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Artificial Intelligence in Education

What is it, where is it now, where is it going?

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Artificial Intelligence holds significant promise to revolutionise our educational systems, but are our educational systems ready for a revolution? Brett Becker explores current advances of AI in education and provides a forward-looking view on how AI might affect our educational systems in years to come.

Very few subjects in science and technology today are causing as much excitement, and as much misconception, as Artificial Intelligence (AI). It seems that everyone from Obama to Putin and Bezos to Zuckerburg are commenting on both the possibilities and the problems that AI could bring to humanity. In the past year Stephen Hawking and Elon Musk have both made global headlines voicing their concerns over the ramifications of AI. Also this year, Google's AlphaGo program beat Ke Jie, the world's number one Go player. This represents a significant AI milestone as Go is extremely complex, significantly more so than chess, and only 20 years ago some doubted that AI could master chess until IBM's Deep Blue beat world-champion Gary Kasperov in 1997.

An important distinction between the AI that Hawking and Musk are concerned with and the AI that powers AlphaGo and Deep Blue is that the latter are examples of narrow (sometimes called weak or domain-specific) AI – non-sentient AI that is focussed on a specific problem. The AI that Hawking and Musk warn of is strong (or general) AI – AI with the ability to perform so-called general intelligent action. It is important to remember this distinction when discussing AI in educational settings as we will soon see.

It is not only the different types of AI that make discussions on the topic fraught with misconception. The interdisciplinary nature of the field and the myriad definitions of AI complicate matters further. Even experts can find it difficult to define AI succinctly. In fact it could be said that AI suffers from a self-fulfilling misconception crisis, as Nick Bostrom, a leading AI expert from Oxford University, explains: "A lot of cutting edge AI has filtered into general applications, often without being called AI because once something becomes useful enough and common enough it's not labelled AI anymore".[1]

What is Artificial Intelligence?

Quite generally, AI is programming a computer (or any device) to perform a task that traditionally is only possible with human intelligence due to its complexity. Complexity is the key word in the previous sentence. Summing the numbers between one and

one trillion isn't complex, but it is tedious and would be incredibly slow for a human to accomplish, however computers excel at this kind of task without the need for AI. What about grading thousands of online multiple choice tests? Again, tedious and slow for a human, straight-forward and fast for a computer. Still, because this task is not necessarily difficult for a human, it also would not require AI to be accomplished by a computer. If we increase the complexity more, and talk about grading a 10,000 word essay on one of Shakespeare's works, we enter the realm of tasks that are complex enough to require real human intelligence. Regardless of how tedious and time-consuming this task may be, it is the complexity that makes this task one that traditionally only a human could perform. To have a computer do so (properly, reliably, and perhaps not for just one specific work of Shakespeare, but any) would require AI.

AI affects most of us every day. If you talk to Amazon's Alexa or to your phone (not just through it) the software that interprets your voice is powered by AI. The reason that your inbox (hopefully) has a lot less spam than it did a few years back is probably due to AI. When you tag someone in a photo on Facebook, AI is used to identify that person in other photos. But what changes has AI had on education, and what effects will it have in the future? Before we answer these questions, we need to inspect today's educational practices and problems a little more closely.

Ireland happens to be global leader in AI, with dozens of companies and research centres focussing on AI highlighted in a recent article titled "Why Ireland is the AI Island".[2] These include companies such as IBM, whose Irish operations have a strategic focus on the Watson AI platform discussed later, and research centres such as CeADAR, the Centre for Applied Data Analytics, where as a collaborator, I have personally witnessed a remarkable increase in AI activity recently.

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Picture a phone from 30 years ago and compare it to the one in your pocket today. The one in your pocket is quite different: it is not tethered to the wall with a wire; it has fewer buttons; it has a camera; it is a conduit to most of mankind's cumulative knowledge; it may be able to recognise your fingerprint or your face. It's also in your pocket! Now picture a classroom from 30 years ago and compare it to today's typical classroom. There are probably few striking differences: perhaps the colour of the board the teacher writes on; perhaps the classroom from 30 years ago has no projector, but maybe it does. Perhaps there are more computers in today's classroom. Perhaps the biggest difference is that everyone has a phone in their pocket! Nonetheless, that says more about the phone than the classroom. Either way, you probably pictured people in a room – a room with many students and one instructor. The students are probably sitting facing the instructor. Indeed, the typical classroom system has changed very little from that of 30, or even 60 years ago. Why is there so little fundamental change? This question reminds me of a quote from Henry Ford: "If I had asked people what they wanted, they would have said faster horses".[3] To effect a big change, as did Ford, we need a revolution – that revolution could be the application of artificial intelligence to education. For more on breaking free from our 19th century factory-model education, see.[4]

Luckin et al. describe Artificial Intelligence in Education (AIEd) as investigating learning wherever it occurs, in traditional classrooms or in workplaces, in order to support formal education as well as lifelong learning. It brings together AI, which is itself interdisciplinary, and the learning sciences (education, psychology, neuroscience, linguistics, sociology, and anthropology) to promote the development of adaptive learning environments and other AIEd tools that are flexible, inclusive, personalised, engaging, and effective.[5] At the heart of AIEd is the scientific goal to "make computationally precise and explicit forms of educational, psychological and social knowledge which are often left implicit".[6]

The two-sigma Problem

In 1984, educational psychologist Benjamin Bloom, best known for his taxonomy of learning domains, sought to determine if there were concrete adjustments to the traditional classroom format that would have positive impacts on student performance.[7] He found that a mastery learning approach (a category of instructional methods which establishes a level of performance that all students must master before moving on to the next unit) helped students by more than one standard deviation. When combined with personal tutoring this increased to two standard deviations, a so-called 'two-sigma' effect on performance. The major takeaway is this: the notion of categorizing students as "high" or "low" achievers was almost entirely incorrect. Students who perform in the 50th percentile in a traditional classroom could effectively perform in the 98th percentile with mastery learning plus one-on-one support.[8]

Ireland happens to be global leader in AI.

Had Bloom achieved the educational panacea? Not quite. Personalised tutoring and mastery learning are both problematic. The former is extremely financially expensive and the latter is extremely temporally expensive. Thus, the 'two-sigma' problem was born: What could be done efficiently, at scale, and be as effective as mastery-based personalised tutoring? For much of the last 25 years, the AIEd community has been focusing, to a large degree, on solving the two-sigmaproblem, moving towards creating systems that are as effective as human one-on-one tutoring.[9]

Where is AIEd Today?

In the last decade, artificial intelligence and adaptive technologies have matured, making both mastery learning and one-on-one instructional methods more scalable than Bloom ever could have imagined [8]. However, these technologies have yet to coalesce into widely adopted systems to facilitate teaching. To a large extent, this is because our existing educational models and systems are still stuck in their traditional forms, hindering the true adoption of AI systems. There have however been major strides in technologies to help teachers currently teaching in traditional models, particularly in freeing up their time so that they can tend to tasks for which human intelligence is still required. AIEd is well placed to take on some of the tasks that we currently expect teachers to do – marking and record keeping, for example. In my research area of computer science education, I have personally witnessed an increasing interest in AI in recent years, particularly to gain insight from the vast

amounts of data that students are producing during their learning, and to automate educator tasks.

As a specific example, Korn[10] reported on the work of Ashok Goel, a professor of computer science at Georgia Tech who last year used an AI program as one of the teaching assistants in his Artificial Intelligence class. The program replied to students' email queries regarding assignments. The program was given the moniker Jill Watson – a nod to the fact that 'she' runs on IBM's Watson AI platform.[11] Georgia Tech researchers began creating Jill using nearly 40,000 postings on a discussion forum, training her to reply to similar questions based on prior responses. Most students were surprised when they were told that Jill was a computer program. Goel explained that Jill only replies when she has a confidence level of 97%, which distinguishes her from customer-service chatbots used by airlines and other industries. He said "Most chatbots operate at the level of a novice... Jill operates at the level of an expert".[10] Goel estimates that within a year, Jill will be able to answer 40% of all the students' questions, freeing his human teaching assistants to tackle more complex technical or philosophical inquiries.

> **To effect a big change... we need a revolution - that revolution could be the application of artificial intelligence to education.**

This is an example of AIEd that does not necessarily replace the teacher, but frees up time for those in teaching roles, akin to what Luckin et al. foresee: "Crucially we do not see a future in which AIEd replaces teachers. What we do see is a future in which the role of the teacher continues to evolve and is eventually transformed; one where their time is used more effectively and efficiently, and where their expertise is better deployed, leveraged, and augmented".[5]

The Ethics of AIEd

No discussion on AIEd would be complete without mentioning the ethics of incorporating AI into our educational systems. A complete discussion of this is beyond the scope of this article, but as Luckin et al. point out, we have a new responsibility to ensure that society as a whole has sufficient AIEd literacy – that is, enough to ensure that we use these new technologies appropriately, effectively, and ethically.[5] The interested reader is guided to [12] for a comprehensive view on the ethics of AI.

> **We see a future in which the role of the teacher continues to evolve and is eventually transformed.**

The Future of AIEd

As for the future of AIEd, some see AI technology not just augmenting the roles of teachers as Jill Watson does at Georgia Tech and as Luckin et al. foresee, but replacing at least some of their traditional roles altogether. Sir Anthony Seldon, vice-chancellor of the University of Buckingham, former master of Wellington College, historian, and well-known political commentator, sees intelligent machines taking over the inspirational role of teachers completely.[13] Certainly, in order for this to be the case, strong (general) AI must become a reality, and whether or not this will ever happen is debated. Keeping within the confines of narrow (domain-specific or weak) AI, Luckin et al. offer several predictions for the next phase of AIEd, noting that it will soon: help learners gain 21st century skills, support a renaissance in assessment, embody new insights from the learning sciences, and give us lifelong learning partners.

AIEd-driven assessments will be built into meaningful learning activities, such as games and collaborative projects...

Luckin et al. see AIEd helping learners gain 21st century skills by helping us develop reliable and valid indicators that will allow us to track learner progress on the skills and capabilities needed to thrive in the coming decades, including characteristics such as creativity and curiosity that are notoriously difficult to measure. It will also help us develop a better understanding of the learning contexts and teaching approaches that allow for these skills to be developed.

They also see AIEd techniques complementing existing learning analytics by providing just-in-time information about learners' successes, challenges, and needs which can be used to shape their learning experiences. For example, AIEd combined with learning analytics will allow us to identify changes in learner confidence and motivation while learning foreign languages, or complex mathematical concepts. This information could then be used to provide timely interventions to help students, perhaps in the form of individual attention from a teacher, technology-assisted support, or some combination of the two.

Luckin et al., also see data gleaned from digital teaching and learning experiences providing new insights that are difficult or impossible to ascertain from traditional assessments. For example, datasets could be analysed to help teachers understand how the learner arrived at their answer, not just if they selected the correct one. This data could also help us understand more fully the cognitive processes such as remembering and forgetting, and the key roles that these have on learning. AIEd analysis might also identify if and when students become bored, confused, or frustrated, to help teachers adapt to and enhance learners' emotional readiness for learning.

AIEd will help us do away with the stop-and-test approach that pervades assessment today. As described by Luckin et al, instead of traditional assessments which rely upon testing small samples of what students have been taught, AIEd-driven assessments will be built into meaningful learning activities, such as games and collaborative projects, and will assess all of the learning taking place, as it happens.

AIEd will provide learners with lifelong learning partners.

AIEd will also embody new insights from the learning sciences to allow us to better understand the learning process and build more accurate models that can predict and influence learner progress, motivation, and persistence. Luckin et al. highlight the work of Paul Howard-Jones, Professor of Neuroscience and Education at the University of Bristol whose work suggests that learning can be improved when it is linked to uncertain rewards, differing from traditional models that apply rewards consistently.[14] AIEd techniques could, for example, tailor the provision of uncertain rewards, calibrating them to a learner's individual reactions and behaviors, and increasing the effectiveness of such techniques even more.

Finally, Luckin et al. claim that AIEd will provide learners with lifelong learning partners. Although the concept of computer-based 'learning companions' is not new, the next generation of learning companions should offer much greater potential. These cloud-based systems will benefit from learner information gleaned not only from educational contexts but from all contexts: social, recreational, etc. Rather than

encompassing all subject areas, these learning companions may solicit specialist AIEd systems or subject-specific expertise from humans where required. In addition, suchsystems could focus on helping learners to become better at learning through developing a growth mindset [15] or an impressive array of 21st century skills. Because of the adaptability of these systems, learning companions can be as suitable for struggling learners as they are for the most accelerated and high-achieving learners.

"Within a decade, AI will have transformed school and university life and given the biggest boost to social mobility our society has ever seen."Sir Anthony Seldon

The examples given here are only a small subset of the many ways that AIEd could transform the future of education. In this section, guided by Luckin et al. – which is highly recommended for more information –I have focussed on those that are quite feasible in the next decade or so. It promises to be an important decade according to Sir Anthony Seldon, who said: "Within a decade, AI will have transformed school and university life and given the biggest boost to social mobility our society has ever seen".[16] Beyond this, AIEd does have the potential to tackle some of the biggest challenges we have in education today, such as addressing achievement gaps, enhancing teacher expertise, as well as addressing teacher retention and teacher shortages.[5] Eventually AIEd may lead to a complete reform of, perhaps even a revolution in, our educational systems.

Fullan & Donnelly describe three forces that must be combined if we are to deliver on the promise of technology to catapult learning dramatically forward: pedagogy, technology itself, and system change.[17] It is hard to resist the conclusion of Luckin et al.: The future ability of AIEd to tackle real-life challenges in education depends on how we attend to each of these three dimensions. That is, we need intelligent technologies that embody what we know about great teaching and learning in enticing consumer-grade products, which are then used effectively in real-life settings that combine the best of human and machine.[5]

Ultimately, combining the best of human and machine for the benefit of the learner is the true goal of artificial intelligence in education.

FOOTNOTES

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IT Sligo Opens Constance Markievicz Building

The €7m refurbished school of Business and Social Sciences at IT Sligo was officially opened in November 2017 by Minister of State for Higher Education, Mary Mitchell O'Connor. The school is named after Constance Markievicz, one of Ireland's most influential female historical figures and one who had a deep association with the North West. The name was chosen following a poll of students and staff at IT Sligo.

Pictured here at the official opening of the 4,400 square-metre facility are Actor Maura Logue in the part of Constance Markievicz with Minister of State for Higher Education Mary Mitchell O'Connor.