THE FUTURE OF EDUCATION SERIES

AI IN EDUCATION

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Summary

In this document we address the use of artificial intelligence (AI) in education. We highlight AI's potential to enhance teaching and learning through personalized tutoring, adaptive learning systems, automated feedback, and streamlined administration. At the same time, we flag serious risks: superficial learning, diminished critical thinking, academic dishonesty, and student isolation. Bolting AI on to outdated educational models, we argue, is not only ineffective—it may deepen existing problems. Instead, we call for a fundamental rethinking based on the science of learning, emphasizing scaffolding, desirable difficulties, active and social learning, and metacognition. The classroom must remain a vital space for human interaction, coaching, and the development of deep understanding—things AI alone cannot deliver. At a pivotal moment for both human learning and machine power, we call for AI to be built on a modernized pedagogical base instead of amplifying the deficiencies of our legacy system.

Introduction

The impact of artificial intelligence on employment, work, and daily life is expected to be profound and far-reaching. Recently, Anthropic's CEO warned that AI could eliminate a large share of entry-level white-collar jobs, potentially driving a sharp rise in unemployment. This warning is especially significant given that a company like Anthropic might typically be cautious about provoking regulatory backlash. In this context, education emerges as a critical line of defense as society confronts the disruptive power of AI.

When AI is spoken about in the context of education, three different topics are often conflated:

1. How AI affects teaching and learning.
2. How to teach the use of AI in life and work.
3. What complementary skills – such as critical thinking – become more important in the era of AI.

This article is about the first topic – how to use AI in teaching and learning.

The Potential Benefits of AI in Education

The release of ChatGPT led to much confusion and consternation in the education sector. Some school districts in the US, France and Australia initially banned AI over concerns about academic integrity. The capabilities of large language models also led to excitement about the potential to deliver long-envisioned capabilities such as personalized tutoring and adaptive learning. In April 2023, Sal Khan gave a TED Talk introducing Khanmigo and advocating for AI as a transformative force in education. The title of the talk encapsulated the excitement and worries: *"How AI could save (not destroy) education"*.

To be sure, there are several ways in which AI can be used to support education:

1. Learner-Focused Applications
    a. Intelligent tutoring systems: AI-powered tutors provide one-on-one instruction, answering questions, giving targeted feedback, and adapting to individual learning needs.[1]
    b. Adaptive learning systems: AI-driven platforms can tailor instructional content, assessments and learning pathways to each student's skill level, pace, and preferences, offering highly responsive and customized experiences.
    c. Immediate feedback: Automatic assessment (see in next section as well) can be a gamechanger for learning. Often, misunderstandings and mistakes are best addressed immediately, enabling students to quickly formulate a valid mental model of the topic being covered rather than waiting for days, and sometimes weeks, for the clarification from an instructor.
    d. Assistive technologies: Speech recognition, text-to-speech, and other technologies assist students with disabilities, such as hearing impairments and dyslexia, in fully participating in the learning process. AI can help students overcome language barriers, especially when learning in a less familiar language.
    e. Academic support, FAQ's, scheduling, nudging, logistics: Educators often spend significant amounts of time providing academic support, be it answering questions, reminding students of upcoming tasks, or managing logistics. AI can easily answer questions and address basic logistics through simple chatbots.

[1] J John Anderson's pioneering work on cognitive tutors at Carnegie Mellon University laid the foundation for many of the opportunities that large language models can now fulfill.

2. Educator-Focused Applications
    a. Automatic grading and assessment: AI tools can automatically grade assignments, including essays and open-ended responses, offering consistent and detailed feedback while saving educators time. Although this may seem controversial – shouldn't the educator be doing the grading? – the fact is a lot of grading is done to well-specified rubrics, and modern LLM's can quite effectively accomplish this task, or, at the very least, do a first pass before handing off to a human.
    b. Content creation: AI can help at many levels. First, AI-powered tools can automatically generate unique versions of assignments by changing numbers, scenarios, question orders, or wording for each student. This can help ensure that everyone gets a different set of problems, making it much harder to share answers. Second, AI tools can help in creating graphics and other content, saving educators time and potentially improving educational efficacy. For example, an animation of a physics concept may be more effective than a static picture. Of course, this could be controversial: is the educator is shirking work by using AI to help create content?[2]
    c. Analytics and Reporting: AI can analyze student data (performance, engagement, attendance) to identify trends, predict outcomes, and help educators intervene early with at-risk students.
3. Institutional or System-Level Applications
    a. Scheduling, management and logistics: Administrators juggle a complex set of changing requirements and constraints in running any institution. AI will likely become a powerful tool in playing out scenarios and offering solutions. A teacher out sick? Which others can fill in based on the classes they have taught? A bus broken down? What other routes can be leveraged with minimal diversions? AI can help optimize scheduling and resource allocation by analyzing classroom usage, faculty availability, and student demand to generate conflict-free schedules and maximize facility use.
    b. Institutional Research and Strategic Planning: AI can be used to massage and analyze and dissect large, unstructured data sets such as enrollment, student performance, and resource utilization trends. This can be used to inform strategic decisions and long-term planning, to benchmark performance against peer institutions, and to assess program effectiveness.
    c. Automate Administrative Processes: Streamline processes such as enrollment, and financial aid with AI-powered chatbots and virtual assistants that guide students, answer questions, and process applications efficiently.

[2] https://www.nytimes.com/2025/05/14/technology/chatgpt-college-professors.html

AI can also automate and streamline student record management, including updates to transcripts, attendance, and permissions, to reduce manual workload and improve accuracy.

We will focus our attention on items1(a)-1(c) and 2(a) because the pedagogical implications are most nuanced.

The Risks of AI in Education

The concerns about AI in education are real. Some risks:

1. Superficial Learning: Perhaps the most pressing question is how to thoughtfully manage the use of AI in education. Research on the "illusion of learning" reveals that students often confuse familiarity with true understanding—a concern that becomes even more urgent with the rise of AI tools. At a time when the quality of learning is under scrutiny and job-readiness is in crisis, the last thing we need is a further decline in deep, meaningful learning.
2. Insufficient Critical Thinking and Independence: Building on this, when students rely on AI for answers and problem-solving, they risk missing the opportunity to develop critical thinking, creativity, and independent learning skills. As with training wheels that are never removed, the real question—here and in the previous point—is when well-intentioned support begins to hinder true mastery.
3. Isolation and Loneliness: Social-media and COVID have already led to significant mental health complications for a generation of teenaged and young adults. Overreliance on AI can further diminish meaningful teacher-student as well as student-student interactions, which are crucial for social-emotional development, engagement, and motivation. This lack of human connection can lead to isolation and decreased student well-being.
4. Academic Integrity: Students can use AI to do homework assignments, like writing essays or conducting research, and to answer exam questions. This undermines the learning process for themselves and others and challenges the foundations of modern educational practice.[3,4]
5. Bias: AI systems can inadvertently reinforce or exacerbate biases inherent in their training data, resulting in unfair or discriminatory outcomes.

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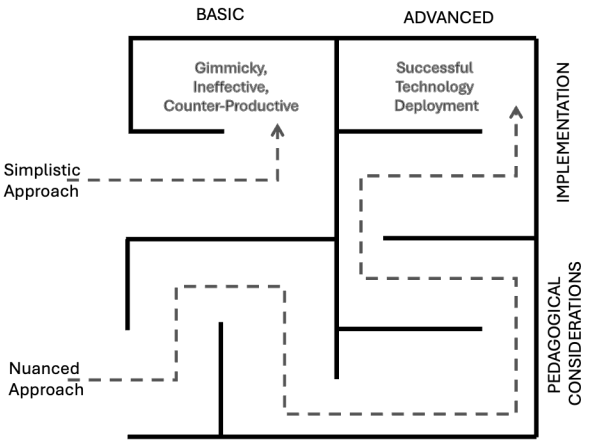
[3] https://www.theguardian.com/education/2025/jun/15/thousands-of-uk-university-students-caught-cheating-using-ai-artificial-intelligence-survey

[4] https://gizmodo.com/china-takes-on-student-cheating-by-shutting-off-ai-nationwide-during-exams-2000613172

Back to Basics: The Science of Learning



Our education systems are already outdated and misaligned with what science tells us about how people learn—and have long needed a thoughtful reboot. AI is so transformative that simply "bolting it on" to traditional education compounds the risks. Fortunately, the science of learning offers a clear path forward. It is time to go back to basics and rethink our entire approach.

Background

The science of learning is well-researched but remains surprisingly underutilized and little known in educational practice. Key concepts are summarized below.

Scaffolding in Learning

Lev Vygotsky was a transformative Belarusian psychologist who, in just 37 years of life, laid a key foundation for modern learning science with his theoretical framework known as the Zone of Proximal Development (ZPD). The idea is that effective learning happens when challenges are just beyond a learner's current abilities—but achievable with guidance. Good curricula, great teachers, and successful coaches often embody this naturally. Although Vygotsky died in 1934, and his work largely forgotten for decades, it was rediscovered in the 60's, gaining significant influence in educational theory and practice.

Wood, Bruner, and Ross (1976) coined the term "scaffolding" to describe structured support provided during learning – within the zone of proximal development. One can think of scaffolding as training wheels on a child's bike. Initially, the training wheels allow the child to master pedaling and steering – taking balance out of the picture, because that might be too much to take in all at once. If insufficient scaffolding is provided, learners might flounder because the cognitive load is overwhelming. If the learning is "over-scaffolded", learners might not achieve mastery, resulting in superficial learning. (We refer to this colloquially as spoon feeding.) But to achieve true learning, the scaffolding must relax over time until it is no longer required. The equivalent in a bike would be to lift the training wheels every other day until the learner masters balance without training wheels.

You arrive in a new city and start using Google Maps to get around—but pretty soon, you realize you're not actually getting a feel for where things are. Here's a trick: go to Google Maps/Settings on your phone and check the box titled "Keep map north up". This will make it slightly more difficult for you to follow directions. You will need to put effort into aligning the cardinal directions, and which way to turn – compared to the "I always point up and the map rotates around me" mode you likely used maps in earlier. And your sense of direction will likely improve. This is a desirable difficulty.

A counter-intuitive insight from cognitive psychology is that learning is best when there is some difficulty involved – so long as the difficulties are constructive. The UCLA cognitive psychologist Robert Bjork coined the term "desirable difficulties" in the 1990's to capture the areas where student effort pays off, as well as techniques for promoting recall and durability of learning. For example, testing on something just learned is not as effective as testing on the topic a day, a week, and again a month later. Several such cognitive techniques can be deployed to improve learning. They may seem to increase difficulty and effort, but effortful learning and desirable difficulties improve learning.

Within the Zone of Proximal Development (ZPD), coaching plays a critical role in learning. Effective teachers and coaches strike the right balance between allowing students to struggle productively and providing just enough support to ensure progress. Exceptional educators can calibrate this balance to the needs of each learner. A structured approach to this is known as "deliberate practice," a concept formalized by psychologist K. Anders Ericsson. Nobel Laureate Carl Wieman later applied these principles in a Stanford physics course, demonstrating significant improvements in student learning outcomes. He and others have strongly argued against lectures as the primary mode of instruction. Yet around the world, the lecture remains a deeply entrenched and remarkably persistent fixture of modern education.

Active Learning

Active learning, with roots tracing back to the polymath Jean-Jacques Rosseau, his intellectual successor, Johann Heinrich Pestalozzi, and at the turn of the 19th century, to John Dewey, emphasizes learning by doing rather than passive absorption of information. Dewey in particular championed experiential education, arguing that students learn best through engagement with real-world problems. His ideas laid the foundation for later thinkers like Jean Piaget, who explored how learners construct knowledge through interaction. Lev Vygotsky's focus on the importance of social interaction (more about that next) and the Zone of Proximal Development also played a role, along with the ideas of Maria Montessori. More recently, scholars such as Eric Mazur and Carl Wieman have revitalized active learning in higher education through peer instruction and evidence-based

teaching methods, reinforcing the enduring value of participation, inquiry, and reflection in the learning process.

Modern pedagogical approaches such as flipped classrooms, project-based learning (PBL), problem-based learning, and productive failure all emphasize active engagement and deeper cognitive processing. In a flipped classroom, students first encounter new material outside of class—often via video or readings—freeing up classroom time for interactive activities and discussion. Project-based and problem-based learning immerse students in real-world challenges that require collaboration, critical thinking, and applied knowledge. Productive failure, a concept championed by Manu Kapur, encourages students to struggle with complex problems before receiving instruction, leveraging initial failure as a catalyst for deeper understanding. Together, these methods shift the focus from passive reception to active construction of knowledge – echoing the words of Rosseau almost 300 years later.

MIT's motto, *mens et manus*—Latin for "mind and hand"—reflects its longstanding commitment to hands-on, practical learning. This extends active learning into the realm of embodied learning, real-world experience, experiments, projects, open-ended problems and applications. At MIT's Sloan School of Management, this is formalized as *action learning*, where students engage directly with companies or field settings to apply classroom knowledge. In parallel, the field of authentic assessment emphasizes evaluating students through real-world tasks rather than traditional paper-based tests—reinforcing the value of learning by doing.

Social-Emotional and Meta-Learning

The contributions of John Dewey and Lev Vygotsky converged with those of a third pioneer, Maria Montessori, on a vital insight: learning is not an isolated intellectual activity but a deeply social and emotional process. Writing from different cultural and philosophical traditions, each emphasized that education must engage the learner cognitively, emotionally, and socially. Dewey viewed the classroom as a microcosm of democratic society, where students grow through active inquiry, communication, and cooperation. Montessori designed carefully prepared environments that promote independence, purposeful activity, and the internalization of self-discipline, with teachers guiding rather than directing. Vygotsky, working within a sociocultural framework, demonstrated that learning is driven by social interaction, describing how language, shared activity, and collaboration shape both what and how children learn.

Later research has shown these insights to be broadly validated by science. Today we know that the development of metacognition—the awareness and regulation of one's own thinking—is essential for effective learning and long-term student growth. Reflection plays a key role in this process, helping students evaluate their strategies, monitor progress, and make intentional adjustments. Through reflection, learners build self-regulation, gaining control over both cognitive processes and emotional responses. These skills are central to social-emotional learning (SEL), which fosters self-awareness, responsible decision-making, executive function and adaptability. The teacher as a guide or mentor supports students in applying metacognitive strategies by offering feedback, and nurturing independence. Together, these practices help students become self-directed, resilient learners, equipped to solve problems and thrive both academically and personally.

Rethinking Education for an Era of AI

The philosophical and research insights presented above provide clear hints at how education needed to be fixed before AI. But going back to the basics gives us insights to take on the challenges that AI brings on. In the spirit of "never waste a crisis," we are now at a moment when we can get it right.

We begin by mapping the opportunities and risks to solutions that the science suggests.

Opportunities→ Risks↓	Intelligent tutoring	Adaptive Learning	Assessment and Feedback
Superficial Learning	Desirable difficulties. Optimal scaffolding. Active Learning, Spaced Repetition, Interleaving. See Appendix.	Vygotsky's ZPD. Ensure that the challenge is maintained as learning progresses.	Authentic assessments. Real-world problems, retrieval practice.
Insufficient Critical Thinking	Relaxing scaffolds. Open Ended Problems. Flipped Classroom. Set up system to refer more persistent misunderstandings to the teacher.	Encourage meta-learning, self-regulation. Instant feedback can help learners quickly understand how and where to improve.	Open-ended problems. Use of AI tools for research. Instant feedback to students.
Isolation and Loneliness	Flipped in-person classrooms with active learning, peer learning, community, coaching. Team projects.	Coaching, deliberate practice.	Reflection, coaching, personal support.

Opportunities→ Risks↓	Intelligent tutoring	Adaptive Learning	Assessment and Feedback
Academic Integrity		Unsupervised assessment: majority formative, limited summative assessment.	In-person assessment, authentic assessment.
Bias and Inequality	We cannot control AI. We must prepare the learner through reflection, meta-cognition, critical thinking.		

Below we summarize some key insights.

- The Classroom as a Critical Arena for Addressing AI's Challenges

  The classroom plays a central role in responding to both the pedagogical risks and opportunities posed by AI. Many of the most effective practices for mitigating AI's downsides as describe above—such as active learning, real-world problem solving, open-ended inquiry, coaching, and mentoring—are best implemented in live, in-person settings. To make space for these interventions, flipping the classroom becomes essential, shifting content delivery outside class time and reserving classroom time for deeper engagement. These practices help guard against superficial learning, foster critical thinking and promote social interactions.

- In-Person Learning as a Remedy for Isolation and Emotional Disconnection

  Beyond cognition, the classroom is key to addressing the growing crisis of student loneliness and disconnection. Reinvesting in in-person education strengthens the social-emotional dimensions of learning, including teamwork, self-regulation, and mentoring relationships—components that cannot be easily replicated online.

- The Need for Highly Calibrated Tutoring

  Online AI tutoring shows real promise, but it can be counterproductive if it isn't tuned to a student's developmental stage. The key is sensing and aligning with the learner's Zone of Proximal Development (ZPD)—pushing just enough to challenge but not overwhelm. In the 1950's, item response theory (IRT) was developed to sense the underlying abilities of students so that standardized could adapt to students' levels. [5] A similar for of sensing is needed to be applied so that AI tutors can be adaptive, thoughtful, and aware of the learner in front of them.

[5] Baker, Frank B. "The basics of item response theory." 2001. Full text https://files.eric.ed.gov/fulltext/ED458219.pdf

- Ensuring Effortful Learning

  Incorporating desirable difficulties—challenges that promote effortful, and therefore lasting, learning—is key to avoiding cognitive shortcuts. Techniques such retrieval practice, spaced repetition, and interleaving are well-supported by learning science and can be more easily implemented at scale through AI-powered platforms. Done right, AI can significantly improve learning effectiveness by delivering these techniques in a personalized and timely manner. [6,7,8]

- Preserving Academic Integrity in the Age of AI

  Academic integrity is increasingly difficult to uphold when AI tools are widely accessible. Because the actions of one non-compliant student can impact fairness for all, we recommend a dual approach:

  1. Out-of-class assessments should be open-ended or authentic in nature and should be considered formative assessments, where AI use is permitted and encouraged, with equitable access.
  2. Summative or high-stakes assessments should be conducted in person or in secure, proctored environments where AI tools are not available, or available in a controlled way – unless the use of AI is part of the assessment (such as in an AI-based software development test).
  3. Instructors must reconsider how they evaluate student learning and explore alternative assessment methods, as traditional formats like essays are increasingly at risk with AI.

  We believe that the proposed approach preserves integrity while embracing the realities of today's tools.

- Bias and the Critical Role of Human Judgment

  AI systems, even with advancing safeguards, will continue to reflect bias. Students (and teachers) must be equipped with the critical thinking skills to recognize and respond to these limitations. The most effective way to build these habits is through

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[6] Bjork, Robert A., and Elizabeth L. Bjork. "Making Things Hard on Yourself, but in a Good Way: Creating Desirable Difficulties to Enhance Learning." In Psychology and the Real World: Essays Illustrating Fundamental Contributions to Society, edited by Morton Ann Gernsbacher, Richard W. Pew, Laura M. Hough, and James R. Pomerantz, 56–64. New York: Worth Publishers, 2011.

[7] Brown, Peter C., Henry L. Roediger III, and Mark A. McDaniel. "Make It Stick: The Science of Successful Learning." Cambridge, MA: Harvard University Press, 2014.

[8] Sarma, Sanjay, and Luke Yoquinto. "Grasp: The Science Transforming How We Learn." New York: Doubleday, 2020.

structured dialogue, reflection, coaching, and mentoring. Ultimately, the most reliable guardrails against AI misuse are not algorithmic—but human.

Conclusions

AI is not a panacea. It can elevate and perhaps even revolutionize learning—but it can also undermine it if poorly integrated. Many of the AI solutions we see in the market are, frankly, high on flash but low on substance. Like any tool, AI's impact depends on the system in which it operates. The introduction of AI in education demands a system-level rethinking—one that was overdue even before AI's arrival.

In that reimagining, the classroom emerges as the hero: a space not just for information delivery, but for connection, coaching, critical thinking, and the kind of deep learning that AI alone cannot deliver.

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Appendix

Some desirable difficulties from cognitive science.

- Retrieval practice is a research-backed learning strategy that involves actively recalling information from memory rather than simply re-reading or reviewing it. In the science of learning, it's one of the most effective techniques for strengthening long-term memory and improving the ability to apply knowledge.[9]
- Forgetting is natural — our brains are wired to discard information that isn't reinforced. Spaced retrieval leverages this by prompting learners to recall information at increasing intervals over time, which strengthens memory and makes learning more durable.[10]
- Interleaving is a desirable difficulty that involves mixing different types of problems or topics during practice rather than focusing on one at a time. While it may feel harder, this approach strengthens the brain's ability to discriminate between concepts and apply knowledge flexibly — leading to deeper, more transferable learning. [11]

[9] Roediger, Henry L. and Mary A. Pyc. "Inexpensive techniques to improve education: Applying cognitive psychology to enhance educational practice," In J. Applied Research in Memory and Cognition, 1 (4), 242–248, 2012
[10] *ibid*
[11] *ibid*