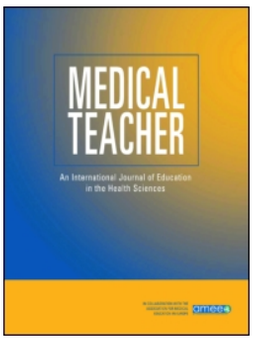

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Artificial intelligence in medical education

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ABSTRACT

Artificial intelligence (AI) is a growing phenomenon, and will soon facilitate wide-scale changes in many professions, including medical education. In order for medical educators to be properly prepared for AI, they will need to have at least a fundamental knowledge of AI in relation to learning and teaching, and the extent to which it will impact on medical education. This Guide begins by introducing the broad concepts of AI by using fairly well-known examples to illustrate AI's implications within the context of education. It then considers the impact of AI on medicine and the implications of this impact for educators trying to educate future doctors. Drawing on these strands, it then identifies AI's direct impact on the methodology and content of medical education, in an attempt to prepare medical educators for the changing demands and opportunities that are about to face them because of AI.

Introduction

Thinking machines and artificial intelligence: a brief history

The notion of thinking machines has existed for centuries, from Descartes' *Automata* (Descartes 1637) to Charles Babbage's *Analytical Engine*, of which Lady Lovelace said could only perform "whatever we *know how to order it* to perform"(Menabrea 1843). In 1950, Alan Turing (Turing 1950) asked, "Can machines think?" and constructed his *Imitation Game* (now called the *Turing Test*). In this test, a human subject interacts with a machine and another human, and, if the subject cannot tell the difference between machine and human, then the machine can be said to be "thinking."

In the twenty-first century, we have the first forays into artificial intelligence (AI). (For this Guide, I propose a working definition of AI as *the behaviors by computer software that are designed to mimic and extend human rational thinking and actions*, based loosely on general texts, such as Poole et al. (1998) and Russel & Norvig (2009)).

There have been AI failures, such as Microsoft's *Tay*, an AI system designed to learn from, and interact with, Twitter users. Unfortunately, Tay was taught by Twitter users to be a racist, sexist bigot, and was taken offline (Vincent 2016).

Contrastingly, there have been AI successes, such as Google's *AlphaGo*, which, in 2016, stunned the world with a 4-1 victory over Go world champion Lee Se-dol (Sang-Hun 2016).

Unlike Babbage's Analytical Engine, both Tay and AlphaGo had entered the realm of the thinking machine, extending their knowledge and thinking beyond what they had been taught; unlike Tay, however, AlphaGo had been taught well, and had behaved acceptably.

Lessons for education

Educational lessons can be learned from AI failures and successes. Most important is that, just like human learners, AI systems take the basics of what they have been taught, grapple with them, get confused, attempt resolutions, extend, and apply. It is too simplistic to argue that good teachers automatically lead to good education, but we do know that teachers influence students and their behavior; Tay and AlphaGo illustrate that good teaching can provide the platform for good AI learning, and bad teaching can harm AI. So, given that AI can learn, could we not use it to teach?

Practice points

- Artificial intelligence (AI) will have an impact on all professions, including those of medicine and medical education.
- Current experiments in AI indicate that the teacher's role is crucial to good AI development.
- The result of AI in medicine will not be to replace the doctor, but to replace and enhance many of the doctors' roles, and create a range of new roles.
- It is crucial that these changes be known in advance, so that medical education can begin preparing medical students for these new roles.

Teachers

In 1980, Arthur C Clarke wrote "Any teacher who can be replaced by a machine should be!"(Clarke 1980). In a view of education as simple knowledge-transfer, replacing human teachers with machines has appeal. In reality, good teaching involves accessing information from many sources, collating, prioritizing, adapting, and then using it within narrow (even unique) circumstances with extremely subtle variations. In addition, creative teachers frequently

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use materials that are not "educational" in any formal sense, but are useful to stimulate thinking, introduce topics, or push boundaries beyond the narrow curriculum. This ability does not yet exist in computers.

AI will undoubtedly impact on medical education *methods*, including intelligent tutoring systems' identifying and responding to gaps in students' knowledge, adaptable virtual facilitators in constructivist learning approaches, data mining (as opposed to using "search engines"), intelligent feedback to students and teachers, and performing mundane tasks like assignment grading and attendance tracking. These will affect *all* education.

To better see the potential of AI in *medical* education, we should consider the end of the process: good and competent doctors. Just as any change in medical education should be guided by this end goal, we need to ask, given the potential that we have already seen for AI to learn, rather than replacing *teachers*, *should we rather be aiming at AI doctors?*

Doctors

Already, computers can perform prediction and diagnosis better than humans (Boguševičius et al. 2002; Esteva et al. 2017; Litjens et al. 2017; Mobadersany et al. 2017; Betancur et al. 2018; De Fauw et al. 2018; Haenssle et al. 2018). But how far off is AI before society accepts an AI doctor? To get some idea, we need to remember a few things:

- AlphaGo's race to world champion was stunningly swift (Cho 2016), and we can expect rapid advances in all fields, including medicine.
- AlphaGo is a single system. A medical AI system would be a global neural network utilizing hundreds of thousands of computers through the internet of things (IoT).
- Although evidence-based medicine (EBM) is the gold standard, there is no proven effective method of research data dissemination and acquisition, and research growth puts this ideal further from our grasp every day. Early experiments show that AI is ideally suited to automatically accessing relevant data from published research and from electronic medical records (EMRs), allowing systems and doctors to stay current (Tafti et al. 2017).
- To be a competent doctor, *an AI system does not have to be the best doctor in the world*. AI has to be better than only the worst graduating student in your class. Further, assuming a standard distribution curve, if AI is better than your average student, it is better than 50% of all doctors. Moreover, as seen from the references above, there are already systems that can perform several tasks better than some of the best, so AI is on track to achieve this.
- And finally, how confident are you in other aspects of all your graduating students, such as their principles and ethics?

The human touch

We may counter these contentions by considering the Human Touch and empathy that all involved in healthcare have for patients (Cayley 2006). Can AI do that? Again, to see this in perspective, we should reflect on salient issues. These include the following:

- Appalling medical experiments performed around the world in the twentieth century (Masters 2018a);
- Declining empathy levels among medical students as they progress through their medical degree (Hojat et al. 2009; Neumann et al. 2011; Chen et al. 2012);
- Pharmaceutical companies' price gouging in pursuing financial profits (Hemphill 2010; Greene et al. 2016; Wardle and Wood 2017) and fearing the Genomic Revolution because cures will eat into their profits (Kim 2018);
- Hospitals' forcing doctors to rush through wards, giving curt responses to patients, and schedules forcing doctors to reduce consultations to 10 or 15 minutes;
- Insurance doctors' overriding treating physicians and deciding on "best" treatments for patients without any physical contact with those patients. A task for practicing doctors: consider some decisions made by those insurance doctors affecting your patients: on average, would an AI system do any worse? And, as AI systems learn empathy (Huang and Rust 2018), their Human Touch will improve. Artificial Human Touch is better than no Human Touch at all.

Yes, there is a need for direct human interaction, especially when breaking bad news, counselling and small procedures like checking blood pressure, suturing, and so forth. But we do not need doctors for this. Breaking bad news and counselling is best performed by properly trained counsellors. Unless we move counselling from "also taught" to a major focus in the curriculum, we should leave this work to professionals. Small procedures like blood-pressure recording and suturing are best performed by well-trained nursing staff.

Can doctors be replaced by computers? While the snappy answer is, "Any doctor who can be replaced by a machine should be!", reality is more subtle. Perhaps, rather than replacing *doctors*, we should look at using AI to replace or enhance some of the doctors' *roles*. We need to understand these new roles so that we can adjust medical education accordingly.

Replacing and teaching the new doctors' *roles*

Identifying AI roles

The literature cited above indicates that AI is able to perform some differential diagnosis and clinical reasoning more competently than humans (ironically, this ability would mean that the computer would "fail" the Turing test (Turing 1950)). Yet AI diagnostic systems carry warnings that they should not replace qualified physicians, and even patients want diagnosis confirmation by physicians (Fink et al. 2018). This is in spite of the fact that some AI systems have been designed precisely *because* trained and qualified physicians made mistakes (Isabel Healthcare 2018). In essence, we are deferring to a system that is proven to have inferior clinical reasoning skills, purely on the grounds that that system is human. Yet, perhaps unnoticed, we already have the early stages of role replacement: the EMR.

Role replacement: early stages

EMRs herald great potential benefit to health services, yet there is so much criticism of EMRs by practicing doctors. The most common is that data capture interferes with normal health care workflow practice and procedures that specifically require direct eye contact between doctor and patient (Unger 2015; Gaither 2016; Sinsky et al. 2016; Shanafelt et al. 2016). The solution seems to be to rectify these EMR design flaws, so that EMRs *do* fit in with normal workflow practice and procedures.

Unfortunately, this "solution" shows a misunderstanding of the EMR's role in modern healthcare. Removing doctors' eyes from patient to computer is not a design *flaw*; it is a design *feature*. EMR systems are not designed *fit in* with normal workflow practice; EMR systems are designed to *change* normal workflow practice. In business terms, EMRs are not *sustaining* technologies, they are *disruptive* technologies (Christensen and Armstrong 1998). And, as EMR systems increasingly interact with AI systems, and as EMR systems increasingly *become* AI systems, so they will increasingly *disrupt* normal workflow practice.

The frustration and anger that doctors feel now is because they are at the initial stages of an important new role, largely characterised by gathering and entering patient data into EMR and AI systems. This may be unwelcome news to doctors, as they may see themselves reduced to data capturers, but it should not be surprising, in spite of what doctors may have been told about the role of EMRs. In real terms, what doctors are experiencing is merely the early stage of EMR usage while AI catches up and moves into the next stage: role change and reversal.

Role change, new roles, and teaching for them

In practical terms, what does AI mean for future doctors' roles? While it is impossible to foresee all implications, some are obvious, and have been mentioned in preceding sections. This section looks at new possible roles and changes to medical curricula content that will be required to meet these new roles.

- *Being proactive in AI system design.* Successful disruptive technologies frequently introduce simplification (Christensen and Armstrong 1998), but that cannot be said about many current EMR systems. To balance change with maintained healthcare, doctors should organise themselves into influencing groups and assist directly in designing and trialing EMR and AI systems. Doctors should be taught at least basic medical informatics, and have a sense of EMR and AI design principles so that they can work directly with designers, ensuring that systems meet healthcare ethical, medical and practical requirements.
- *Working with AI diagnostic systems.* Doctors need to know how to work constructively with AI diagnostic and other systems to best serve their patients' needs. For this, they will require training on these systems to become as familiar with them as they are with any other medical tools. Training should start now. Waiting until these systems are pervasive before beginning training will be counterproductive, as the learning curve and psychological impact will be tremendous. In addition to technical training, wider questions around ethics, roles, protocols, and liability need to be addressed.
- *Communicating with AI systems.* Doctors need to be taught how to inform AI systems of the relevant information, so that EMRs can match new information to information inside and outside the EMR, and prompt doctors to request further information on areas that appear unclear. This is an iterative process. In addition, doctors require careful training on verbal communication, written communication, voice input, and translating tactile information, suspicions and hunches into digital information, and how to use data-mining tools within clinical environments.

  Doctors also need to be taught how to engage with AI systems that develop "personal" relationships with patients, watching for early warning signs, and simultaneously allowing patients to easily transfer between providers, gathering and collating data, identifying trends and anomalies, and triggering appropriate organisational responses.
- *Deeper counselling and related activities.* Related to communication skills, doctors need to be taught improved counselling skills. Doctors without these skills would be more suitably employed away from patients, and counselling can be performed by qualified counsellors. This will grow in importance as AI opens new medical fields, such as *enhanced medicine* (medical procedures enhancing the human mind and body beyond what is currently considered "normal").
- *Psychological reorientation of one's roles***.** Some doctors' roles will change so much that they will no longer be recognisable, and many roles might no longer fit the pattern of what we currently mean by the word "doctor." This will have to be addressed at all levels, especially in Continuing Medical Education (CME).
- *Teaching new medical AI.* From Tay and AlphaGo, we know that we need doctors who can teach AI properly. Initially, patient information will have to be gathered by doctors and given to AI systems. But AI will have to be taught to gather this information itself, and how to work properly with it.

  We already have examples of medical AI system errors because of poor teaching—IBM's Watson was taught oncology skills through hypothetical cases only (Ross and Swetlitzlke 2018), a practice considered unacceptable when teaching human doctors. It was not surprising that it made so many mistakes. Good AI needs teams of experts from medical, educational and computing fields.

  Complex issues already inherent in medical informatics' ethics (Masters 2018a) will need to be built into medical AI as guiding principles. Only by including these ethical *principles* into AI, can AI move from Artificial *Intelligence* to Artificial *Wisdom*.

  Individual EMR AI systems will need to be taught to communicate with greater, global AI systems, as smooth communication is crucial for effective system evolution. But the technical areas form only one aspect. A larger area requiring addressing is language. Medical jargon is fraught with inconsistencies (Lee and Whitehead 2017), and AI systems can already address these restrictions,

and have communicated with each other far more efficiently than humans can. The problem is that humans cannot understand machine-developed AI languages, and have responded by shutting down the systems (Wong 2016). We will need medical practitioners who can work with these new languages.

- *Robotics.* Although in its infancy, and mostly under human control, surgical robotics has already shown potential in changing surgery, and the direct positive impact on healthcare will be profound (Nag et al. 2017; Schroerlucke et al. 2017; Porpiglia et al. 2018; Stiegler and Schemmer 2018; Stravodimos et al. 2019). Intelligent robots are simply robots with AI software, and this software will eventually perform surgery without humans. Soon, these surgical methods will be standard, and medical schools that are not teaching robotic surgery will fall behind rapidly.
- *E-patients.* Although the concept of e-patients (Masters 2017; Masters 2018b) is beyond this Guide's scope, we can note that AI will dramatically impact upon the e-patient. Patients will become accustomed to seeing, may *expect* to see, doctors' using AI, and be judgemental of those who are not.

  As AI improves, patients will frequently by-pass doctors, preferring to interact with AI systems from their home or other remote locations through voice, wearable and implanted computers. Combining these facets will change the very nature of the patient, as humans evolve into *Homo Nodus* (Masters 2015), a node on a vast Internet of Things.

  A particular difficulty will be AI companies' wishing to prevent patients' accessing personal AI systems directly, or without paying a substantial fee. This discussion is already old, as the goal is to move beyond hospital-owned and controlled EMR systems to encrypted, patient-owned and controlled systems, to which patient's AI systems grant health personnel access only when needed, that access is authenticated and tracked, and data usage is tracked and audited. Doctors have to be taught how to interact with e-patients as part of the AI environment.

It is inevitable that similar to the way in which industrialisation led to "deskilling"(Frey and Osborne 2013), many health professionals' tasks and roles will be taken over by AI, new roles will be necessary, and medical education must prepare for those new roles. Detailed curricula need to be developed and updated as the technology and environment evolve. Much material development will need to be performed by development teams that include patients.

Conclusion

This Guide has considered thinking machines from Descartes and Turing to Artificial Intelligence with AlphaGo. As AI moves deeper into medical practice, we may have fears that the "real" work will be done by computers, and doctors will have nothing to do, and will know nothing. That is possible, if we want it to be. Just as likely, however, new roles for health professionals will emerge, many roles not yet foreseen, roles requiring new medical education.

Some readers may be skeptical about the seemingly science-fiction outlook of this Guide. One should remember, however, that tens of billions of dollars are poured into AI research annually (Bughin et al. 2017), and the amount of data currently available to computer systems is unprecedented; AI will impact directly on every aspect of our lives, and there is no reason to believe that medicine and medical education will be spared. It is our responsibility to prepare ourselves, our students and our doctors, for the future with AI, so that quality healthcare can be delivered.

Those who ignore AI will have temporary comfort, but, when they finally realise that it is all around them, they will wonder how they missed it.

Far from *replacing* doctors, students, or medical educators, AI will open new horizons. It is not so much that those who *can* be replaced by AI *will* be; it is more that those who *wish to* be replaced by AI *will* be. For the rest, the opportunities will be vast. Whatever the future, "We can only see a short distance ahead, but we can see plenty there that needs to be done" (Turing 1950).

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