REIMAGINING EDUCATION WITH AI

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Abstract

This chapter examines AI's transformative potential in education, focusing on Generative AI (GenAI) and Large Language Models (LLMs) while at the same time emphasizing the importance of grounding and guiding AI efforts with learning science and education research findings. It synthesizes analyses and expert recommendations, highlighting opportunities like personalized learning and enhanced teacher productivity, alongside challenges such as over-reliance on AI. Practical steps for instructors include adopting a question-first approach, utilizing AI for personalized feedback, designing AI-enhanced learning experiences, fostering critical thinking, and ensuring ethical AI use. The chapter concludes with strategic recommendations for leveraging AI to sustainably improve educational practices

Keywords: Artificial Intelligence (AI) in education, Generative AI (GenAI) in Education**,** Student Learning with AI, Teaching with AI, AI and Education Transformation**,** Education Technology and AI

INTRODUCTION

What is obvious and not so obvious

Artificial Intelligence (AI) tools are becoming increasingly prevalent across all educational levels - primary, secondary, tertiary, and continuing education. This trend is driven by the evolving capabilities of Generative AI (GenAI), including Large Language Models (LLMs), and the expanding accessibility of these technologies.

Significant advancements in combining LLMs with other AI modalities (eg. image, video, and sound creation) and methods (eg., reinforcement learning, verifiable logic-based "formal models," knowledge graphs, and deep learning neural networks) are also crucial, though less widely recognized. For instance, Google Deep Mind's AlphaProof and AlphaGeometry combine LLM capabilities with symbolic methods, achieving logical reasoning and verification. These applications successfully solved four out of six problems in the 2024 International Math Olympiad, matching the performance of a human silver medalist (AlphaProof and AlphaGeometry teams, 2024).

While it is easy to envision widespread AI adoption in education, actual integration that significantly enhances student learning and educational outcomes is more complex. As pointed out by (Bastani et al. 2024), while generative AI LLM tools can make tasks significantly easier for students, if they are used as a crutch rather than used as a supporting learning tutor, they come with the risk of deteriorating the student's ability to effectively learn some of the skills required to solve these tasks.

Our premise is that effective AI implementation in education and related conceptual, policy and experimental efforts to reimagine education with AI should be guided by contemporary learning science and educational research principles to achieve sustainable improvements in student learning and related outcomes and should have accompanying

support by education administrators. Conversely, efforts driven by the mere desire to use AI just for the sake of it are likely to falter.

High Potential for Improvement Though with Challenges and Obstacles

The potential for AI to improve education is substantial. A rigorously randomized control trial study conducted by the Rand Corporation during 2007-2009 across seven US states demonstrated that high school math students using an AI-based cognitive tutor system nearly doubled their knowledge growth compared to a control group without the cognitive tutor (Pane et. al., 2016). The median student's performance improved by approximately eight percentile points, nearly double the average rate (Carnegie Learning 2023 A, Carnegie Learning 2023 B).

These studies are based on AI methods informed by cognitive and learning science predating significant AI advancements like Deep Learning and GenAI Large Language Models. Recent developments in AI capabilities, especially LLMs and their hybrid use with other AI methods, are expected to lead to more documented improvements in student learning and attainment (e.g., Rashid et al 2024).

Despite the potential, there are challenges. Some public-school systems have halted their use of LLM's due to difficulties encountered (Goldstein 2024, Ovide 2024). Public school teachers in the UK have noted that although they see the potential time saving and benefits of using AI tools for providing feedback to students, they also have concerns about educators overly relying on such tools to the point of losing the ability to make accurate professional judgements, and potentially lose track of where their students are in their learning journeys. The UK teachers also noted that feedback is more than an academic exercise – it is also social and taking that task out of the hands of teachers may risk damaging the relationship between

teacher and student, which is a key predictor of students' academic development (UK Dept of Education 2024).

Over-reliance on tools like ChatGPT can be detrimental, leading to decreased creativity, critical thinking, and increased laziness and plagiarism rates (Zhang et. al. 2024), or to lessened ability to perform without the availability of the AI tool (Bastani et al. 2024). Based on interviews with a range of K-12 and college educators, the New York Times newsletter and opinion writer Jessica Gross noted "…my overall takeaway is that while there are a few real benefits to using AI in schools — it can be useful in speeding up rote tasks like adding citations to essays and doing basic coding — the drawbacks are significant. The biggest issue isn't just that students might use it to cheat — students have been trying to cheat forever…The thornier problem is that when students rely on a generative AI tool like ChatGPT to outsource brainstorming and writing, they may be losing the ability to think critically and to overcome frustration with tasks that don't come easily to them." (Grose 2024). These are examples of why approaching AI integration in education must be done with care and with a deep appreciation of the nuances.

Examples of AI tools and Education Applications

The range of AI tools available for educational settings is rapidly expanding. These tools, some specifically designed for education and others adapted from broader applications, are increasingly prevalent. Table 1 lists 26 examples, showcasing the variety of tools from numerous providers. Educators familiar with AI trends could likely identify even more examples.

Table 1 - Illustrative examples of AI tools used currently in education

#	AI Educational Tool (Website)	Key Features	Scale of Usage	Improvement Target
1	Brainly https://brainly.com/	Provides personalized assistance to help learners maintain focus on their studies.	Large scale adoption	Improve student learning.
2	Carnegie Learning CLEAR family of interactive AI tutor solutions ClearMath: https://www.carnegielearning.com/solutions/math/ ClearLiteracy: https://www.carnegielearning.com/solutions/literacy-ela/ CLEARLanguage: https://www.carnegielearning.com/solutions/world-languages/	Cognitive tutors for K-12 math, language arts and world language education based on decades of fundamental and applied research in cognitive psychology, learning science and AI.	Large scale adoption (Used by hundreds of thousands of K-12 students in public school systems in the US)	Improve student learning. Improve teacher task productivity. Validated through many rigorous empirical studies, e.g., in one large RCT trial, middle school math student users realized nearly double the gains of a typical year's worth of learning.
3	ChatGPT http://chatgpt.com	Offers conversational style interaction to assist with a variety of tasks including answering questions and providing explanations.	Widely used across various platforms	Enhance natural language understanding and generation capabilities
4	Coursera https://www.coursera.org/	Offers courses with immediate feedback on assignments for improvement.	Large scale adoption	Improve student learning
5	Codecademy https://www.codecademy.com/	Presents interactive coding challenges to develop real-world skills.	Large scale adoption (50M learners, 190+ countries, 3.7B code submits)	Improve student learning
6	DreamBox https://www.dreambox.com/	Offers personalized math lessons that adapt to the learner's abilities.	Large scale adoption	Improve student learning for math
7	Duolingo https://www.duolingo.com/	Offers language learning through adapted exercises with real-time feedback.	Large scale adoption (Tens of millions of both monthly and daily active users)	Improve student learning for languages

8	Gemini https://gemini.google.com/app	Provides personalized learning experiences using Google's advanced AI technologies	Integrated into billions of Android devices	Improve multimodal capabilities and user interaction
9	Gradescope https://www.gradescope.com/	Automates the grading process for educators.	Large scale adoption (+2600 Universities)	Improve teacher task productivity
10	Grammarly https://www.grammarly.com/	Provides real-time writing feedback and suggestions for improvement.	Large scale adoption	Improve productivity of achieving proper grammar and clear sentences for students
11	GitHub Copilot https://docs.github.com/en/copilot/about-github-copilot	A code completion tool that helps with coding in various languages.	Large scale adoption	Improve productivity of coding for professionals and students
12	GPT 4.0 Omni Tutor https://gpt40mni.com/features/high-quality-problem-solving-and-tutoring/	Capable of tutoring by observing and assisting with problem-solving in math and in other subjects	In the launch phase	Improve student learning
13	IBM Watson Tutor https://www.ibm.com/watson	Delivers personalized learning experiences based on individual interests.	Limited experimentation	Improve student learning
14	Khan Academy https://www.khanacademy.org/	Adjusts content difficulty dynamically to suit the learner's learning level.	Large scale adoption	Improve student learning
15	Kahoot! https://kahoot.com/	Engages users with adaptive feedback for an interactive learning experience.	Large scale adoption	Improve student learning
16	Microsoft Copilot (based on ChatGPT) https://copilot.microsoft.com/	Enhances user experiences and supports businesses across various devices.	Large scale adoption	Improve task productivity for professionals and and students
17	Norilla https://www.norilla.com/	Patented mixed-reality educational system bridging physical and virtual worlds to improve STEM learning	Early stage company with growing number of pilots	Improve student learning for young children learning STEM
18	Pearson AI tools for their learning and teaching resources: Study tools for MyLab and Mastering https://www.pearson.com/en-us/higher-education/products-services/aistudytool.html?start=2 Study tools for eTextbooks https://www.pearson.com/en-us/higher-education/products-services/etextaistudytool.html Essay Evaluation https://pmark.pearsoncmg.com/templates/assets/upload/IEA-FactSheet.pdf (prior version)	Instructor study tools for MyLab and Mastering support to create personalized assignments. Student tools support personalized step-by-step guidance, content summarization, and concept explanations. Essay evaluation tool to support instructor with automated or augmented essay assessment.	Study tools to be released in Fall 2024. Prior version of essay assessor (pre GenAI) already in use. Expected release of new version with GenAI.	Improve student learning. Improve teacher task productivity.
19	Perplexity https://www.perplexity.ai/	Provides accurate, trusted, and real-time answers to any question.	Widely used for information discovery and curiosity	Enhance AI's ability to provide in depth information and

				personalized search experiences.
20	Quizizz https://quizizz.com/?lng=enReinforces	Reinforces learning through personalized quizzes.	Large scale adoption (150+ countries)	Improve student learning
21	Quizlet https://quizlet.com/	Creates personalized study plans and quizzes to track learning progress.	Large scale adoption (300M learners)	Improve student learning
22	Smart Sparrow https://www.smartsparrow.com/	Provides tailored instruction to meet individual learning needs.	Large scale adoption	Improve student learning
23	Turnitin https://www.turnitin.com/	Detects plagiarism and provides detailed feedback.	Large scale adoption	Improve teacher productivity for plagiarism detection and for detection of usage of GenAI created written essays
24	Wisedom Plan https://wisdomplan.ai/	AI-powered learning platform to master skills	Earlier stage company with growing number of users	Improve planning and scheduling of learning tasks in support of improving student learning
25	Wolfram Alpha https://www.wolframalpha.com/?USA	Analyzes and interprets data across domains to provide connected knowledge.	Large scale adoption	Improve productivity of solving math problems for professionals and students and improve student learning for math
26	Zaavy (by Deel) https://www.zavvy.io/	HR talent management platform to support employee onboarding, career, skill and competency planning and development, learning management and training plans, and performance reviews	Earlier stage company with growing number of small and mid-size company users, recently acquired by a large HR services company	Reduce time required for new employees to come up to speed and productively contribute; Support continuing learning and performance improvement for existing employees.

Source: Authors'own.

Early adopters of GenAI in education have focused on enhancing learner engagement, teacher productivity, and curriculum development. The benefits of GenAI in education include improved learner engagement and three other key areas: content synthesis (virtual expert), content generation, and coding and software (Table 2). These AI systems offer personalized access to knowledge, tailored to individual learning needs and paces, potentially transforming education from traditional teacher-led methods to learner-centered paradigms.

Table 2. How Education Institutions are using Generative AI

- **Learner Engagement**: Gen AI solutions can turn tedious, manual processes into more engaging and efficient interactions. For example, MATHia gives learners a successful math experience, while getting all the real-time feedback and assessments they need to understand where they're at and where they're headed. MATHia is designed to provide individual learner support and insightful data making the process more streamlined and less onerous for both students and teachers.	- **Content Synthesis (Virtual Expert)**: Gen AI models augment teacher performance by summarizing and drawing insights from massive amounts of information—for example, querying the latest educational regulations across geographies; creating research reports, lesson plans, learner sentiment analyses, and instruction manuals; or acting as a "virtual expert." Canvas is Northeastern's learning management system and digital home base for course content, assignments, and communication. Canvas streamlines all the digital tools and content that teachers and learners love, for a simpler and more connected learning experience.	- **Content Generation**: Gen AI models can create customized content in real time for many use cases, such as personalized learning materials, based on learner profiles, history, and course details. Microsoft Copilot is an AI assistant for education, providing AI-powered chat for the web with commercial data protection at no additional cost. Copilot can save time for educators, staff, and higher education learners to focus on what matters most. Copilot uses the latest AI models like GPT-4 and DALL-E 3, and answers are based on today's information with sources for where the content is coming from. - **Coding and Software**: Gen AI code assistants are helping educational institutions address tech debt and accelerate the pace of innovation.

Source: Authors' own.

This rest of this chapter is structured as follows:

1. We begin with an overview of frameworks that define human learning. Enhancing student learning is central to educational efforts and should guide the use of AI, including GenAI, in education.

2. Next, we provide recommendations for educators in this new AI epoch, emphasizing the implications of AI tools on the learning process and teaching methods. Experimentation that supports learning-to-learn with AI is crucial.
3. We then discuss the expanding areas of learning science and education research focusing on AI, offering curated pointers to research that can guide the use of AI in education.
4. Following this, we provide curated, practitioner-oriented resources with practical examples and tools for reimagining education with AI.
5. We conclude with our views on potential future scenarios and final observations.

Our goal is to help educators move beyond a superficial approach to AI implementation. Instead of using AI just because it is popular, we advocate for a nuanced, evidence-based approach. By focusing on the nature and processes of human learning, both with and without AI, and understanding the linkages to teaching and the educational ecosystem, we can constructively reimagine education in the age of AI, leading to positive, sustainable outcomes.

Experts Interviewed

To support the preparation of this chapter we conducted in-depth interviews with four distinguished experts:

Kenneth Koedinger

- Hillman Professor of Computer Science, Human-Computer Interaction and Psychology at Carnegie Mellon University (CMU)
- Head of CMU's Human-Computer Interaction Institute and LearnLab
- Co-founder of Carnegie Learning

Marsha Lovett

- Vice Provost for Teaching and Learning Innovation, CMU
- Co-Coordinator of CMU's Simon Initiative for improving student learning outcomes
- Oversees CMU's Eberly Center for Teaching Excellence & Education Innovation
- Professor of Psychology (Teaching), CMU

Steve Ritter

- Co-Founder and Chief Scientist of Carnegie Learning

Paul LeBlanc

- Former President of Southern New Hampshire University (July 2003 – June 2024)
- Co-Founder and Board Chair of the educational consulting firm Human Systems
- Noted innovator and leader in online education, advocate for education transformation, and author of *Students First: Access, Equity, and Opportunity in Higher Education* (2021), and *Broken: How Our Social Systems are Failing Us and How We Can Fix Them* (2022).

Their insights are integrated throughout this chapter.

UNDERSTANDING HUMAN LEARNING - THE STARTING POINT FOR LEARNING WITH AI

In *How Learning Works: 8 Research-Based Principles for Smart Teaching* (Lovett et al 2023), student learning is described as a process that results in changes in knowledge, beliefs, behaviors, or attitudes due to experiences. These changes enhance the potential for improved performance and future learning. Learning must have a lasting impact on how students think and act and is an active process that students must engage in themselves; it cannot be

imposed upon them. Steve Ritter encapsulates this by stating “When students are learning something, we expect them to do it better when they do it again,” underscoring that effective learning improves student performance.

Frameworks For Understanding Student Learning

To effectively use AI in education, we need model-based frameworks that explain how learning occurs. Below are summaries of three useful frameworks from education and learning science research.

Nine stages of Learning

The first of these frameworks is shown in Table 3. Adapted from (Yanez-Moretta & Loaiza-Ramirez 2023), this framework outlines nine stages of learning. Our comments on AI’s role in each stage are included in the table to help educators think about specific ways to use AI to support student learning and gather evidence to verify its effectiveness.

Table 3 – Nine stages of student learning and how AI can be used to enhance each stage

Learning stage	Description of stage	How AI can be used to enhance this stage of learning
1. Motivation	The driving force that initiates and sustains behavior towards achieving goals.	For 1) motivation, 2) interest combined: AI can use student data and background information to contextualize content and tailor the style and mode of interaction to personalize the learning experience in ways that are motivating and that amplify interest. Data on individual preferences and performance can be used to automatically curate and/or generate content that aligns with students’ interests more effectively than traditional one-size-fits-all educational approaches enabling more personalized learning experiences at scale which were previously unattainable due to resource constraints.
2.Interest	The cognitive and emotional inclination towards a particular topic or activity.	
3. Attention	A combined cognitive and emotional process of selectively focusing on one aspect of the environment while ignoring others.	AI’s ability to monitor task performance and dynamically predict how to adjust content difficulty so that the student is neither overwhelmed nor bored can lengthen the period of sustained student attention and engagement.

4. Acquisition	The act of gaining new knowledge or skills.	For 4) acquisition, 5) understanding & internalization, 6) assimilation combined: AI-driven tools can provide rapid and targeted feedback across various types of "learning-by-doing" efforts that are progressively larger in step size and complexity across the spectrum of task exercises, practice sessions, assignment or project output creation and evaluation, and more open ended explorations. Targeted feedback within and across these various levels of learning-by-doing enable the student to make the corrections and adaptations needed to "get it right" or to "make it better," leading to deeper understanding of lower-level tasks and of higher-level complex concepts. This AI-driven targeted and personalized feedback, when applied in accordance with learning science principles, leads to improved learning and skill performance. A student can often learn a fixed amount of content in a shorter period of time or learn more in a given fixed period of time or go further over multiple time periods than what have been possible without the support of this type of interactive feedback. AI enabled rapid feedback, when applied in the context of good learning design based on sound learning science, speeds up the processes of acquisition, understanding & internalization and assimilation, and can sometimes even amplify them as well.
5. Understanding & internalization	Comprehending knowledge or skill and integrating it into one's own cognitive and performance framework.	
6. Assimilation	The incorporation of new information or practices into existing knowledge structures or performance routines.	
7. Application	Using knowledge or skills in applied contexts and practical situations.	AI can make it easier to create "interesting" virtual scenarios for practical application opportunities through simulations and projects that mimic real-world situations—providing many aspects of experiential learning that might otherwise be logistically challenging or prohibitively costly to provide for each student, especially for shorter duration assignments and projects. For situations where the students can work with external entities to do experiential learning in the context of a real domain, the AI tools provide the advantages described in the combined discussion above of 4) acquisition, 5) understanding & internalization, 6) assimilation, enabling the students to do more application iterations and explorations within a given time period (e.g. a 1 or 2 semester project).
8. Transference	The ability to apply learned knowledge or skills to minor or major variations of familiar problems or situations, or to new types of problems or situations.	AI can be used to generate scenarios and supporting learning-by-doing tasks and problems that can facilitate the transfer of knowledge and skills. This can be done to support the application of already demonstrated knowledge and skills to different domain settings or variations of domain settings, as students often encounter difficulties with this type of transition even though they have already demonstrated the knowledge or skill in a setting they already familiar with. It can also be done to support the application of extensions to already familiar knowledge and skills in the same domain or different domains, as students also often stumble with this type of transfer as well. AI can be used to help the student more systematically bridge from demonstrated knowledge and skill in an already family domain to variants and extension, either of the knowledge and skills, of the domain, or of a combination of both.

9. Evaluation	A systematic process of determining if a target or objective has been achieved. Also, a higher-level process of determining the merit, worth, and significance of something, including a target or objective, or higher-level goal.	Evaluation occurs at multiple levels and in multiple ways across a student's learning journey. For any specific setting and situation, teachers must carefully determine what aspects of individual student evaluation, class evaluation across all students and overall course evaluation can be supported by the current AI tools available to them. There are situations where AI can effectively and reliably automate the evaluation and grading of assignments and provide both real-time and summarized periodic feedback back to the student and to the teacher. Where this is possible, it enables the teacher to recoup time that would otherwise have been spent on doing the administrative work of routine grading and to reallocate that time to student engagement (e.g. to further assist students who need support for stages 1, 2, and 3 above, or to provide additional coaching for all of the other stages, 4 thru 9). The extent to which AI tools can be used for various aspects of evaluation will continue to increase, providing strong supporting benefits to both teachers and students. At the same time, the ways in which AI is used for evaluation, and the ongoing monitoring of the quality and reliability of the AI-based assessment are both areas that will require increasing amounts of human attention.

Source: Nine learning stages adapted from Yanez-Moretta & Loaiza-Ramirez (2023) with our comments on AI usage.

Principles of Learning

Table 4 summarizes six of the eight key principles of learning from "*How Learning Works"* (Lovett et al, 2023), along with our comments on how AI can align with these principles. These principles are the distillation of a huge body of cognitive science, learning science and education research, and of years of experience of coaching higher education instructors on how to address problems they encounter in delivering their courses. They help an instructor in diagnosing learning issues, designing effective content, and creating engaging learning environments.

These principles provide a sound basis for integrating AI into courses and learning experiences, offering clear guidance and goals for using AI tools effectively, such as diagnosing prior knowledge, improving knowledge organization, guiding mastery with targeted practice and feedback, and enhancing student engagement and motivation.

Table 4 –Key principles of how human learning works with implications for learning with AI

Learning Principle (from *How Learning Works*, 2nd edition)	**AI Tool Application & Implications**
Students' prior knowledge can help or hinder their learning.	**AI Diagnostic Tools & Adaptive Learning Paths**: These tools evaluate and build upon a student's existing knowledge, customizing learning to enhance understanding.
How students organize knowledge influences how they learn and apply what they know.	**Concept Mapping & Intelligent Tutoring Systems**: AI aids in structuring knowledge through visual aids and guided learning, promoting better retention and application.
Motivation determines, directs, and sustains what students do to learn.	**Gamification & Personalized Encouragement**: By making learning engaging and providing personalized support, AI tools can boost and sustain student motivation.
To develop mastery, students must acquire component skills, practice integrating them, and know when to apply them.	**Skill Acquisition Practice and Application**: AI breaks down complex tasks and provides varied contexts for practice, aiding mastery of skills.
Goal-directed practice coupled with targeted feedback enhances the quality of students' learning.	**Feedback Systems & Goal Setting**: Immediate, specific feedback and goal tracking from AI tools enhance the effectiveness of student learning.
To become self-directed learners, students must learn to monitor and adjust their learning approaches.	**Learning Analytics & Reflective Prompts**: AI provides insights into learning habits and encourages self-reflection, fostering independence in learning.

Source: Learning principles from Lovett M.C., Bridges M.W., DiPietro M., Ambrose S.A, & Norman M.K. (2023) with our comments on AI usage.

Educators who understand these key learning principles will be more effective and productive in using AI tools to support student learning and teaching. With respect to changes occurring with the use of new AI technologies, especially GenAI, Marsha Lovett, co-author of these principles states, *"I think the principles may stay the same, but they may unfold differently."*

Lovett highlights the importance of practice and feedback, noting that GenAI can create practice opportunities and provide individualized feedback, thus enhancing the learning experience:

> *"Learning occurs by doing, not just by passively listening. Practice and feedback are very important aspects of learning. It's not just the practice, but the feedback on the practice that learners get individualized to their situation. It is difficult for a teacher to scale the ability to give this type of targeted and contextualized feedback, especially with a*

heterogeneous mix of students. This is a great opportunity to think about and experiment with how generative AI tools can help create content for practice and provide feedback."

Interactive Constructive Active and Passive (ICAP) Framework

Table 5 summarizes the well-known ICAP (*Interactive, Constructive, Active*, and *Passive*) framework (Chi and Wylie 2014, Chi and Boucher 2023) for distinguishing different modes of active learning and also helps to understand the impact of AI in education. AI's contribution is limited if students remain in a passive learning mode. The ICAP definition of interactive, which requires both partners or all team members in a dialogue to be constructively generating and contributing their own new content in response to what others have put forth, over multiple iteration cycles, points to the potential for using GenAI-based AI tools as a dialogue partner, tutor and coach. GenAI by its nature is well suited to serve as one of the dialogue partners, with the caveat that all human students participating in the interactive dialogue must be making their own constructive contributions and putting in constructive and interactive effort to assess the validity of the GenAI output and to initiate revisions as needed.

Table 5- The ICAP (*Interactive*, *Constructive*, *Active*, and *Passive*) Framework to distinguish between different types of active learning with implications for learning with AI

Heuristics of Two Indices to Operationally Define the ICAP Modes

2 Heuristic Indices	ICAP Modes			
	Passive	***Active***	***Constructive***	***Interactive***
What physical behaviors are present?	Orienting or attending behaviors	Manipulating behaviors	Generating behaviors	Reciprocally co-generating behaviors
What visible outputs (if any) are produced?	No visible outputs produced	Visible outputs contain information provided in the instructional materials	Visible outputs contain information that goes beyond the existing instructional materials	Visible outputs contain information that goes beyond 1) the instructional material and 2) a partner's contributions
	Plausible cognitive or thinking processes			
	Storing new information	Activating, thereby strengthening relevant prior knowledge	Inferring new knowledge	Inferring new knowledge and building upon partner's knowledge

Implications for Use of AI for Learning and Teaching	
Caution about student overreliance on AI-generated outputs	Students should avoid simply generating and reusing AI outputs without further contribution.
Encourage students to generate beyond AI outputs	Students need to create outputs that go beyond what AI initially generates and add constructive contributions.
Teach effective use of AI as a dialogue partner	Students should learn to use AI for reciprocal co-generation of output over multiple iterations towards their goals.

Source: ICAP framework from Chi and Boucher (2023) and from Chi and Wylie (2014) with our comments on AI usage.

RECOMMENDATIONS FOR TEACHERS IN THIS EPOCH OF AI

Ken Koedinger Recommendations

- **Adopt a question-first approach***:* Koedinger advocates prioritizing learning through answering questions over traditional lectures or background reading. Questions framed in specific contexts enhance learning.

- **Utilize GenAI for Scenarios and Questions:** Teachers can use GenAI to create scenarios and to generate contextualized questions about these scenarios. GenAI is useful for designing multiple-choice questions as well as other types of questions, and for providing feedback. It can also generate variations of scenarios to reinforce learning across different contexts. Koedinger notes, "In my teaching, and my learning science research work with my group, we have seen a 3x rate of increase in our ability to generate questions for our education content, though these questions still need to be checked and refined."
- **Design Practice Task and Practice Testing with Feedback:** GenAI is beneficial for designing practice tasks and practice testing and providing feedback. Targeted practice and feedback substantially improve student performance with research studies showing a 5x or 6x learning benefit compared to only reading or listening to lectures (Koedinger et al 2015, Carvalho et al 2022). GenAI can be used to design practice and generate feedback at both lower levels of detail and at higher conceptual levels. Koedinger emphasizes that "fundamental skill building and conceptual understanding go hand in hand. The student needs both."
- **Combine Questions with Active Learning***:* Koedinger recommends using AI to support an active learning design with multiple types of practice tasks that combine responding to various types of questions, reviewing worked examples, doing explorations, conducting experiments, and taking practice tests. Student responses based on this approach may lead the instructor to reconsider the amount of background reading needed as well as where and how such readings should be integrated within the course.
- **Explore Beyond GenAI***:* "Not all important and effective uses of AI in education are GenAI based," Koedinger points to Norilla (listed in Table 1), which uses AI to create interactive experiments in mixed reality environments for STEM learning.

Steve Ritter Recommendations

- **Context matters***:* From observing over 700,000 secondary school students using the Carnegie Learning AI-based cognitive tutoring tools just in the 2023 Academic Year and nearly 5 million prior student users cumulatively, Ritter emphasizes, "Context matters! Students often struggle to apply what they learned to new contexts." He recommends using AI to help students apply their knowledge in different contexts.
- **Rewrite Problems with GenAI***:* Use GenAI to rewrite pre-existing word problems to avoid misunderstanding and create diverse, contextually rich problems. While human oversight is needed for quality control, GenAI can scale this process.
- **Provide Richer Feedback:** GenAI enables more conversational and interactive feedback, moving students from routine tasks to engaging, real-world problems. Ritter notes, "We can move students from more routine, low-level tasks to less routine, more engaging, and more real-world tasks."
- **Support Meta-Learning***:* AI can support both task-learning and meta-learning. GenAI can create "observers" and "coaches" to help students develop introspection and critique skills.

Marsha Lovett Recommendations

Redefine the Teacher's Role*:* As AI tools become more integrated into coursework, Lovett recommends that teachers focus on:

- **Set learning and performance goals:** clearly define what instruction and practice should enable students to do and ensure that AI tools support, rather than supplant, their practice and learning.
- **Guide student focus**: help students stay on track with their learning goals, especially when using AI tools.

- **Structure AI tools usage**: clarify when and how AI tools should be used.
- **Provide scaffolding and guidance**: teach students to use AI tools responsibly and productively.
- **Offer personalized feedback**: use a mix of teacher and AI-generated feedback for both formative and summative evaluations.
- **Establish quality control**: monitor and ensure the quality of AI and student-generated outputs, addressing any issues.
- **Cultivate an empirical approach**: when incorporating AI, study if/how it is enhancing students' experience or outcomes, and then adjust (or even discontinue) accordingly.

The integration of AI tools is changing the educational landscape, requiring teachers to adapt their roles and time allocation. Tasks like setting goals, guiding focus and providing feedback will become more significant as AI tools are more widely used. Lovett emphasizes the important role that the teacher plays in managing the student's cognitive load. It is not just about getting the student to do more practice, but about optimizing the student's time spent on *germane* cognitive load and minimizing time spent on *extraneous* cognitive load. Teachers should guide each student to focus on the essential parts of the learning task and avoid distractions.

Familiarity with AI tools is crucial for teachers to effectively integrate them into their teaching practices. This is Lovett's most basic recommendation, serving as the basis for her other recommendations. The rapidly growing number of consumer-based, user-friendly AI applications (as illustrated by Table 1) makes this increasingly easier for teachers. Testing assignments with AI tools to understand the responses and refine the design of the assignments with AI tools to understand the responses and refine the design of the assignment

through this feedback, is a new type of teaching habit that Lovett recommends developing (perhaps with the help of your institution's teaching support center). She also recommends that teachers embrace the perspective that "the power of these GenAI tools is in the dialogue" as understanding this point is important for guiding how teachers use these AI tools for their content planning and student guidance.

Recommendations for Using AI to Assess English Language Essays

While AI tools can assist in assessing and grading essays, a cautious approach is necessary. After evaluating the cross-sectional and longitudinal validity and reliability of four prominent LLMs (Google's PaLM 2, Anthropic's Claude 2, and OpenAI's GPT-3.5 and GPT-4), Park, Barret, and Escalante (2024) concluded: "In the near future, we expect these generative AI tools to reliably, accurately, and rapidly assess hundreds or thousands of writing samples in a short period…While optimistic about this technology, we urge caution in using current LLMs for assessing language. Prior to integrating LLMs into assessment processes, we strongly urge language educators and program administrators to conduct rigorous validity and reliability analyses to ascertain the alignment of the LLM's evaluations with those of human raters and with themselves."

These authors point out that the reasons for caution in applying LLMs for automated essay scoring at this point in time include:

- **Quirks in Assessment**: Several LLMs exhibited notable quirks when assessing student writing.
- **Non-Deterministic Nature**: The same input may not generate the same output due to randomness in sampling methods and temperature.

- **Frequent Updates**: The frequency of model updates makes it difficult to make a definitive reliability judgment.

This is why they strongly recommend that practitioners using LLMs for automated essay scoring conduct their own reliability analysis specific to their educational context. This is another example of why the use AI in education must be approach with discernment and nuance and for why rigorous evaluation is required before integration.

Summary observations on how the role of teachers will evolve in this age of AI

With increasing use of AI by students, educators and education institution, the role of teacher is evolving significantly. Teachers are becoming **Facilitators of Learning** responsible for educating learners about the value, implications and ethical considerations of AI. They are tasked with teaching students how to utilize AI as an indispensable tool in various aspects of life including work, play, learning, and communication.

Additionally, teachers are now **designers of AI-enabled learning experiences**, thoughtfully integrating AI tools into the curriculum. For instance, a professor at Cornell University's College of Human Ecology incorporated GenAI into final projects, accelerating project completion and enhancing learning outcomes (Kelly 2024). At Arizona State University, over 250 GenAI educational projects were being pursued across campus as of mid-2024 with the initial round of examples including a conversation simulator to practice patient-provider interactions, an assistant to learn a foreign language, and philosophy students role playing a famous philosopher and debating an AI-generated persona (King 2024).

Teachers also take on the role of **interpreters of AI insights**, preparing students to critique AI outputs and using AI to derive pedagogical insights from student performance data, thereby informing individualized teaching methodologies (Yim and Su, 2024; Chaudhry and Kazim, 2021). Furthermore, as **mentors and coaches**, teachers can work with

educational institutions to deploy AI for routine instructional delivery, assessment, and course administration, allowing them to spend more time providing tailored support and fostering learner motivation.

Lastly, teachers **navigate ethical considerations**, guiding students in responsible AI use, data privacy, digital citizenship, and related ethical issues. They foster discussions on the validity of AI outputs created by GenAI. To stay ahead in this evolving landscape, educators must engage in continuous professional development to remain updated with the latest AI practices and advancements, ensuring they can effectively support learning and teaching.

POINTERS TO RESEARCH FOR GUIDING THE USE OF AI IN EDUCATION

Research on designing, constructing, and using AI-based systems to enhance student learning dates back to the 1980s and early 1990s. Early pioneering efforts by teams at the intersection of cognitive psychology and AI led to the creation and testing of intelligent cognitive tutors for secondary school math students (Anderson et al 1990, Koedinger & Anderson 1993, Koedinger & Mathan 2005, Anderson et al 1995, Koedinger & Corbett 2006). Since then, extensive research has been published across various disciplines, including Education, Psychology, Educational Psychology, Cognitive Psychology, Artificial Intelligence, Human-Computer Interaction, and interdisciplinary communities focused on technology-enhanced learning. Educators using AI without awareness of this extensive body of knowledge risk redundant efforts and "rediscovering" basic principles related to supporting student learning with AI.

For those unfamiliar with existing research on AI in education, we recommend starting with the following sources:

- **The Handbook of Artificial Intelligence in Education (2023)**: Contains 27 summary articles by leading experts and 11 short essays on future directions.
- **The International Artificial Intelligence in Education (AIED) Society**: Includes the International Conference on Artificial Intelligence in Education and the Journal of Artificial Intelligence in Education.

Research communities focused on educational data mining and learning analytics also frequently publish work on AI in education:

- **The International Educational Data Mining Society**: Includes the International Conference on Educational Data Mining and the Journal of Educational Data Mining.
- **The Society for Learning Analytics Research**: Includes the International Learning Analytics Conference and the Journal of Learning Analytics.
- **The ACM Learning @ Scale Conference**.

For example, the Educational Data Mining (EDM) 2024 international conference included a tutorial on "Leveraging Large Language Models for Next-Generation Educational Technologies." The proceedings[1] featured research reports on using various LLMs for educational tasks, such as:

- Evaluating and Optimizing Educational Content with Large Language Model Judgments
- Assessing the Promise and Pitfalls of ChatGPT for Automated CS1-driven Code Generation
- GPT vs. Llama2: Which Comes Closer to Human Writing?
- Combining Dialog Acts and Skill Modeling: What Chat Interactions Enhance Learning Rates During AI-Supported Peer Tutoring?

[1] https://educationaldatamining.org/edm2024/proceedings/

- How Can I Improve? Using GPT to Highlight the Desired and Undesired Parts of Open-ended Responses

Additionally, research on reinforcement learning in education serves as a reminder that GenAI-based LLMs are not the only important aspect of AI:

- Towards Generalizable Agents in Text-Based Educational Environments: A Study of Integrating RL with LLMs
- How Much Training is Needed? Reducing Training Time using Deep Reinforcement Learning in an Intelligent Tutor

Carnegie Mellon University (CMU) has been a pioneer in AI in education since the mid-1980s, developing a large ecosystem spanning fundamental and applied research, open-source data sets and tools, and practitioner-oriented outreach programs. These efforts are summarized on the Learning Sciences and Technologies website of CMU's Human-Computer Interaction Institute. Key dissemination methods include the Masters in Educational Technology and Applied Learning Science (METALS) program and their continuing education short-course certificate programs in Learning Education.

The MIT Conference on Digital Experimentation, established in 2014, explores capabilities for rapidly deploying and iterating micro-level, in-vivo, randomized experiments in complex social and economic settings at scale. The conference sometimes includes examples from AI-based learning environments. Koedinger emphasizes the importance of educational experiments at scale for guiding effective AI use in education. MIT's RISE (Responsible AI for Social Empowerment and Education) Initiative, started in 2021, aims to prepare diverse K-12 students, an inclusive workforce, and lifelong learners for an AI-powered society. The RISE initiative also hosts an AI and Education Summit presenting leading-edge real-world examples and related research.

Research on human learning complements understanding of how to use AI effectively in education. A great starting point is the compendium, *In their own words: What scholars and teachers want you to know about why and how to apply the science of learning in your academic setting* (Overson et al., 2023). While not specifically focused on AI, it provides a foundation for targeting AI use to support learning and teaching. Useful frameworks from the learning science community include:

- **The ICAP Framework** (Chi & Boucher 2023)
- **The Knowledge-Learning-Instruction (KLI) Framework** (Koedinger et al 2012): Posits that AI acts as an "Instructional Event" sparking "Learning Events" through tailored content.
- **The Practice-Based Learning framework** (Asher et al 2024; Carvalho et al 2024 under review): Confirms the much greater power of learning by doing, that deliberate practice with immediate instructional feedback and support leads to better learning results than learning from reading or lecture.

RESOURCES FOR REIMAGINING EDUCATION WITH AI

The "Reimagine Education" International Awards & Conference

The call to "reimagine education" has been a popular refrain among education organizations and stakeholders for decades. Building on this momentum, in 2014, Professor Jerry Wind from the Wharton School teamed up with Quacquarelli Symonds (QS), a higher education consulting and ranking firm, to launch the Wharton-QS Stars "Reimagine Education"[2] awards international competition. Now known as the QS Reimagine Education Awards & Conference, this annual event has grown significantly, receiving over 1200

[2] https://www.reimagine-education.com/

submissions per year from around the globe, evaluated by a panel of over 900 international expert judges. Awards are given in 17 categories, including the Global Education Award and the Global EdTech Award.

Since its inception, the event has aimed to inspire, encourage, and honor innovative pedagogical approaches that enhance learning outcomes and employability, with a vision to equip over a billion future learners worldwide. The numerous submissions, especially the category and overall award winners demonstrate how educators and institutions globally are implementing practices to reimagine educational approaches and improve outcomes.

Table 6 lists the overall Global Education Award-winning submissions from 2018 to 2023. These projects address sustainability, character development, design challenges, employability, inclusivity, and peer learning. In the last column, we speculate on how these efforts could be further enhanced with AI to make them more personalized, adaptive, and effective. Many submissions for 2024 and beyond are expected to incorporate AI, especially GenAI. The education community should monitor the annual winners for examples of reimagining education with AI.

Table 6 – Winning projects at "Reimagining education" in the past five years – category Global Education Award[3]

Year	Winning Project in the Global Education Award	Institution Name	Project Description	Potential for AI Enhancement (Our suggestions which are not from the teams who submitted the projects)
2023	Taylor's Purpose Learning	IMPACT Labs – Taylor University	A program aligned with the UN's Sustainable Development Goals to provide purpose-driven education.	AI could enhance personalized learning paths within the labs, using predictive analytics to tailor sustainability education to individual learning styles and progress.
2022	The jubilee Centre for Character	University of Birmingham	An interdisciplinary research centre focussing on character, virtues and values in the interest of human flourishing.	AI could be used to analyze and track the development of character traits and virtues over time, providing insights into the effectiveness of different educational strategies and interventions.
2021	Design for Impact	Queensland University of Technology	A project addressing real-world design challenges, developed in collaboration with over 45 industry and community partners integrating sustainability into design education.	AI could support this initiative by providing dynamic data analysis tools to identify emerging societal trends and global issues that can be addressed through learner projects.
2020	Job Smart	University of Sydney Business School	An employability initiative offering authentic employability at scale.	AI could further develop this project by integrating advanced job market analysis to predict future skills needs and adapt the employability skill-building activities accordingly.
2019	Cybathlon	ETH Zurich	A sub-project of Cybathlon at ETH Zurich, offering teachng modules on robotics and inclusivity.	AI could potentially be used to enhance the development of assistive technologies suitable for everyday use with and for people with disabilities.
2018	Peerwise	The University of Auckland	An online platform where learners create, answer, and discuss multiple-choice questions promoting active learning, critical thinking, and peer learning.	AI could analyze the quality of learner-generated questions, provide automated feedback, and personalize question recommendations based on individual learner performance.

Source: Authors' own using information from the QS Reimagining Education Awards website.

[3] https://www.reimagine-education.com/__all_winners/

Resources For Reimagining Education With AI In Higher Education

Harvard Business Publishing (HBP) has produced a series of articles on how teachers and students are using AI, with an emphasis on GenAI, in tertiary education settings. These articles are distributed through their Inspiring Minds series, AI category (HBP 2024a) and bundled into small compendiums (HBP 2024b). These practitioner-oriented articles provide examples and lessons learned from using AI in higher education. Universities are also compiling lists of AI applications on their websites, such as the 43 examples listed by the University of San Diego[4]. Many university teaching centers provide frequently asked questions (FAQs) guidance, and supporting resources on using GenAI for teaching and learning (e.g., CMU Eberly Center staff and SMU CTE staff).

The Digital Education Council conducts a global AI survey of students "to provide insights into student perceptions of AI in higher education. (Digital Education Council 2024). The 2024 survey, based on responses from over 3800 students across 16 countries, reports that over 86% use AI tools for their work, with ChatGPT, being the most commonly used tool. The survey includes data on AI use cases, student concerns about AI, and perception of fairness in AI evaluations. This feedback provides valuable input for higher education faculty and staff on using AI for learning and teaching.

Inside Higher Ed published a white paper (Varda 2024) with examples of how some universities are using AI-based chatbots within their "student success" related support processes to help with tasks such as engaging admitted freshman in the "summer melt" period to provide support so as to minimize no-shows, responding to student financial aid enquiries, and enabling academic advisors to scale the process of sending proactive, conversational and personalized texts to students such as reminders and resource recommendations throughout

[4] https://onlinedegrees.sandiego.edu/artificial-intelligence-education/

the year and using the responses as part of a broader analytics based effort to identify potential student success barriers early on and flag them for advisers. The white paper also summarizes how University of Michigan and Arizonia State University have taken an enterprise-wide approach to supporting AI usage across staff, faculty and students.

Resources For Reimagining Education In K-12 Education

TeachAI[5] is an international consortium focused on increasing the capacity of K-12 educators to teach with and about AI. They released the AI Guidance for Schools Toolkit to help education authorities, school leaders, and teachers incorporate AI in primary and secondary education and understand potential risks (Code.org et al 2023).

The US Department of Education's Office of Educational Technology has published reports on using AI in education with an emphasis on K-12 education. The first report provides insights on using AI for learning, teaching and formative assessment (US Dept of Education 2023) and outlines 7 recommendations:

1. Emphasize Humans in the Loop
2. Align AI Models to a Shared Vision for Education
3. Design Using Modern Learning Principles
4. Prioritize Strengthening Trust
5. Inform and Involve Educators
6. Focus R&D on Addressing Context and Enhancing Trust
7. Develop Education-Specific Guidelines and Guardrails

The follow up report (US Dept of Education 2024) focuses on guidelines and practices for designing AI software systems for education, with recommendations on designing for

[5] https://www.teachai.org/

education, providing evidence for impacts, advancing equity, ensuring safety, and promoting transparency.

A recent news summary by (Chan 2024) summarizes five different AI tools gradually introduced since June 2023 that are now being used by across a growing number of primary and secondary schools in Singapore's public education system. Three of the tools are marking systems that act as a learning feedback assistant providing immediate feedback to students on math, English language, and short answer on-line quiz assignments. The fourth tool is an adaptive learning system for supporting self-paced learning for upper primary level math students and upper secondary level geography students. The fifth tool is a lesson plan authoring copilot that aids teachers with constructing the sections, activities and components of their lesson plans. These materials and examples illustrate the growing body of resources available for using AI in K-12 and higher education. We recommend exploring these sources and staying updated on new resources that meet your specific needs.

SCENARIOS FOR TRANSFORMING AND REIMAGINING EDUCATION WITH AI

We summarize four levels on a ladder of possibilities for moving forward with transforming and reimagining education with AI in Table 7.

1. **Ideal Scenario:** Educational institutions achieve high performance across learning, teaching, and administration through effective AI use. They excel in reshaping the educational journey, enhancing learner motivation, and improving knowledge acquisition and application. These organizations continue to innovate and improve through systematic experimentation and a strong ability to "learn-how-to-learn" exploring AI frontiers to increase effectiveness.

2. **Progressive organizations**. These institutions are in the early stages of transformation, developing plans, dedicating resources, and preparing teachers, administrators, and students. They actively engage in experimentation to improve and adapt step-by-step towards the ideal scenario. Teachers increasingly serve as facilitators, interpreters, mentors, and coaches.
3. **Conversative experimenters.** These organizations recognize AI's potential but are either too risk-averse or unable to coordinate the necessary socio-technical changes. They encourage faculty experimentation with AI but lack the speed, scope, and support needed for substantial changes. They are not adequately preparing for the future, risking obsolescence.
4. **At risk Organizations**. These institutions are at high risk of obsolescence, struggling for students, financing, and viability. They are in a downward spiral, unable to move forward effectively.

Existing and usually more traditional universities, colleges and continuing education providers generally fall into one of these four categories. **More recent and newly emerging providers of education who are often non-traditional are aggressively demonstrating new approaches to making use of AI in education settings**. Some of the entities listed in Table 1 such as Coursera and CodeAcademy are examples of more recent, non-traditional, alternative providers of education. We expect that AI will enable a new generation of disruptive entrants to make their way into various segments of the higher education ecosystem. As shown by the work of Professor Clayton Christensen, truly disruptive innovation (adhering to Christensen's careful definition of the process and phenomenon) almost always comes from new entrants who were not previously established leaders in a sector (e.g., Tesla in the auto industry, AirBnB in the accommodations sector, or Amazon in retail).

There are already efforts underway by people with deep experience with the massive scaling of online education and with educational transformation to create new AI enabled entities for educational delivery that will challenge more traditional existing approaches. For example, Matter and Space, a start-up co-founded by Paul LeBlanc and George Siemens is aiming to redesign the education system with a focus on the segment of people who do not have access to traditional higher education. Using AI for personalized learning, their aim is to create an experience where the platform knows the student better than anyone else and has abilities to adjust around student needs in real-time, makes them feel valued, and support them more holistically.[6] It is important to monitor how these new types of efforts evolve as they provide another window for observing alternatives for reimagining education.

Table 7 – Scenarios of AI adoption in education

Scenario	Description
Ideal Scenario	Education is fully transformed by AI, including all interactions with learners, such as offering a digital assistant, concierge, course navigator, etc.
Progressing Towards Ideal	Organizations that recognize the potential of AI in transforming all aspects of education, are developing plans, dedicating resources, and engaging in continuous experimentation in critical areas.
Conservative Experimenters	Universities where some faculty and leaders understand the transformative potential of AI in education, but due to risk-aversion, they only encourage limited experimentation without preparing for the inevitable future.
Risk of Obsolescence	Entities not even at the level of conservative experimentation are at significant risk of failure and disappearance unless they adapt promptly.

Source: Authors' own.

CONCLUDING COMMENTS

The integration of GenAI in education is paving the way for a paradigm shift, enabling personalized, interactive content for every learner. This allows learners to access content

[6] https://www.insidehighered.com/news/tech-innovation/artificial-intelligence/2024/01/04/online-pioneers-begin-urgent-pursuit-value

anytime, anywhere, in any language, and in the format that best suits their learning style. Additionally, AI facilitates scaling up experiential learning, enabling learners to apply, test and adaptively refine their knowledge in real-world scenarios.

Encouraging faculty to embrace AI involves a dual-track approach where they are supported in acquiring the necessary skills and familiarity with both the guiding principles of human-based learning science as well as with AI's capabilities. Improvements in student learning outcomes are much more likely to be realized with this dual emphasis on how students learn guiding how AI should be used to support learning. To realize these possibilities, a paradigm shift in our current educational model is necessary. This involves challenging the status quo and acknowledging AI's integral role in our future. Education must transform to leverage AI's capabilities and opportunities effectively.

Implications for All Stakeholders

All stakeholders in the education system—administrators, educators, students, policymakers, and technology providers—must actively engage in experimenting with AI-empowered education and with carefully and honestly evaluating the results of these experiments and pilot efforts. By embracing AI, stakeholders can collaboratively explore innovative teaching methods, enhance learning experiences, and address existing challenges. This collective effort will drive the evolution of educational practices, ensuring that AI integration is both effective and equitable. Encouraging a culture of experimentation and continuous improvement will help stakeholders identify best practices and scalable solutions, ultimately leading to a more dynamic and responsive education system.

Continuous refinement and adaptation are crucial in light of evolving technological advancements. Successful AI integration in education requires strategic alignment with human learning principles, proactive quality assurance, and thoughtful adaptation of

instructional roles. This is a major socio-technical transformation, with people being a large part of the puzzle.

The increasing usage of AI in education needs to be accompanied by a rethinking of traditional assessment methods based on long-standing and often standardized academic success metrics. With AI-based systems, students will increasingly be able to receive real-time high-quality feedback and formative assessment throughout the course as well as summative assessment at the end of the course by an AI tutor and evaluator that is also able to generate and evaluate richer, contextualized, and more real-world like exercises, problems and challenges. Broader aspects of this transformation include questioning what graduates need to know to be successful in the age of AI, how majors should change, and what jobs and roles we should train graduates for, considering AI's pervasive use for augmentation and automation.

An inspiring example of reimagining education comes from Singapore's Minister of Education, who emphasized the need for "Pedagogy of One" at the Redesigning Pedagogy International Conference 2024. He called for mass personalization in education, leveraging technology, data, and collective teaching experiences. Singapore's National AI Strategy 2.0 identifies AI in education as a strategic priority, committing to accelerating AI adoption across all education levels.

To move forward or enhance ongoing AI usage efforts, educators should:

- Compare their current practices with AI opportunities outlined in this chapter.
- Identify at least one area for experimentation to transform their educational paradigm.
- Utilize the recommendations, examples, and resources included in this chapter.
- If successful, consider submitting the experiment to the Reimagine Education initiative.

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