents and teachers; they expect their education to reflect these levels of technology integration. As this generation of learners reaches medical schools, there are three important questions to consider: What type of learners will these “digital natives” be? What changes will they precipitate in the way education is structured? How will medical educators deal with these students’ growing expectations to integrate new technologies in the curriculum?

#### **Trend 4: The emergence of new instructional technologies**

The generation of digital natives entering medical schools and the instructors who teach them will be faced with an ever-increasing set of technological tools and resources designed to complement teaching and learning. As these newer technologies evolve, they will provide exciting opportunities but may also cause stress for both educators and students who feel unsure about how to use these technologies effectively. The task for medical educators is to use these new technologies effectively to transform learning into a more collaborative, personalized, and empowering experience that can inspire a new generation of learners. Bonk<sup>14</sup> captures the essence of this new age of technology tools for education by stating, “Anyone can now learn anything from anyone at anytime.”

New technologies have revolutionized development and distribution of video learning resources. Digital video clips on almost any topic can command a sizeable audience that also actively participates in the rating of the videos and the posting of video responses.<sup>18</sup> The significance of this is that these users are not just passive viewers; many of them are actively engaged in a new form of communication and expression. In one instance among many, Bridge et al<sup>19</sup> conducted a five-year retrospective study of streaming video use at Wayne State University School of Medicine and found the student response to be overwhelmingly positive, with just a small percentage of students reporting that they rarely or never used streaming video of lectures.

Web 2.0, a term used to describe an evolving set of online tools and resources, includes a wide variety of social networking sites, virtual environments, wikis, blogs, and podcasts.<sup>20</sup> These technologies offer educators and students new ways of teaching and learning through innovative approaches to accessing, sharing, and creating information. A project that enables using the Web as a global support group illustrates one of the disruptive effects of these new types of resources. Founded in 2004 by three Massachusetts Institute of Technology engineers, Patients Like Me<sup>21</sup> is a social network for people who share information about mental and physical illnesses, input health information related to prescriptions and symptoms, and connect with others who share their ailment.

In addition to the many Web 2.0 tools, new technologies such as high-fidelity simulators and virtual patients can provide new learning experiences that were unimaginable just a few years ago. Research on the effectiveness of simulations is growing, and some studies have identified the features of effective medical simulations using high-fidelity simulators<sup>22</sup> and screen-based virtual patients.<sup>23</sup>

#### **Trend 5: Accelerating change**

A 2008 report from Microsoft, *Being Human: Human-Computer Interaction in the Year 2020*,<sup>24</sup> predicts that within the next decade, individuals will interact with thousands of computers as virtually every piece of equipment we use, from televisions to automobiles to medical devices, will be embedded with computer chips, interwoven into every aspect of daily life. Gaudin<sup>25</sup> postulated that by 2020, the keyboard and mouse will no longer be needed to control a computer. Scientists at Intel Research Labs are already developing systems that will allow users wearing a head set to interact with computers. BrainGate<sup>26</sup> is conducting clinical trials using computer chips implanted in the brains of severely disabled individuals with traumatic spinal cord injury and loss of limbs that link the neurons of the human brain directly to a computer and allow them to communicate and control common everyday functions. Although the idea of implanted chips in the brain may seem more like science fiction than science fact, there are those who believe that “the

development of a human-wearable chip or card that stores all personal information and can be used to manage all kinds of transactions on all computational platforms” is possible in the not-too-distant future.<sup>27</sup> The expansion of new technologies, more information, new types of learners, and the accelerating pace at which they will appear show no signs of slowing down.

### **Recommendations**

In response to these technological trends, we developed the following recommendations, which academic health leaders and policy makers might use as a starting point for dealing with the challenges facing medical education over the next decade.

#### **Recommendation 1: Use technology to support learning**

*Faculty should use technology to provide and support experiences for learners that are not otherwise possible—not as a replacement for face-to-face experiences but as a supplement to them.* It is now well established that instructional technologies such as e-learning can facilitate effective learning.<sup>28,29</sup> The same appears to be true of other technologies such as simulation. However, there does not seem to be any inherent superiority of newer technologies over traditional methods, and in fact most technologies come with attendant disadvantages.<sup>30</sup> Hence, it seems the advantage of newer technologies comes not because they improve learning per se but because in many instances they can enable learning in situations where it would otherwise be difficult or impossible. For example, Internet-based technologies can overcome barriers to learning such as time and distance, individualize instruction, and manage information. Technology-enhanced simulation can facilitate deliberate and repeated practice and team training and can permit practice of clinical problems that are rare or expose patients to unnecessary risks. Often, the most effective instructional designs involve a combination of traditional and technology-enhanced methods. The question, then, is not whether we should use technology to support education, but when and how to employ these technologies.



## Recommendation 2: Focus on fundamentals

*Because technologies evolve rapidly, faculty members should focus on fundamental principles of teaching and learning rather than specific technologies in isolation.* As technologies continue to evolve—and presently the pace of evolution seems to be accelerating—the sheer number of new gadgets, software programs, and Internet sites can bewilder even the most tech-savvy faculty member. Rather than try to stay abreast of the latest technology, or feel guilty for not being able to achieve this impossible task, educators will find greater success in focusing first on the learners' needs and course objectives. They should then select an instructional approach to meet these needs and objectives, using technology as needed to support this approach. "Technology" thus assumes its appropriate role as a toolbox from which educators may select the appropriate tool (or combination of tools), depending on the needs at hand. Content experts (e.g., health care practitioners) may find it helpful to engage the assistance of instructional designers in selecting an optimal instructional solution. Although the evidence base informing instructional design is growing,<sup>22,23,31,32</sup> much remains to be learned about how to effectively harness new technologies for education.<sup>29,33,34</sup>

## Recommendation 3: Allocate a variety of resources

*Medical schools should allocate a variety of resources to support the appropriate use of instructional technologies.* The support that medical schools should provide to faculty members includes educating faculty about the technologies students use and helping them learn to use new technologies as needs arise. The effective use of technology requires support from a variety of experts in instructional design and educational technology, and thus a variety of resources are needed. Such resources might include instructional designers with expertise in various technologies, adequate time for faculty to learn and create curricular materials enhanced with technology, and suitable software and hardware. Faculty members should be content experts, but they do not necessarily need to be technology experts. Teams composed of e-learning specialists, Web designers, and videographers could support the design

and development of new instructional materials while guiding medical school faculty in the use of new technologies.

## Recommendation 4: Support and recognize faculty as they adopt new technologies

*Medical schools should support faculty members as they adopt new technologies.* Faculty members may feel intimidated by students who use technologies with which they are unfamiliar. Likewise, they may feel frustrated as they watch colleagues employ new technologies in their instruction, or they may sense that their instruction could benefit from a certain technology yet feel incapable of using it because of a lack of training. It will be important for schools to support faculty members in these situations, enabling them to become comfortable with the technologies students use (or, perhaps even better, learn not to worry about the issue), and help them learn and use new technologies as needs arise. Ruiz et al<sup>35</sup> note that "e-learning requires faculty competencies that go beyond traditional instructional activities." Evidence of academic scholarship could include documentation of the effective use of these new technologies. Course development grants as well as adequate time to learn new technologies are necessary if faculty members are to adopt new ways of teaching.

## Recommendation 5: Foster collaboration

*National organizations should provide funding and leadership to enhance a national/global infrastructure to foster collaboration to develop and share resources as well as discuss instructional ideas in medical education.* Effective curricular innovations in the health sciences should be disseminated nationally and internationally through an infrastructure that supports collaboration and ongoing discussion. This infrastructure would allow medical educators to share and discuss innovations, best practices, and implementation plans for the use of instructional technologies as well as provide opportunities to collaborate in developing curricula and instructional ideas in a central, easily accessed Web site.

Several online resources provide ideas for how this online community can be structured. For example, the Health Education Assets Library (HEAL), developed in conjunction with members

of the International Association of Medical Science Educators, is a digital repository that "allows medical educators to discover, download, and reuse over 22,000 medical education resources."<sup>36</sup> HEAL gives medical educators access to a wide range of multimedia resources that can support health care education. MedEdPORTAL, a free, peer-reviewed publication service and repository for health-related teaching materials, assessment tools, and faculty development resources, is an example of an excellent online publication service designed to help educators publish and share teaching materials.<sup>37,38</sup> The structure of MedEdPORTAL differs slightly from HEAL in that it typically publishes more complete, stand-alone resources such as tutorials, virtual patients, simulation cases, lab guides, videos, podcasts, and assessment tools.<sup>36</sup> "BioMedExperts" is not a repository of resources but, rather, an online community that generates expert profiles by analyzing PubMed publications. It then connects researchers with similar expertise and interests to create professional networks and support collaboration and interdisciplinary research.<sup>39</sup> However, none of these resources provides sufficient opportunities for the community building, collaboration, and discussion needed to support 21st-century medical education. We envision the development of a comprehensive infrastructure to support a professional network for medical educators that incorporates the most useful repository features of MedEdPORTAL and HEAL and the connection capabilities of the BioMedExperts model.

## The Future Is Here

Innovative technologies have evolved and have changed our thinking and practice in numerous ways, in education and simply in everyday life. Current trends strongly suggest that we must adapt our instructional strategies in order to adequately educate the next generation of health care professionals. The recommendations we have provided will, we hope, serve as a guide in helping leaders and policy makers deal with the many challenges that will certainly come over the next decade. The future has already begun to appear, at least in terms of the futuristic technologies that are now being used in education. The world has

become faster, more complex, and more technologically driven, for us as educators and for our current students. Although we cannot predict the future with certainty, one thing is clear: We must embrace, adapt to, and harness technology in order to meet the needs of present and future health professionals.

*Acknowledgments:* The authors gratefully acknowledge the participation and input of participants at the “2020 Vision of Faculty Development Across the Medical Education Continuum” writing conference, held at Baylor College of Medicine on February 26 to 28, 2010.

*Funding/Support:* This work was supported by the writing conference acknowledged above. The conference was funded by the Medallion Fund and the Josiah Macy Jr. Foundation.

*Other disclosures:* None.

*Ethical approval:* Not applicable.

*Previous presentations:* Information from this article was presented at the writing conference mentioned above.

## References

- Christensen C. Disruptive innovation and catalytic change in higher education. *Forum for the Future of Higher Education*. 2008;43–46. <http://net.educause.edu/ir/library/pdf/ff0810s.pdf>. Accessed December 8, 2010.
- Baylor College of Medicine. Faculty Development Conference: A 2020 Vision of Faculty Development Across the Medical Education Continuum; February 26–27, 2010; Houston, Tex. <http://www.bcm.edu/fac-ed/index.cfm?pmid=15709>. Accessed December 8, 2010.
- Wells HG. *World Brain*. Garden City, NY: Doubleday, Doran & Co., Inc; 1938.
- History of Wikipedia. [http://en.wikipedia.org/wiki/History\\_of\\_Wikipedia](http://en.wikipedia.org/wiki/History_of_Wikipedia). Accessed December 8, 2010.
- Bush V. As we may think. *Atl Mon*. 1945;176:101–108.
- Erichsen JE. *Modern Surgery: Its Progress and Tendencies*. London, UK: H.K. Lewis; 1873.
- Kappelman L. The future is ours. *Commun ACM*. 2001;44:46–47.
- Kanter S. The future of academic medicine: What can academic medicine do about it? *Acad Med*. 2009;84:405–406. [http://journals.lww.com/academicmedicine/Fulltext/2009/04000/The\\_Future\\_of\\_Academic\\_Medicine\\_What\\_Can\\_Academic.1.aspx](http://journals.lww.com/academicmedicine/Fulltext/2009/04000/The_Future_of_Academic_Medicine_What_Can_Academic.1.aspx). Accessed December 8, 2010.
- Kelly K. The speed of information. [http://www.kk.org/thetechnium/archives/2006/02/the\\_speed\\_of\\_in.php](http://www.kk.org/thetechnium/archives/2006/02/the_speed_of_in.php). Accessed December 8, 2010.
- Cornall R. Speech at Queensland University of Technology Faculty of Law Graduation Ceremony. [http://www.ag.gov.au/www/agd/agd.nsf/Page/AbouttheDepartment\\_Speeches\\_2008\\_QUTFacultyofLawGraduationCeremony](http://www.ag.gov.au/www/agd/agd.nsf/Page/AbouttheDepartment_Speeches_2008_QUTFacultyofLawGraduationCeremony). Accessed December 8, 2010.
- Swartwout J. AOA continuing medical education. *J Am Osteopath Assoc*. 2000;100:697–702.
- Harris L. Google Health heads to the hospital: A new partnership at a Boston hospital could forecast future success. *Technol Rev*. May 28, 2008. <http://www.technologyreview.com/web/20823/?a=f>. Accessed December 8, 2010.
- Christensen C. *The Innovator’s Dilemma*. Cambridge, Mass: Harvard Business School Press; 1997.
- Bonk CJ. *The World Is Open: How Web Technology Is Revolutionizing Education*. San Francisco, Calif: Jossey-Bass; 2009.
- Prensky M. Digital natives, digital immigrants. *On the Horizon*. 2001;9:1–6.
- Palfrey J, Gasser U. *Born Digital*. New York, NY: Basic Books; 2008.
- Norris C, Soloway E. Emerging, disruptive technologies for teaching and learning: A brief survey. In: Crawford C, Carlsen R, McFerrin K, Price J, Weber R, Willis DA, eds. *Proceedings of Society for Information Technology & Teacher Education International Conference 2006*. Chesapeake, Va: AACE; 2006:2353–2355.
- ComScore. YouTube surpasses 100 million U.S. viewers for the first time. [http://www.comscore.com/Press\\_Events/Press\\_Releases/2009/3/YouTube\\_Surpasses\\_100\\_Million\\_US\\_Viewers](http://www.comscore.com/Press_Events/Press_Releases/2009/3/YouTube_Surpasses_100_Million_US_Viewers). Accessed December 21, 2010.
- Bridge PD, Jackson M, Robinson L. The effectiveness of streaming video on medical student learning: A case study. *Med Educ Online*. 2009;14:1–5. <http://www.med-ed-online.org/pdf/Res00311.pdf>. Accessed December 8, 2010.
- O’Reilly T. What is Web 2.0? <http://oreilly.com/web2/archive/what-is-web-20.html>. Accessed December 8, 2010.
- Patients Like Me Web site. <http://www.patientslikeme.com>. Accessed September 10, 2010.
- Issenberg SB, McGaghie WC, Petrusa ER, Gordon DL, Scalese RJ. Features and uses of high-fidelity medical simulations that lead to effective learning: A BEME systematic review. *Med Teach*. 2005;27:10–28.
- Cook DA, Erwin PJ, Triola MM. Computerized virtual patients in health professions education: A systematic review and meta-analysis. *Acad Med*. 2010;85:1589–1602. [http://journals.lww.com/academicmedicine/Fulltext/2010/10000/Computerized\\_Virtual\\_Patients\\_in\\_Health.16.aspx](http://journals.lww.com/academicmedicine/Fulltext/2010/10000/Computerized_Virtual_Patients_in_Health.16.aspx). Accessed December 8, 2010.
- Harper R, Rodden T, Rogers Y, Sellen A, eds. *Being Human: Human–Computer Interaction in the Year 2020*. [http://research.microsoft.com/en-us/um/cambridge/projects/hci2020/downloads/BeingHuman\\_A4.pdf](http://research.microsoft.com/en-us/um/cambridge/projects/hci2020/downloads/BeingHuman_A4.pdf). Accessed December 28, 2010.
- Gaudin S. Intel: Chips in brains will control computers by 2020. *ComputerWorld*. November 19, 2009. [http://www.computerworld.com/s/article/9141180/Intel\\_Chips\\_in\\_brains\\_will\\_control\\_computers\\_by\\_2020](http://www.computerworld.com/s/article/9141180/Intel_Chips_in_brains_will_control_computers_by_2020). Accessed December 8, 2010.
- BrainGate Web site. <http://www.braingate.com>. Accessed December 8, 2010.
- Asaolu OS. On the emergence of new computer technologies. *Educ Technol Soc*. 2006;9:335–343. [http://www.ifets.info/journals/9\\_1/27.pdf](http://www.ifets.info/journals/9_1/27.pdf). Accessed December 8, 2010.
- Cook DA, Levinson AJ, Garside S, Dupras DM, Erwin PJ, Montori VM. Internet-based learning in the health professions: A meta-analysis. *JAMA*. 2008;300:1181–1196.
- Cook DA. The failure of e-learning research to inform educational practice, and what we can do about it. *Med Teach*. 2009;31:158–162.
- Cook DA. Where are we with Web-based learning in medical education? *Med Teach*. 2006;28:594–598.
- Cook DA, Levinson AL, Garside S, et al. Instructional design variations in Internet-based learning for health professions education: A systematic review and meta-analysis. *Acad Med*. 2010;85:909–922. [http://journals.lww.com/academicmedicine/Fulltext/2010/05000/Instructional\\_Design\\_Variations\\_in\\_Internet\\_Based.42.aspx](http://journals.lww.com/academicmedicine/Fulltext/2010/05000/Instructional_Design_Variations_in_Internet_Based.42.aspx). Accessed December 8, 2010.
- Mayer RE, ed. *The Cambridge Handbook of Multimedia Learning*. New York, NY: Cambridge University Press; 2005.
- Cook DA. One drop at a time: Research to advance the science of simulation. *Simul Healthc*. 2010;5:1–4.
- Cook DA. The research we still are not doing: An agenda for the study of computer-based learning. *Acad Med*. 2005;80:541–548. [http://journals.lww.com/academicmedicine/Fulltext/2005/06000/The\\_Research\\_We\\_Still\\_Are\\_Not\\_Doing\\_An\\_Agenda\\_for.5.aspx](http://journals.lww.com/academicmedicine/Fulltext/2005/06000/The_Research_We_Still_Are_Not_Doing_An_Agenda_for.5.aspx). Accessed December 8, 2010.
- Ruiz J, Mintzer M, Leipzig R. The impact of e-learning in medical education. *Acad Med*. 2006;81:207–212. [http://journals.lww.com/academicmedicine/Fulltext/2006/03000/The\\_Impact\\_of\\_E\\_Learning\\_in\\_Medical\\_Education.2.aspx](http://journals.lww.com/academicmedicine/Fulltext/2006/03000/The_Impact_of_E_Learning_in_Medical_Education.2.aspx). Accessed December 8, 2010.
- Health Education Assets Library (HEAL) Web site. <http://www.healcentral.org>. Accessed December 8, 2010.
- Reynolds R, Candler C. MedEdPORTAL: Educational scholarship in teaching. *J Contin Educ Health Prof*. 2008;28:91–94.
- Association of American Medical Colleges. MedEdPORTAL Web site. <http://www.aamc.org/medportal>. Accessed December 8, 2010.
- Collexis. BiomedExperts Web site. <http://www.biomedexperts.com>. Accessed December 8, 2010.