**Can Modern AI replace teachers? Not so fast! Artificial Intelligence and Adaptive Learning: Personalized Education in the AI age**

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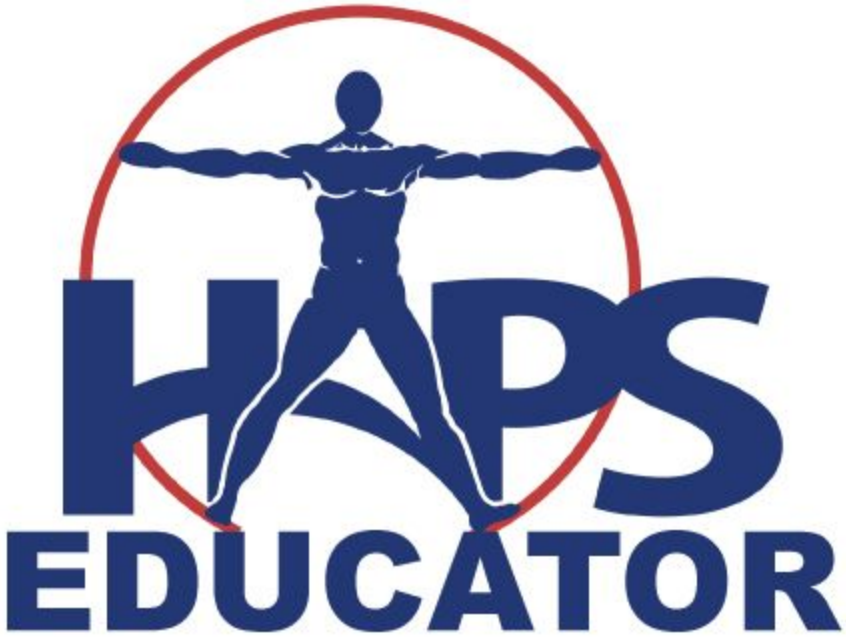


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# Can Modern AI replace teachers? Not so fast! Artificial Intelligence and Adaptive Learning: Personalized Education in the AI age

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## Abstract
Artificial intelligence (AI) is transforming many fields, including education. Can modern AI replace teachers? We discuss some popular AI applications for adaptive learning, how they are related to personalized education, what makes these applications "intelligent," and how the quality and quantity of student-generated data changes the behavior of adaptive learning systems and the learning experiences of students. If the data are scarce and corrupt, the benefits of adaptive learning are minimal. Motivated and persistent students generate greater amounts of high quality data and, as a result, tend to have better learning experiences. This can increase the gap between high achieving and low achieving students. More realistic student models and better understanding of the pedagogical context are needed to improve the performance of the AI educational systems. These are some of the reasons why experienced teachers cannot be replaced by the current AI applications.
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**Key words:** artificial, Intelligence, adaptive, learning, AI

## Is AI everywhere?
We live in the age of artificial intelligence (AI). Pervasive, but mostly hidden, it is taking over many jobs, devices, technologies and media, promising to transform all fields, from industry and commerce to medicine and education (Hawkins and Blakeslee 2007, Nilsson 2009).

Increasingly, our actions and decisions are guided by AI (Bostrom 2014). It tells us how to drive to our destination (GPS), what to buy (online shopping and ads), what to read (online search) and whom to date (dating sites).

Can it also tell educators how to do their jobs better, or even replace teachers completely? After all, AI is about to start replacing many professionals, from truck drivers to radiologists.

Reliance on AI is inevitable because in many situations modern AI is more effective and much more efficient than people. Not only can it win in chess and Jeopardy, it can also evaluate radiological images better than radiologists and avoid traffic accidents better than truck drivers, saving lives in both cases.

In education, AI promises to deliver what has always been the highest goal of pedagogy, wise and caring guidance for each student, adapted to the individual's needs. AI would potentially provide customized learning resources and activities, combined with the pace and style of instruction that best suits each individual student (Luckin *et al*. 2016).

As a result, all learners would have their own highly intelligent digital tutor (Andriessen and Sandberg 1999, Beck *et al*. 1996) and the problem of personalized education could be solved once and for all. The remaining teachers would supervise and adjust this computational *adaptive learning*.

But can modern AI actually deliver this? What can AI do at the moment and what are the problems that slow down its progress?

## What is AI?
AI is the computing that aspires to do what people do, only better. It encompasses perception (computer vision and hearing), reasoning (understanding and generating language in forms such as Siri and Alexa), learning, prediction, making decisions, and performing actions (robots and self-driving cars).

To do all of this intelligently, modern AI needs effective learning algorithms and a lot of high quality data for algorithm training (Russell and Norvig 2010, Domingos 2015). The most popular and successful algorithms today are *artificial neural networks*, biologically inspired programs based on the neural networks of the brain.

The data are specific to the applications. For example, all our choices online – what we click, read, watch, and buy – are valuable data for the AI algorithms that are trying to figure out how to serve us better (and also how to sell us more goods and services).

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The data feed learning and learning improves the program's intelligence, which means that the AI makes better predictions and decisions. The more high-quality data are available for training, the better the outcome. This continuous cycle of self-improvement reinforces the program's abilities. It is similar to some positive feedback mechanisms in physiology.

But if the data are scarce or confusing, the AI program may perform progressively worse, becoming more clueless instead of smarter and smarter. For example, if you are clicking on the online ads at random, you are providing AI with meaningless, confusing data. In this case, AI needs to recognize this immediately. Otherwise it will be learning from corrupt data, which may lead to wrong predictions and bad decisions. Artificial intelligence specialists informally call this "garbage in, garbage out."

Something similar can happen in adaptive learning. In fact, it is quite likely to happen, considering what students are supposed to do while using many popular programs.

## What is adaptive learning?

Adaptive learning (AL) is an educational approach that uses computing algorithms in order to organize the interactive learning experience and adapt to the individual needs of each student. Therefore, it is part of personalized education. Another type of personalized education is, for example, one-on-one tutoring, with no computers involved. This type of personalized education has been around since the times of Socrates, and probably even predates Socrates.

Modern AL is mostly intelligent. This means that it uses AI. There are some straightforward computer algorithms in educational programs that do not use AI, but they have become rare. Not all adaptive learning systems are intelligent, and not all intelligent learning systems are adaptive, but for the most part they intersect (Brusilovsky and Peylo 2003).

A simple example would be a computer program that provides various learning resources and engages students in the interactive learning (Sleeman and Brown 1982). When a student makes a mistake answering a question, the program does not simply give him another similar question. Instead, it searches for the patterns in all of the student's prior interactions with the program and analyzes them. Based on this, it creates a model of the student and uses it for the optimal response (Brusilovsky and Millan 2007).

This response, which might be a suggestion to review a relevant paragraph, to watch a short video, or to answer a series of increasingly difficult questions, depends not on just one wrong answer but on the complete knowledge about the student that the program has accumulated so far. It is different for each student because each student has interacted with the program in a different way. The program remembers all of these interactions and makes its own conclusions about the appropriate resources, pace, and style of learning for each student.

The objective is to stay in the zone of proximal development (Murray and Arroyo 2002), making the learning suggestions not too easy but also not too hard. If the learning suggestions are too easy, the student's experience gradually becomes boring. If they are too challenging, the student may become increasingly frustrated. In a way, these programs are similar to computer games, which are designed to keep the players interested, occupied, and even addicted to the game, all of this being critical for the game's success.

Many big publishing companies invest millions of dollars in adaptive learning programs that complement popular textbooks. These applications are available either online or on desktop computers (Daniel *et al*. 2015). The companies are compelled to invest heavily in adaptive learning programs, fearing competition and hoping for a high dividend. This is a new business model for publishing companies because highly profitable textbooks are not selling as much as they used to and AL access is the new source of profits. Access to adaptive learning programs cannot be stolen as easily as free PDFs of the textbook. More importantly, AL applications can eventually replace textbooks as the main educational resource of the future.

## How do the students react? Two divergent scenarios.

For a few semesters, all of my anatomy and physiology students systematically used online AL resources provided by the publisher. Every semester my classroom observations and student comments were essentially the same. The feedback seemed consistently inconsistent and ambiguous. Then patterns started to appear.

As the class begins using AL resources, students usually respond in surprisingly different ways. Some love the experience and others hate it. The two common scenarios that suggest possible reasons for this wide range of reactions are described below.

Motivated, persistent students use the AL programs a lot, reading and answering many questions, reviewing all the suggested materials and thinking hard about the topic. In other words, they do what the program expects them to do. In the process, they supply the program with abundant data of good quality. The program uses the data to learn about the student, adapting to the student's individual learning needs. This makes the learning experience even more exciting and rewarding for the student, further motivating the learner to work hard.

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Now let us consider another group of students who are easily distracted and bored. They are not very persistent and motivated in learning. These students tend to skip practicing altogether. Even if they start answering the questions, they may stop early. Overall, they generate much less data than motivated, persistent students. With scarce data, the AI program cannot help these students very much, which makes it even more difficult for students to complete the assignment.

Another problem with easily distracted students is that the quality of the data is usually not very high. If these students are forced to reluctantly answer all the questions, they may start clicking on the answers at random, without reading or thinking about them at all. This behavior is easy to anticipate since the students are trying to complete the assignment as fast as possible instead of trying to learn as much as possible. These students may quickly become bored and frustrated.

However, randomly clicking on answers is not what the program expects students to do. The program becomes confused. It gives the student new questions that make as little sense to the learner as the old ones did. The frustration grows. What was supposed to be an easy way out – clicking through the questions, as useless as that is – becomes an increasingly difficult path. This may account for some persistent and very personal student responses I had in my anatomy and physiology classes, for example, "I hate this program so much!"

In this case, the low quantity and poor quality of student data makes AI "blind." It becomes as dumb and ineffective as it can be ("garbage in, garbage out"). This also explains, to some extent, why there are always a few students who benefit from AI adaptive learning much more than others.

The paradox is clear: adaptive learning may help the most the ones who need this help least. It also may help the least the ones who need this help most. As a result, instead of decreasing the gap between the high achieving and low achieving students, these AI tools can actually increase the gap.

Interestingly, it is the same AL game for all, but for some it is exciting and even addictive and for others it is boring and tedious. It very much depends on how you play it from the start. The harder you try, the better it becomes. The more you skip and cheat, the harder it is to play it. The program can adapt to the learner, but the learner needs to adapt as well, in order to get the greatest benefits.

The AL experiences of my students were program-specific, but the AL achievement gap paradox is not. This hypothesis is rooted in the basic understanding of the modern data-driven AI, machine learning. The user provides the data. Good data means effective AI. Poor data means ineffective AI. It cannot be otherwise.

Unfortunately, there are no rigorous studies of the AL and achievement gap in the current literature. Hopefully, close attention to this problem will help improve performance of the AI educational systems. Students who need more assistance should get more, not less, from AL programs.

## Can modern AI replace teachers?

The AL programs discussed in this article cannot replace an experienced educator. These programs can be useful learning tools, especially for some students. They can help teachers by providing additional student training that frees classroom time for higher level learning activities. However, adaptive learning programs can also be easily confused by corrupt or scarce student data. Adaptive learning programs do not understand the wide range of the all-important pedagogical contexts. They do not know how to deal with students who habitually avoid learning or are afraid of learning and have never had a positive learning experience. The student models created by adaptive learning programs may be too simplistic and they are often unrealistic.

Teachers, on the other hand, have always been engaged in their own version of adaptive learning. We adapt our teaching to the particular class and to individual students, as much as we can, based on our experience, intuition, testing results and the available "bag of tricks," which has the limited selection of educational resources and techniques we have at our disposal.

The feedback we use for creating our own "student models" includes very important non-verbal clues in the classroom, such as facial expression, posture, movement, immediate reactions, and interactions in groups. We build personal working relationships with many students and respond in class and online with good humor and grace.

Can AI emulate all of this in the future? The next generation adaptive learning programs are on the way (Lane *et al.* 2016, Luckin *et al.* 2016). They will be much more sophisticated in their understanding of pedagogical context and in the range of potential adaptations to the learning needs of the student. It is possible that future adaptive learning pedagogical programs will change the way we learn.

## About the author

Vasiliy Kolchenko is a professor of biology at New York City College of Technology, The City University of New York. Vasiliy teaches anatomy and physiology, pathophysiology, and bioinformatics. He is developing a new introductory course in artificial intelligence and neuroscience. His research includes biosensor development and graphic representation in science education. He also writes and performs music. This is his Teaching Science song: https://www.youtube.com/watch?v=CpeI5wHvKE4

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