

Medical Education Must Move From the Information Age to the Age of Artificial Intelligence

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Abstract

Noteworthy changes coming to the practice of medicine require significant medical education reforms. While proposals for such reforms abound, they are insufficient because they do not adequately address the most fundamental change—the practice of medicine is rapidly transitioning from the information age to the age of artificial intelligence. Increasingly, future medical practice will be characterized by: the delivery of care wherever the patient happens to be; the provision of care by newly constituted health care teams; the use of a growing array of data

from multiple sources and artificial intelligence applications; and the skillful management of the interface between medicine and machines. To be effective in this environment, physicians must work at the top of their license, have knowledge spanning the health professions and care continuum, effectively leverage data platforms, focus on analyzing outcomes and improving performance, and communicate the meaning of the probabilities generated by massive amounts of data to patients, given their unique human complexities. The authors believe that a “reboot”

of medical education is required that makes better use of the findings of cognitive psychology and pays more attention to the alignment of humans and machines in education and practice. Medical education needs to move beyond the foundational biomedical and clinical sciences. Systematic curricular attention must focus on the organization of professional effort among health professionals, the use of intelligence tools involving large data sets, and machine learning and robots, all the while assuring the mastery of compassionate care.

William Osler is reported to have said that medicine is a science of uncertainty and an art of probability. Yet today, this time-honored perspective is being refined, if not challenged. The changing state of the medical profession and the medical education reforms that will enable physicians to more effectively enter contemporary practice are frequent topics of white papers and news stories. Common reform themes include a renewed emphasis on communication, teamwork, risk management, and patient safety. We believe that these reforms are important but insufficient. More attention needs to be given to addressing the most fundamental change of all—the practice of medicine is rapidly

transitioning from the information age to the age of artificial intelligence. The consequences of this transition are profound and demand the reformulation of undergraduate medical education programs. A fundamental principle of this reformulation is that students must understand and manage the difference between “information” and “artificial intelligence.”

Information Versus Artificial Intelligence

The information age (roughly from the 1970s to the emergence of machine learning tools during the 2010s) featured the use of data that were accurate and timely, specific and organized for a purpose, and presented within a context that gave them meaning and relevance, as well as led to an increase in understanding and decrease in uncertainty.¹ The primary challenges for physicians during this time were determining validity and how to effectively use the available information.

Artificial intelligence—or the mimicking of human cognition by computers—was once only a futuristic vision. Now, the ability of a computer or a computer-controlled robot to

perform tasks commonly associated with intelligent beings is widely accepted. More important, the term “artificial intelligence” applies to the development of systems that are endowed with the intellectual processes characteristic of humans, such as the ability to reason, discover meaning, generalize, and/or learn from experience.² The manipulation of data using applications of artificial intelligence has significant implications for medical education. The current, largely memorization-based curriculum must transition to one that teaches competence in the effective integration and utilization of information from a growing array of sources.

For example, managing the exponential growth in the number and type of available sensors, both within and outside the human body, and their connectivity to personal and organizational information infrastructures, is just one of the challenges emerging in the age of artificial intelligence. The implications of using big data, including large compilations of data that are available to both physicians and their patients, increasingly sophisticated uses of machine learning (e.g., Watson and Alpha Go), and the narrowing of the knowledge differential between physicians and

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patients, also pose substantial challenges to the current medical education model. Whether physicians use decision support software based on reliable artificial intelligence or manage robots deployed in hospitals, patients' homes, or within the human body, they will need to be educated in this new paradigm.

Medical Education Reform Has Largely Focused on the 20th Century

Efforts to reform medical education, largely based on the findings in national reports funded by foundations and government agencies, have become routine and have been rolled out every few years since Abraham Flexner's 1910 report. The American Medical Association noted that from 2000 to 2015 there were 15 national reports calling for medical education reform.³ These proposed reforms paralleled many of the previously identified areas for reform, including the management of chronic conditions and care coordination, systems-based practice, practice-based improvement, and effective communication. Tradition, accreditation concerns, faculty resistance to change, and the need to prepare students to perform well on national board exams are generally considered the major factors impeding needed reform. Susan Skochelak of the American Medical Association argued: "What's been missing [from these reforms] is the science of health-care delivery. How do you manage chronic disease? How do you focus on prevention and wellness? How do you work in a team?"³

In a 2016 lecture, Wartman advocated a "reboot" of medical education, noting that many of the current reforms that have been identified are necessary but not sufficient for 21st-century medical education.⁴ He also noted that the track record of medical education reform depicts an industry that is slow to adopt meaningful change. The acquisition of 21st-century skills for medical practice requires, in our opinion, a more radical transformation of medical education. Although the dictum "see one, do one, teach one" may have characterized the way physicians learned clinical skills in the past, it is now clear that, for training to be effective, learners at all levels must have the opportunity to compare their performance against a standard and to

continue to practice until competence is achieved.⁵ Pressed by their leaders, external stakeholders, and a public troubled by lapses in quality of care and unsustainable cost increases, physicians are facing stiffer challenges in designing initiatives that more closely link the goals of learning with both the delivery of better care and measures of greater accountability.⁶

Employers are making a compelling case for a tighter integration of undergraduate, graduate, and continuing medical education. They need physicians who work at the top of their license with other members of the health care team; have knowledge that spans the breadth of the health professions and care continuum; leverage data platforms by using smartphones, social media, and other devices; and focus on analyzing outcomes and improving performance, including customer service.⁷

No one would cheer more loudly for meaningful change in medical education than Abraham Flexner. The flexibility and freedom to change—indeed, the mandate to do so—were part of his message. He would undoubtedly support the fundamental restructuring of medical education that is needed today. So, the question becomes: How do we reform medical education from the dominant 20th-century model into one that can address the emerging challenges of the 21st century, especially the increasing application of big data and artificial intelligence in professional practice?

A Medical Education Reboot for the 21st Century

We believe that the foundation for a medical education reboot lies in the community's recognition that future medical practice will be an explicit partnership among physicians, other health care professionals, machines (which includes both software and hardware), and patients. Future medical practice will have four characteristics that change the ground rules for physicians. First, care will be provided in many locations. Technology will move with and inside patients, providing a continuous flow of data. Large data storing and processing infrastructures will become more readily accessible in real time. Patients, insurers, and regulators will insist on convenience and demonstrable results.

Second, care will be provided by newly constituted health care teams. The sacrosanct one-to-one doctor-patient relationship will be replaced by patient relationships with multiple health providers (e.g., nurses, social workers, physical and occupational therapists, care managers, home health aides, social support groups, family members, and new kinds of health care providers yet to be defined, without regard to where patients live). Physicians or others who serve as team leaders will need to learn how to gain the most value from team care. Such practice will necessitate the careful redesign of the scopes of practice of team members to align with new practice modalities. As a result, we believe that current licensure constraints will be challenged and modified.

Third, care will be delivered based on a growing array of data from multiple sources, accessible large data sets, and artificial intelligence. The incorporation of machine-based analysis of huge meta-data sets will become standard for patient care, leading to continuous monitoring of each patient. A new interpretive and functional practice infrastructure will be developed over time both to manage the data and to provide valid assessments of the expanding volume of information. Physicians will practice in an environment where decision making takes place within the complex intersection of patients and their families, machines, and an expanding variety of health professionals.

Fourth, and finally, the interface between medicine and machines will need to be skillfully managed. Machines will know more in many areas and be able to perform more tasks that traditionally have been performed by physicians. Thus, caregivers will need to come to terms with the fact that devices increasingly will outperform humans, both cognitively and physically.

Necessary Skills for Future Practice

New skills and expertise will be required as we move to an age of artificial intelligence, including better use of the findings of cognitive psychology, closer alignment of humans and machines in education, and enhanced use of simulations focused on the integration of machines in care delivery and on patients as active collaborators in their care.

Cognitive psychology has demonstrated that facts and concepts are best recalled and put into service when they are taught, practiced, and assessed in the context in which they will be used. Several decades of research on clinical expertise have elucidated the thinking of physicians as they evaluate signs and symptoms, select and interpret diagnostic tests, and synthesize data to develop clinical assessments and care plans.⁸ As noted by one observer, “Educational standards need to be refreshed, refined and improved as technology changes and the data fog thickens.”⁹

There is no disagreement that a fundamental understanding of the biomedical sciences and their interconnectedness with clinical knowledge and expertise in practice should remain central to medical education. However, the 21st-century curriculum also should include components to strengthen physicians’ capacity to practice with more precision in a data-rich environment supported by artificial intelligence. As one example, learners must be exposed to big data in the context of decision making. They must develop a solid understanding of the four Vs of big data: volume (the amount of data today is vast compared with the amount in the past); variety (data come from many different sources of varying validity); velocity (data are being generated very fast, and momentum is increasing); and veracity (the quality of the data being generated needs to be assessed).

Learners also will need to develop a basic understanding of how data are being aggregated, analyzed, and ultimately personalized in health care delivery through artificial intelligence applications. They will need to be able to think broadly about how to manage the variety of applications, whether embodied in decision support software, robots, or more sophisticated social media applications. As Yang and Veltri¹⁰ noted, “The most critical challenge is how we can transform the health care data into additional values for precision medicine, preventive medicine, and predictive modeling.”

Conclusion

How to teach medical students to practice successfully in a health care environment transformed by artificial intelligence applications should be a central focus of curricular reform today. It requires the whole-hearted support of accreditors who are willing to be more open to innovation and experimentation and able to move far beyond the old model with its emphasis on fact-based memorization and clinical clerkships that are often unrelated to students’ future practice. Future medical school graduates will need to participate in new modalities of lifelong education if they are to perform at the top of their license and adapt to a value-based financing system. They will need to incorporate a solid understanding of the capabilities of health professionals across the care continuum, enhance teamwork in their professional practice, possess a comfortable knowledge of information platforms and intelligence tools, strengthen their customer service skills, and reinforce the effective use of information and intelligence to improve performance and outcomes. The foundation for these professional attributes must be embedded in undergraduate medical education curricula.

Two additional skills, one new, one old, also must be emphasized and carried throughout the curriculum. The first is the mastering of statistical expertise that enhances the ability of the physician to communicate the meaning of the probabilities generated by data platforms to patients in the face of their uniquely human complexity. The second involves constant training and evaluation toward being a truly compassionate provider, something that must not be overlooked as medicine becomes increasingly high tech.

In other words, medical education will need to move beyond the foundational biomedical and clinical sciences and updates on emerging diagnostic and therapeutic trends. It will need to evolve to include systematic curricular attention to the organization of professional effort among a variety of health professionals, the use of information and intelligence tools such as machine learning and

robots, a relentless focus on improving performance and outcomes, and ensuring the mastery of compassionate communication with patients.

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