7-22-2021

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Medical Teacher

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/imte20

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To cite this article: William B. Cutrer, W. Anderson Spickard III, Marc M. Triola, Bradley L. Allen, Nathan Spell III, Steven K. Herrine, John L. Dalrymple, Paul N. Gorman & Kimberly D. Lomis (2021) Exploiting the power of information in medical education, Medical Teacher, 43:sup2, S17-S24, DOI: 10.1080/0142159X.2021.1925234

To link to this article: https://doi.org/10.1080/0142159X.2021.1925234

Published online: 22 Jul 2021.

MEDICAL TEACHER
2021, VOL. 43, NO. S2, S17–S24
https://doi.org/10.1080/0142159X.2021.1925234

Exploiting the power of information in medical education

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ABSTRACT

The explosion of medical information demands a thorough reconsideration of medical education, including what we teach and assess, how we educate, and whom we educate. Physicians of the future will need to be self-aware, self-directed, resource-effective team players who can synthesize and apply summarized information and communicate clearly. Training in metacognition, data science, informatics, and artificial intelligence is needed. Education programs must shift focus from content delivery to providing students explicit scaffolding for future learning, such as the Master Adaptive Learner model. Additionally, educators should leverage informatics to improve the process of education and foster individualized, precision education. Finally, attributes of the successful physician of the future should inform adjustments in recruitment and admissions processes. This paper explores how member schools of the American Medical Association Accelerating Change in Medical Education Consortium adjusted all aspects of educational programming in acknowledgment of the rapid expansion of information.

KEYWORDS

Metacognition; active learning; clinical informatics; electronic health record; artificial intelligence; medical education

Introduction

The explosion of medical knowledge demands a thorough reconsideration of medical education, including what we teach and assess, how we educate, and whom we educate. The rapid expansion of health information impacts all stakeholders in the health care system. Health care professionals manage unprecedented amounts of biomedical knowledge and patient-related data. Patients access their personal electronic records and communicate about their conditions with their physicians and other health care professionals through online patient portals. Payers analyze aggregated information to make business decisions regarding investment in the system. Indeed, all stakeholders are interacting in redesigned delivery systems that increasingly rely on transparently reported outcomes based on large volumes of data to substantiate the quality, safety, and cost of care of individuals and populations. The data-driven approach to health also guides the best uses of resources and advancement of clinical and translational research.

Future providers will need to be self-aware, self-directed, resource-effective team players who can synthesize and apply summarized information and communicate clearly. This demands a shift in education that acknowledges the tremendous influence of information on the practice of medicine and responds accordingly.

Practice points

- The explosion of medical knowledge demands reconsideration of medical education, including what we teach and assess, how we educate, and whom we educate.
- Effective care requires physicians to maintain a firm mastery of fundamental concepts coupled with the ability to access and utilize up-to-date information as needed.
- The modern medical learner and practitioner need to have a deep understanding of cognition and the interface of providers and information technology.
- Digital natives do not inherently possess the requisite skills; medical schools must provide scaffolding to explicitly teach and model how one leverages information resources to continue to learn throughout a busy clinical career.
- Educators should leverage informatics to improve the process of education itself, enabling precision education.
- Perhaps a new type of student must be recruited who can blend skills in data and information management with traditional humanistic values of medicine.

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Several warning signs indicate that physicians have not been adequately trained for the current health care delivery context. Undesirable rates of medical error, high costs of care, and prevalence of burnout among providers (IOM 2000; Kohn et al. IOM 2001; NASEM 2019) are challenges that have been historically been attributed to health care policy and economics, which are indeed key drivers. However, these challenges may also have some root in information overload. The fact that dedicated and talented physicians struggle to keep up raises concerns that medical training is not adequately preparing physicians to manage evolving information and an increasingly complex process of care delivery.

The Lancet Commission on Education of Health Professionals for the 21st Century (Frenk et al. 2010) distinguished three levels of education: informative – focused on the development of knowledge and skill; formative – focused on developing values of a professional; and transformative – focused on preparing learners to act as change agents and leaders. The authors issued a call to action to realize transformative medical education, stating that

> transformative learning involves three fundamental shifts: from fact memorization to searching, analysis, and synthesis of information for decision making; from seeking professional credentials to achieving core competencies for effective teamwork in health systems; and from non-critical adoption of educational models to creative adaptation of global resources to address local priorities. (Frenk et al. 2010)

As information becomes more prevalent and widely accessible, the professional vision of the physician must shift from an individual who memorizes and possesses an extensive body of medical knowledge to one who searches for, curates and applies information. The traditional Flexnerian two + two model in the U.S. historically anchored medical education in the classroom for the first two years, focusing on the delivery of a body of basic science content in the absence of clinical application. This created a false impression that the knowledge base underpinning care is static. Although educational programs continually update content and physicians assert the need for lifelong learning, the structure of medical education often disconnects the activity of learning from the process of rendering care in the 'real world.'

Of the Lancet Commission's final recommendations, one specifically calls for

> Exploitation of the power of IT for learning through the development of evidence, capacity for data collection and analysis, simulation and testing, distance learning, collaborative connectivity, and management of the increase in knowledge. Universities and similar institutions have to make the necessary adjustments to harness the new forms of transformative learning made possible by the IT revolution, moving beyond the traditional task of transmitting information to the more challenging role of developing the competencies to access, discriminate, analyse, and use knowledge. More than ever, these institutions have the duty of teaching students how to think creatively to master large flows of information in the search for solutions. (Frenk et al. 2010)

The AMA Accelerating Change in Medical Education Consortium

Spurred by a recognition that a fundamental shift in both the priorities and processes of medical education was indicated, the American Medical Association (AMA) launched the Accelerating Change in Medical Education initiative in 2013. The AMA funded a consortium of 11 schools in 2013 and expanded to 32 schools in 2016 to support the development and scaling of creative medical education models across the United States (Skochelak and Stack 2017). Although the consortium expanded further in 2019, adding another five medical schools and extending into graduate medical education with the Reimagining Residency program, this manuscript describes efforts during the first five years of the consortium among the 32 medical school members at that time.

The primary objective at the formation of the initiative was to drive transformative change in medical education (Lomis et al. 2020). Although most physicians would say they are committed to lifelong learning, there is evidence that traditional approaches to continuing professional development do not provide opportunities for meaningful learning (Moore et al. 2009). The AMA recognized the need to disrupt historical educational structures to strengthen the link between practice and education. The resulting community of innovation applied a systems perspective in a collective re-evaluation of the very purpose of medical education across the continuum.

Members of the consortium shared the AMA's recognition that successful practice throughout one's career – practice that supports optimal care for patients and populations in constantly evolving contexts, as well as the well-being of the provider – relies upon each physician's continual integration of learning during the process of care delivery. Consortium schools sought to enhance focus on developing learners' skills in self-directed learning: recognizing information needs, finding information, critically appraising and applying information, and then monitoring results. This required providing new instructional formats, experiences, and topics.

Similarly, members of the consortium strove to apply the power of information to processes of educating future and practicing physicians. Traditional approaches to core clinical educational experiences are acknowledged to be somewhat haphazard (Armstrong et al. 2004). It is difficult to ensure that each learner is gaining exposure to the appropriate mix of patients and diagnoses and to assess that each is acquiring the expected competencies. The resulting gaps and inefficiencies are costly in both resources and time. Historical requirements for continuing certification similarly commonly fail to align with a physician's personal scope of practice. Consortium members explored opportunities to apply informatics to the learning process to enable more individualized and targeted training.

In this manuscript, we outline shared lessons learned in our efforts to lay the groundwork for the learning health care system (IOM 2007). Consortium members changed *what* we teach and assess, *how* we educate, and *whom* we educate.

Information is changing *what* we teach and assess

Fully acknowledging that information is readily accessible during the process of delivering health care pushes schools to carefully review traditional content and assessment approaches. Rather than attempting to cover 'everything' in the foundational curriculum – which is increasingly impossible – it is advisable to teach less in some areas, relying more upon point-of-care information tools and certainly to reduce emphasis on factual memorization. This subsequently frees curricular time and faculty resources to place greater emphasis on skill sets needed to support ongoing learning.

> Professionals, therefore, have special obligations and responsibilities to acquire competencies and to undertake functions beyond purely technical tasks—such as teamwork, ethical conduct, critical analysis, coping with uncertainty, scientific inquiry, anticipating and planning for the future, and most importantly leadership of effective health systems. (Frenk et al. 2010)

Consortium member schools applied a variety of approaches and new content areas to support the development of learners' ability to exploit information.

Metacognition and dealing with ambiguity

In an effort to help students build an appropriate image of the medical profession and a skill set related to functioning as effective team members within the health care system, consortium member Vanderbilt University School of Medicine implemented a longitudinal curriculum that explicitly addresses metacognition and reasoning, cognitive bias, diagnostic error, emotional intelligence, and other key domains. To foster trust and transparency, sessions are delivered in the context of stable learning communities, with a developmental progression that tackles increasingly complex and ambiguous situations over years of training. Emphasizing the concept of the learning health care system, this curriculum is coupled with a process of evidence-based informed self-assessment throughout training.

Electronic health records

Consortium member Indiana University School of Medicine prepares learners to exploit information via a teaching electronic medical record system (tEMR) that is a clone of an actual clinical EMR, using de-identified and misidentified real data on more than 10,000 patients. The platform provides a more authentic learning environment for delivering clinical scenarios in classroom-based activities. Starting in the first year of medical school, students access data on patients, leverage just-in-time information links, and practice clinical decision-making skills. Students use the tEMR to identify errors and patient safety issues, initiate quality improvement and measure the success of these efforts, explore the potential for personalized medicine and gain comfort in comparing their own practice patterns with those of their peers. Students can virtually manage a panel of e-patients and compare their diagnosis and treatment to those rendered during the actual care process. Additionally, standardized patients have been trained to simulate the e-patients included in the tEMR in specific health care scenarios for face-to-face learning encounters. Thus, students experience firsthand the utility and challenges of using health information technology to deliver cost-effective quality health care. Consortium members are also collaborating to develop online training modules to foster more efficient utilization of the electronic health record, with the aim of enhancing practice satisfaction and patient care.

Informatics

Members of the consortium collaborated to articulate competencies that medical students should attain in informatics. A panel of consortium members presented their collaborative efforts at the 2017 annual symposium of the American Medical Informatics Association. Consortium member Oregon Health & Science University School of Medicine extended this work and implemented a longitudinal curriculum spanning all years of training to support these competencies (Hersh et al. 2014).

Data science

New York University School of Medicine is training students in the use of big data to enhance practice outcomes. Their 'Health Care by the Numbers' longitudinal curriculum (https://ace.iime.cloud/sparcs/) leverages a web-based tool to mine real clinical data from the New York State Department of Health Statewide Planning and Research Cooperative System, which incorporates almost 5 million de-identified patient-level records. These de-identified data are used to create a virtual multi-practice care group. Students create and analyze panels to deepen their understanding of quality and value.

Augmented intelligence

Artificial intelligence (AI) will further accelerate the integration of information and dramatically change health care delivery and the role of physicians and other health care professionals. The term augmented intelligence emphasizes the assistive role of artificial intelligence tools that serve to amplify the capability of human intelligence. AI offers great promise in health care (Matheny et al 2019), but also presents potential perils, including risk of amplifying human bias. This argues the need for explicit training for all physicians. The consortium hosted an interdisciplinary panel to consider the implications of AI for medical education during the 2019 AMA ChangeMedEd® conference. A subgroup of consortium leaders has drafted potential core objectives for medical students, and the AMA is completing a purposeful qualitative exploration of AI education at medical training institutions across the U.S. and internationally.

Information is changing *how* we educate

Fostering Master Adaptive Learners

In his book Thank You for Being Late, Pulitzer-prize winning New York Times columnist and author Thomas Friedman comments upon the sense of information overload in contemporary society (Friedman 2016). The title derives from the recognition that the pause created when someone is late for a meeting offers a rare moment for reflection in an over-stimulated world. Friedman argues that the pace of advancement in technology and information has outstripped the pace of human adaptability; the sense that things around us are changing too rapidly for humans to keep up drives pervasive societal anxiety.

Nobel laureate Herbert Simon articulated this issue as a matter of managing one's attention:

> What information consumes is rather obvious: it consumes the attention of its recipients. Hence a wealth of information creates a poverty of attention, and a need to allocate that attention efficiently among the overabundance of information sources that might consume it. (Simon 1971)

Friedman asserts that humans need deliberate training to foster adaptability. This concept is certainly applicable in the rapidly evolving context of health care delivery. Enhancing the ability to deal with ambiguity and adapt to change is necessary to empower medical learners for their roles in the future (Simpkin and Schwartzstein 2016).

Instilling adaptive skills for the future demands a shift in the orientation of educators; educators must become guides in an ongoing process of co-discovery with learners. The need for more active learning formats to foster skills in self-directed lifelong learning has been acknowledged in accreditation standards for medical schools (LCME 2021). Many schools have moved away from memorization toward critical appraisal, shifting the proportion of content delivery via traditional lecture to include more active learning formats. Problem-based learning and team-based learning encourage deeper knowledge, and consortium schools have leveraged these formats as early opportunities to build other critical competencies in teamwork, communication, and professionalism (Pettepher et al. 2016). However, a dissonance quickly arises when such active formats are implemented. Students have been recruited to medicine largely for their success in traditional teacher-centered contexts that emphasize information delivery and value individual accomplishment. Consortium members found that active, team-based educational formats may initially feel inefficient and uncomfortable for both learners and many faculty members (Yengo-Kahn et al. 2017). It is important that educators explain that the struggles associated with new formats are a deliberate, essential part of the educational process.

It is hazardous to assume that a younger generation of digital natives would possess advanced skills in searching for information; faculty facilitators must be trained to attend more explicitly to the process of knowledge acquisition. To promote critical thinking over memorization, assessment must also change. Consortium schools offered opportunities for students to demonstrate reasoning and the ability to manage ambiguity by increasing essay-based exams to counter traditional single-best-answer multiple-choice exams. Additionally, simulation experiences at some schools were enhanced by embedding the same informational resources that would be expected to be utilized during the delivery of clinical care into objective structured clinical encounters (Bhutiani et al. 2016).

Collaborative consortium efforts in adaptive learning

Members of the consortium recognized a need for a different approach to learning and sought to provide a framework to support a consistent and reproducible learning process. Collaboration among consortium members lead to the articulation of the Master Adaptive Learner model (Cutrer et al. 2017), designed to position learners to be adaptive to constantly changing complex systems. This framework can support learner advancement through the stages of the Dreyfus model from novice to competent to proficient to expert (Dreyfus 2004). But the Master Adaptive Learner model extends further, beyond routine expertise toward adaptive expertise, 'based on the ideal that individuals will learn and innovate in response to practice challenges' (Cutrer et al. 2017). Rather than focus primarily upon the delivery of a body of content during the course of medical school, structured educational programs must place equal priority on explicit training in a reproducible strategy for future learning.

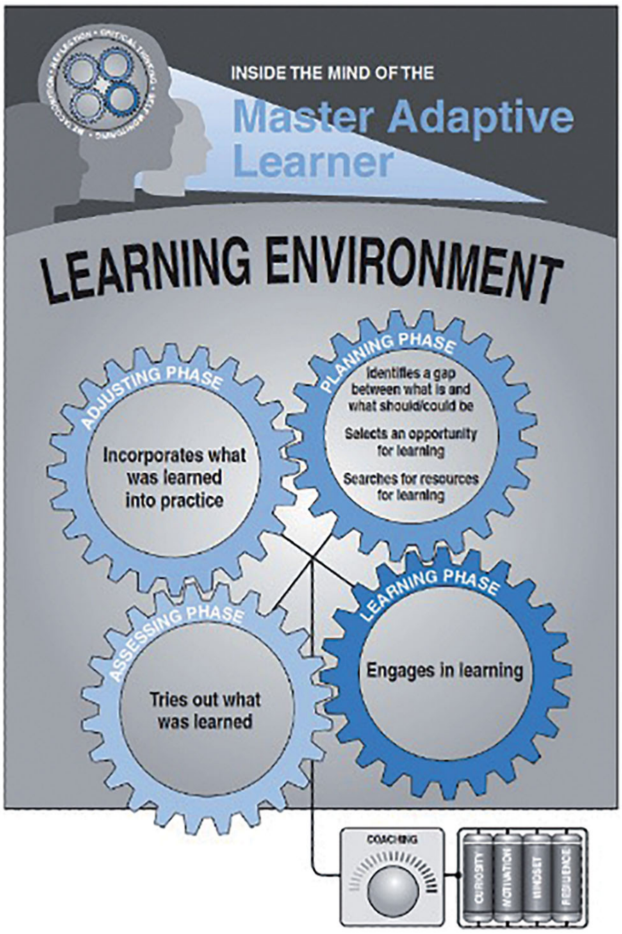

Figure 1. Characteristics and contexts that allow the Master Adaptive Learner Process. Reprinted with permission from Cutrer et al. (2018).

The Master Adaptive Learner model (Figure 1) directs learners through four phases—Planning, Learning, Assessing, and Adjusting. In the Planning Phase, a critical step often skipped by more novice learners, the individual identifies one or more gaps in practice (knowledge, skills, or attitudes), followed by selection of a gap to focus on, and searching for resources to address the need. Gap identification can be greatly aided by evidence concerning one's practice, such as competency-based assessment data for students or patient-specific or patient panel outcome data for resident and attending physicians. But gaps may also be triggered by changing practice circumstances requiring adaptation. The individual will move into the work of the Learning Phase that includes critical appraisal of resources for learning and the utilization of effective learning strategies. Moving into the Assessing Phase, one strives for informed self-assessment, reviewing evidence around the learner's performance or practice to determine whether the Learning Phase has addressed the identified gaps. The learner moves into the Adjusting Phase, focused on incorporating the new learning into practice, considering both the individual and the system levels.

A few other key aspects of the Master Adaptive Learner model are important to highlight. In the lower portion of the diagram, four batteries represent key characteristics the Master Adaptive Learner will demonstrate: Curiosity, Motivation, Mindset, and Resilience. These characteristics are critical to developing adaptive expertise, powering the learner as they encounter uncertainty, difficulty, and setbacks during the learning process. The framework provides a common language and shared mental model that enables a coach-learner interaction to optimize each phase of the process and deepen the impact of the learning. The Master Adaptive Learner process is situated within critical background influence of the health care learning environment; consortium members found that organizational culture and the hidden curriculum must be addressed to create an environment conducive to adaptive learners.

To bring this model to life requires changing educational structures to provide opportunities for self-regulated learning and co-production of new knowledge. The Master Adaptive Learner model provides a cohesive description of the desired goal and the process, which enables faculty development and facilitates conversations with learners. To further advance implementation of the Master Adaptive Learner model, members of the consortium collaborated to publish an instructor-focused guide on training future clinicians to develop adaptive skills (Cutrer et al. 2019).

Consortium exemplars in fostering adaptive learners

Consortium schools have implemented innovative programs to prepare students to exploit information and have utilized the Master Adaptive Learner model to varying degrees. Many schools emphasize skills in searching and critically appraising the literature. Some provide explicit training in metacognition and tolerance for ambiguity. Some sites are creating structures to encourage students to generate and prioritize learning queries during clinical care, and some have created enough curricular flexibility and supportive learning environments to enable individualized learning pathways. Highlights of programs put in place at some consortium institutions illustrate varying strategies.

Harvard Medical School launched its Pathways Curriculum with the goal of creating master adaptive learners. To achieve this goal, Harvard has reorganized its entire curriculum using a case-based collaborative learning model and creating a mastery-oriented culture as opposed to a performance-oriented culture (Schwartzstein et al., Pathways Writing Group 2020). Faculty value their students' reasoning, not just whether the answer is correct. Students receive detailed feedback about performance and are encouraged to reflect on how to improve. The program aspires to a state in which students neither hesitate to admit uncertainty nor attempt to hide their shortcomings for fear of disapproval. The in-course assessment policy includes high-frequency, low-stakes testing and has been designed to discourage the negative cycle of fall-behind-and-cram. The school has developed a formalized method of analyzing exam questions using Bloom's taxonomy. Harvard is providing course directors with feedback regarding the proportion of questions that are high-order thinking versus low-order thinking on their exams. Faculty are also trained to ask 'why' and 'how' questions in the pre-clerkship phase to stimulate curiosity and assess understanding. This is reinforced in the clinical phase in which faculty are also trained to transform the nature of the questions they ask students at the bedside in order to facilitate deeper understanding (Royce et al 2019).

Vanderbilt University School of Medicine created a new category of course for the post-clerkship curriculum to translate the Master Adaptive Learner model from the classroom to the clinical arena. The Integrated Science Courses are designed to reinforce the foundational sciences that underpin clinical medicine to include traditional pre-clinical sciences as well as social and behavioral sciences, health services, population science, quantitative methods, and informatics (Dahlman et al. 2018). Students engage in meaningful clinical experiences and draw upon workplace learning to deepen their understanding of foundational science topics. Students are required to identify knowledge gaps in the course of patient care, prioritize among them, and complete the Master Adaptive Learner cycle. Institutional information specialists provided students feedback on the quality of their queries and provide training in accessing information. Students present their findings back to the clinical team, allowing assessment of skills in information appraisal and application while serving to educate other members of the care team on the given topic. Modeling the Master Adaptive Learner model in clinical environments was a critical test to its viability as preparation for future learning and learner adaptability.

Precision education

Consortium schools have also exploited the power of information to enhance the process of education. The Lancet Commission calls for

> outcome-based programmes tracked by assessment, capacity to integrate knowledge and experiences, flexible individualisation of the learning process to include student-selected components, and development of a culture of critical inquiry—all for equipping physicians with a renewed sense of socially responsible professionalism.

Competency-based medical education strategies – with clearly defined expectations, developmental sequencing, tailored learning experiences, and programmatic assessment (Van Melle et al., International Competency-based Medical Education Collaborators 2019) – support the concept of precision education, akin to precision medicine. Informed self-assessment is a critical step in the Master Adaptive Learner model. Multiple consortium schools invested in informatics platforms to create digital portfolios that capture student experiences and assessments. These platforms organize and display a variety of longitudinal assessment data across courses and across time. This provides an evidence base to engage learners in informed self-assessment and the development of individualized learning pathways. These schools also established coaching roles to guide students in assessing progress and establishing personal learning goals. Advances in artificial intelligence are anticipated to promote an eventual evolution of 'smart' portfolios that recommend targeted learning experiences and guide assessments in real-time throughout clinical phases of training, based on learner activity in electronic health records.

Education also becomes more precise when educators leverage information to critically appraise program outcomes. Aggregate data from student portfolios can be applied to evaluate the performance of the educational program itself. Some consortium schools have used portfolio data to monitor for potential bias in evaluations of student performance and to reveal gaps in educational experiences that limit cohorts of students from attaining desired competencies (Lomis et al. 2017).

Consortium exemplars in precision education

Vanderbilt University School of Medicine developed VSTAR, a web-based platform comprised of several applications that support curriculum development and implementation, assessment, feedback, and self-directed learning (Spickard et al. 2016). The VSTAR Portfolio contains a real-time dashboard display of all assessment data for each student-organized by competencies and entrustable professional activities. Students and their designated faculty members monitor progress across time and settings and can compare the individual to aggregate cohort performance. The school has created technology to automatically capture student notes in the electronic health record and utilize natural language processing to rank each note for relevance to the Vanderbilt Core Clinical Curriculum (Spickard et al. 2014). At regular intervals, students systematically analyze all assessment data in their portfolios to determine their milestone levels for specified school competencies and devise a personalized learning plan (PLP). Faculty members who serve as portfolio coaches use the same process to independently analyze the portfolios of a group of students assigned to them, then meet with each student to refine self-assessments and PLPs. Promotions committees use the reconciled student/coach assessments to determine whether student progress has been satisfactory in each competency domain and whether students are ready for promotion to the next phase of training. Aggregate assessment outcomes are readily and routinely monitored in the platform and have revealed instances in which experiences to support the development or demonstration of competency were insufficient for an entire cohort, spurring appropriate curricular revisions.

At Oregon Health & Science University School of Medicine (OHSU), students begin the curriculum with a pre-matriculation self-assessment and advance through individualized learning plans as they achieve key milestones across all competency domains. These milestones are tracked by a web-based personal portfolio, REDEI, and students receive badges for their achievements. Learners can monitor their progress in real-time, track trends in their performance, and compare themselves to the aggregate performance of all OHSU medical students who entered the program in the same academic year. Students are assessed by frequent 360 evaluations, checklists, faculty observation, OSCEs, procedure and case logs, patient surveys, reviews of medical documentation, simulation experiences, standardized patient examinations, multiple-choice examinations, computer-based virtual cases, direct observation in clinical settings, and reflective writing. Faculty members serve as student coaches and mentors, closely monitoring students' academic progress, helping students set personal learning goals and strategies, and determining their readiness for advancement through the curriculum based on demonstrated competencies. Their customized curriculum is then adjusted accordingly.

At Sidney Kimmel Medical College at Thomas Jefferson University, the JeffCAT (Jefferson Competency Assessment Tool) is an educational dashboard software that aggregates assessment data from a variety of sources, maps these assessments to educational competencies, and provides reports to a variety of users including students, faculty, and administration. Students can track their performance history on specific competencies over time, performance on specific measured events, and compare their performance to their cohort via median and standard deviation statistics. In the clinical realm, 'point of education' checklist-based assessments are collected by direct observation. Student advisers and faculty monitor the performance of the students assigned to them and receive alert flags for students that perform below expectations, enabling quick follow-up. Academic affairs can view cohort performance to provide strategic planning and continuous quality improvement as required by the Liaison Committee on Medical Education (LCME). Mapping to milestones aligned with graduate medical education programs can provide data for an educational handover from undergraduate to graduate medical education and may decrease reliance on one-dimensional scores in the process of residency recruitment and selection.

Emory University School of Medicine recognized that competency-based education demands broad, active management of data to track curricular experiences and learning outcomes of the educational program. Such management entails aggregating data from multiple systems and demands a shared mental model between informaticians and educators regarding how data are collected, stored, reported, and interpreted. Emory integrated previously disjointed systems for data collection to design a cohesive architecture for educational data management, creating systems and tools for sharing educational data within and across the institution's educational programs.

New York University (NYU) School of Medicine leverages information to critically appraise long-term programmatic outcomes with its Tracer project, which uses publicly available practice data to better understand the influences of education programs on health care quality outcome measures (Triola et al. 2018). The team evaluates issues on both the school and national levels, such as the relationship between curricular reform and the ultimate outcomes, value, and quality of care delivered; deeper understanding of which patients graduates are caring for and in what settings; and predictive models of what care will look like and what skills will be needed by current students and trainees. The NYU team is now serving as a data coordinating center to generate similar reports for other medical schools in the consortium.

Information is changing *whom* we educate

To realize the vision of transformative education, the Lancet Commission pointed out that

> The professionals' most important contribution is often finely-tuned judgment and decision-making skills rather than knowledge gradients. Thus, advanced information technology is important not only for more efficient education of health professionals; its existence also demands a change in expected

> competencies. Put simply, the education of health professionals in the 21st century must focus less on memorising and transmitting facts and more on the promotion of the reasoning and communication skills that will enable the professional to be an effective partner, facilitator, adviser, and advocate. (Frenk et al. 2010)

Given the profound implications of exploiting information in medical education, perhaps a new type of student will be most successful. The profession's historical value for an individual's ability to master content is centered upon a vision of the physician as the possessor of knowledge. Acknowledging the overwhelming exponential increase in biomedical knowledge, Stead and colleagues advocate for 'shifting the paradigm from individual brains to systems of brains' (Stead et al. 2011). Physicians of the future must be open to collaborating with one another and with the information infrastructure.

Recent changes to the U.S. Medical Colleges Admissions Test (MCAT) reflect an acknowledgement of the need for skills in ongoing acquisition and analysis of information with the addition of a section on critical analysis and reasoning skills that do not rely on an internalized knowledge base. Professional values must shift as well. The traditional sense of self-reliance on a mastered 'fund of knowledge' must be replaced by a humility that acknowledges one's own limits and openly seeks assistance. The physician must attain a sufficient personal fund of knowledge to appropriately query and access information tools in a manner that augments performance (Friedman 2009). A fine balance must be sought between embracing distributed cognition yet maintaining personal accountability.

Further research is needed to understand what attributes enable a physician to interact well with information tools and with artificial intelligence algorithms. Certainly, a penchant for data analysis seems useful. Yet there is a need to maintain the humanistic attributes that enable one to effectively translate those data skills to the lived experiences of individual patients or of a community. Such a combination of abilities and attitudes may be rare at this moment; explicit efforts will be needed to evaluate for this during selection processes and to foster it throughout medical training.

A consortium conference focused on holistic selection processes was hosted by the AMA in conjunction with the University of Connecticut School of Medicine in Farmington in 2019. Designated consortium grant team members were joined by admissions officers from each member school. Approaches to selection for undergraduate and graduate medical education were reviewed in light of the need to enhance the diversity of the physician workforce. The group also recognized that the processes and goals of medical education have changed to such a degree that programs must seek a different type of candidate. Techniques to assess an applicant's tolerance for ambiguity, skills in information appraisal over memorization, systems thinking, openness to feedback, willingness to participate in continual improvement, value for the input of teammates, and resilience in learning become particularly critical to identify and foster physicians poised to fully exploit information throughout their careers to optimize the care of patients and populations.

Conclusion

The rapid expanse and pervasive accessibility of health information impacts all stakeholders in the health care system. Moving forward this will only intensify. Medical education has an opportunity to exploit the explosion in the amount of information relevant to clinical care and learning, the pervasive availability of such information, and the increasing ability to process large volumes of information in order to make it useful. Fully exploiting the power of information in medical education demands continued collaboration around innovations in what we teach and assess, how we educate, and whom we educate. Thoughtful engagement within each area—what, how, and whom—will benefit from cooperative efforts between medical schools and from engaging with learners. Medical educators need to become master adaptive learners themselves, harnessing their own personal and programmatic improvement efforts to role-model the essential nature of this shift in expectations of trainees. Investing the time and energy in refocusing training programs will cultivate transformative, adaptive change agents who will continue to impact and improve the learning health care system for years to come.

Acknowledgments

The authors would like to thank their home institutions, fellow members of the American Medical Association's (AMA) Accelerating Change in Medical Education Consortium, and the AMA for their support of innovation.

The AMA Supplement is sponsored and supported by The American Medical Association.

Disclosure statement

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the article.

Disclaimer

The opinions expressed in this article are those of the authors and do not necessarily reflect American Medical Association policy.

Funding

This work was funded in part by the American Medical Association.

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