Artificial Intelligence in Education

Introduction

REL Northwest responds promptly to requests from state and local education leaders for evidence-based information on topics that address high-leverage needs in the Northwest region.

In response to a request for support on sharing the research on how Artificial Intelligence (AI) has been used in education and what considerations emerged from empirical evidence, REL Northwest drew on its expertise to gather relevant research on the topic and synthesize it in this resource sheet.

How AI has been used in education

The review of the research suggests that AI has been used in education in five broad categories:

- AI-driven instruction and tutoring
- Personalized learning
- Assessment
- Predictive and learning analytics
- Administrative and logistical tasks

A summary of how research has been used in each of these categories is included below.

AI-driven instruction and tutoring

AI-driven instruction and tutoring systems can provide real-time, automated instructions and explanations, and can be adaptive to guide individual student learning and provide immediate feedback and support.[1,2,3,4] These systems can automatically generate resources and opportunities—including math problems, writing prompts, and game-based activities—for students to practice skills. More recently, researchers and developers are building new types of large language models and generative AI-based conversational tutoring systems.[4]

AI for instruction and tutoring has been used across content areas including math, science, reading, writing and language, programming, logic, and argumentation. To date, improved student outcomes are most well documented in math, most likely because the domain is well defined. Developing AI models to support writing and language applications has tended to be more complex and has had more recent success with the advancement in large language models.[5]

Personalized learning

AI has been used to design personalized learning.[6] At the classroom level, AI can analyze aggregate student data and educational research to help create customized, modernized curriculum. At the student level, AI can analyze individual data to develop personalized learning pathways that align with students' individual pace and needs.

Assessment

AI has many applications for educational assessments.[7] AI has been used to automatically generate assessment items and adaptively assess students.[8] On the AI-generated assessments, the difficulty levels of questions are customized to the performance of individual students. AI has also offered opportunities for nontraditional assessments, such as AI-assisted peer assessment, game-based assessment, and

continuous assessment that leverages learning process data. AI has also been used to automate assessment scoring and provide immediate, formative feedback for students.[8,9] While it has historically been easier to apply AI to math, there has been an increasing amount of literature documenting the use of AI in writing and language assessments.[10,11]

Predictive and learning analytics

Predictive models can be used to estimate a student's chance of success and identify a student's strengths and weaknesses. They can help guide learning to remediate weak skills and keep students in their zone of proximal development to maximize learning outcomes. For example, AI can analyze attendance data and grade history to anticipate which students may be at risk of falling behind, or it can use aggregate student performance data to provide guidance for educators on where to focus instruction. There is also literature documenting the use of AI in learning analytics to measure and support more abstract content areas and skills, such as social–emotional learning and problem-solving.[2,12,13] AI also uses multimodal analytics to evaluate modeling of emotion, affect, eye gazing, and attention, which helps educators better understand their students' learning processes.

Administrative and logistical tasks

AI support can significantly streamline classroom functions, which can help free up educators' time and energy.[5,7] Specifically, AI can automate the assigning, grading, and scoring of assignments; schedule classes; and manage attendance. There has also been auto-analysis of classroom observation videos, which supports teacher professional development. This has been especially helpful for remote and hybrid learning contexts.

Considerations based on the research

Four considerations on leveraging AI to support education emerged from the empirical evidence in the review of research:

- Understand and address the ethical concerns associated with AI in education.
- Be prepared to continuously improve AI applications.
- Effectively prepare people to work with AI.
- Use AI as a tool, not as a substitute for humans.

Understand and address the ethical concerns associated with AI in education.

Extant research points to several ethical concerns and risks attached to using AI in education. To effectively implement AI practices, decisionmakers should be informed about these limitations and take steps to address them directly. For example, one concern is the risks surrounding data security and privacy when employing large amounts of student learning data in data mining and analytics.[14] Those who wish to implement AI in education should develop and maintain comprehensive data protection standards. Another concern is that AI algorithms can carry biases and can systematically perpetuate and worsen inequities.[15,16] Decisionmakers should be informed about how algorithmic and data biases manifest in AI systems and should take active steps to mitigate them so that AI can help advance equity in education.

Be prepared to continuously improve AI applications

Themes across literature suggest that it is helpful to view AI applications as a continuous cycle of improvement rather than a one-and-done solution.[17] Decisionmakers should be alert to new applications based on feedback and evidence and adopt applications that are suitable to their own settings and needs.

Effectively prepare people to work with AI

To ensure that AI can have the desired impact, stakeholders and users should be effectively prepared to work with AI in their educational context.[18,19] This includes providing educators and instructors with sufficient training to understand the fundamentals of AI and how to utilize AI tools competently, ensuring that the implementation is transparent to the humans involved to establish trust and psychological safety.[20] A toolkit from TeachAI offers research-based guidance to help stakeholders integrate AI into educational contexts.[21]

Use AI as a tool, not a substitute for humans

Sources in the literature indicate that AI should be used to enhance human roles in education, rather than replace them entirely. Both humans and AI have their strengths. For example, AI can scale up and automate, but humans can be social, independent, creative, and flexible.[7] There are benefits that leverage the strengths of both. Relying too much on AI-driven tools may hurt a student's social interaction skills, exploration, discovery, and strategic thinking ability. However, AI can be a helpful tool, so educators should consider teaching students' skills to leverage advanced AI tools when appropriate. For example, machine learning could leverage human guidance (e.g., reinforcement learning from human feedback). Furthermore, some sources discuss the specific advantages of human–AI collaborative approaches that cannot be achieved using AI alone.[6,22]

References

The following list of references is organized into two sections. The first section contains references that focus on practical information, including AI practices in education, studies and examples of AI in educational contexts, and research-based recommendations. The second section contains references that focus more on theoretical information including the philosophy of AI, human and AI cognition, and AI in society.

Practical information

1. **The Impact of Artificial Intelligence on Learner-Instructor Interaction in Online Learning**

   Seo, K., Tang, J., Roll, I., Fels, S., & Yoon, D. (2021). The impact of artificial intelligence on learner-instructor interaction in online learning. *International Journal of Educational Technology in Higher Education*, *18*(1), 54. https://doi.org/10.1186/s41239-021-00292-9

   This study analyzed the voices of 12 students and 11 instructors on AI in online learning. Participants envisioned AI systems having great potential to enable personalized learner–instructor interaction at scale and improving the feeling of connection. However, they also had concerns about responsibility, agency, surveillance issues, and the risk of violating social boundaries. This article is useful for those interested in maximizing the positive impact of AI systems in education while minimizing negative impact.

2. **Intelligent Tutoring Goes to School in the Big City**

   Koedinger, K., Anderson, J., Hadley, W., Mark, M., & others. (1997). Intelligent tutoring goes to school in the big city. *International Journal of Artificial Intelligence in Education*, *8*(1), 30–43. https://www.researchgate.net/publication/2834538_Intelligent_Tutoring_Goes_To_School_in_the_Big_City

   This paper presents an evaluation of the Pittsburgh Urban Math Project (PUMP) and its use of an intelligent tutor, PAT, to support grade 9 Algebra in three urban Pittsburgh schools in the 1993–1994 school year. This study found that, on average, students who used the PUMP curriculum and PAT tutor outperformed those who didn't by 15 percent on standardized tests and by 100 percent on tests targeting PUMP curriculum objectives. The paper goes on to discuss how these tutoring systems might be scaled up to work best for urban high school settings. This resource may be useful for those who want to see an example of how AI tutoring has been used to support student achievement.

3. **The Writing Pal Intelligent Tutoring System: Usability Testing and Development**

   Roscoe, R. D., Allen, L. K., Weston, J. L., Crossley, S. A., & McNamara, D. S. (2014). The Writing Pal intelligent tutoring System: Usability testing and development. *Computers and Composition*, *34*, 39–59. https://doi.org/10.1016/j.compcom.2014.09.002

   This study describes the Writing Pal (W-Pal) intelligent tutoring system, designed to improve students' writing proficiency using explicit strategy instruction, game-based practice, essay writing practice, and automated formative feedback. Researchers found that students found W-Pal informative, valuable, and enjoyable, and they identified areas for improvement. W-Pal has since been significantly updated according to these findings, and the article describes how this system could be used to supplement writing instruction. This is a strong resource for those who wish to use AI to support writing instruction.

4. **Towards the Automated Induction of Conversational Tutoring Systems**

   Schmucker, R., Xia, M., Azaria, A., & Mitchell, T. (2023*). Towards the automated induction of conversational tutoring systems.* Ruffle & Riley. https://arxiv.org/pdf/2310.01420.pdf

   Conversational tutoring systems (CTSs) offer learning experiences driven by natural language interaction. They are known to promote high levels of cognitive engagement and benefit learning outcomes, particularly in reasoning tasks. Nonetheless, the time and cost required to author CTS content is a major obstacle to widespread adoption. This resource may be useful for those who would like to learn about a novel type of CTS that leverages the recent advances in large language models.

5. **Scaling Up Intervention Studies To Investigate Real-Life Foreign Language Learning in School**

   Meurers, D., De Kuthy, K., Nuxoll, F., Rudzewitz, B., & Ziai, R. (2019). Scaling up intervention studies to investigate real-life foreign language learning in school. *Annual Review of Applied Linguistics*, *39*, 161–188. https://doi.org/10.1017/S0267190519000126

   This article discusses a study that uses technology to support large-scale interventions into regular classes. Researchers developed a web-based workbook that provides immediate scaffolded feedback on language learning exercises to replace a printed workbook used widely in German secondary schools. The first results of this ongoing, yearlong randomized study confirm that the technology's scaffolded feedback are effective, indicating that the approach is well suited to the learning in a real-context world. This resource is useful for those looking for examples of effective technology-based interventions in classroom settings.

6. **Educational Equity Through Combined Human–AI Personalization: A Propensity Matching Evaluation**

   Chine, D. R., Brentley, C., Thomas-Browne, C., Richey, J. E., Gul, A., Carvalho, P., Branstetter, L., & Koedinger, K. (2022). Educational equity through combined human-AI personalization: A propensity matching evaluation. In M. M. Rodrigo, N. Matsuda, A. Cristea, & V. Dimitrova (Eds.), *Artificial Intelligence in Education* (pp. 366–377). Springer International Publishing.

   This article presents an evaluation of "personalized learning"—a hybrid human–AI math tutoring approach that combines human mentorship and AI tutoring to personalize learning to individual students' needs. This study found that students who used this program had gains on their standardized math assessment scores that were nearly double the gains of students who did not use this program. These findings suggest that programs that combine low-cost paraprofessional mentors and computer-based tutoring have the potential to support greater educational equity. This is a great resource for those looking for examples of hybrid human–AI educational interventions, and for those interested in AI-based tutoring or instruction.

7. **Digital-First Learning and Assessment Systems for the 21st Century**

   Langenfeld, T., Burstein, J., & von Davier, A. A. (2022). Digital-first learning and assessment systems for the 21st century. *Frontiers in Education*, *7*. https://www.frontiersin.org/articles/10.3389/feduc.2022.857604

   Digital-first learning and assessment systems are delivered online, any time, and anywhere at scale, contributing to greater access and more equitable educational opportunities. This paper presents two examples—a digital-first learning tool with an embedded assessment, the Holistic Educational Resources and Assessment Science; and a digital-first assessment, the Duolingo English Test. This is a great resource for those looking for examples of AI-driven or digital learning and assessment systems.

8. **The Interactive Reading Task: Transformer-Based Automatic Item Generation**

   Attali, Y., Runge, A., LaFlair, G. T., Yancey, K., Goodwin, S., Park, Y., & von Davier, A. A. (2022). The interactive reading task: Transformer-based automatic item generation. *Frontiers in Artificial Intelligence*, *5*. https://doi.org/10.3389/frai.2022.903077

   AI has been used to automatically generate items for assessments, a process known as automatic item generation (AIG). However, the traditional approach to AIG is limited—for example, AIG applies more easily to some content areas, like math, than others. Furthermore, AIG depends on highly skilled content area experts to create each AIG model. In this paper, the authors describe the interactive reading task, a deep language modeling approach for creating reading comprehension assessments. This allows assessment creators to fully automate not only the process for creating source passages and comprehension questions but also the assessment scoring process. This paper presents the results of this approach from the practice test of the Duolingo English Test. This resource is for those who want an example of how AI has been used in writing and language assessments.

9. **Towards Reflective Writing Analytics: Rationale, Methodology and Preliminary Results**

   Buckingham Shum, S., Sándor, Á., Goldsmith, R., Bass, R., & McWilliams, M. (2017). Towards reflective writing analytics: Rationale, methodology and preliminary results. *Journal of Learning Analytics*, *4*(1), 58–84. https://doi.org/10.18608/jla.2017.41.5

   Reflective writing tasks can help learners build important qualities for lifelong learning but can also carry some challenges when it comes to formative feedback. This paper reports the progress of a writing analytics application that can provide natural language processing to give real-time, relevant feedback for students on their writing. Preliminary results are encouraging and show improvements from the first version to second version, but there are some issues that should be addressed for future improvements. This is an excellent resource for those who want to use AI and technology for writing assessment and feedback but also want to know what the drawbacks could be and how they could be improved.

10. **AcaWriter: A Learning Analytics Tool for Formative Feedback on Academic Writing**

    Knight, S., Vijay Mogarkar, R., Liu, M., Kitto, K., Sándor, Á., Lucas, C., Wight, R., Sutton, N., Ryan, P., Gibson, A., Abel, S., Shibani, A., & Buckingham Shum, S. (2020). AcaWriter: A learning analytics tool for formative feedback on academic writing. *Journal of Writing Research*, *12*(1), 141–186. https://doi.org/10.17239/jowr-2020.12.01.06

    AcaWriter is a learning analytics tool that provides feedback to support writing education at scale. This resource discusses the AcaWriter's theoretical background, technical details, and it discusses examples where AcaWriter was customized to support specific educational contexts. Finally, authors include recommendations of how to use a collaborative approach when it comes to digital and AI writing tools. This is helpful for those interested in exploring an example of an AI writing feedback tool.

11. **CoAuthor: Designing a Human–AI Collaborative Writing Dataset for Exploring Language Model Capabilities**

    Lee, M., Liang, P., & Yang, Q. (2022). CoAuthor: Designing a human-AI collaborative writing dataset for exploring language model capabilities. *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems*. https://doi.org/10.1145/3491102.3502030

    This paper discusses CoAuthor, a large dataset designed to reveal ChatGPT's capabilities in assisting creative and argumentative writing. The authors show how CoAuthor can answer questions about ChatGPT and its capabilities, and how this work might support a better discussion around the promises and pitfalls of AI that assists with writing. This is a good resource for those interested in AI in writing and writing assessment.

12. **Mapping the Landscape of Social and Emotional Learning Analytics**

    Joksimović, S., Dawson, S., Barthakur, A., Poquet, O., Wang, Y. E., Marmolejo-Ramos, F., & Siemens, G. (2022). Mapping the landscape of social and emotional learning analytics. In Y. "Elle" Wang, S. Joksimović, M. O. Z. San Pedro, J. D. Way, & J. Whitmer (Eds.), *Social and Emotional Learning and Complex Skills Assessment: An Inclusive Learning Analytics Perspective* (pp. 27–47). Springer International Publishing. https://doi.org/10.1007/978-3-031-06333-6_3

    This resource discusses how learning analytics and educational data mining might help measure social–emotional learning skills such as creativity, critical thinking, and emotional regulation. This is very helpful for people who want to envision new ways to use AI and technology to advance social–emotional learning.

13. **Artificial Intelligence, Real-Time Feedback and Workplace Learning Analytics to Support In Situ Complex Problem-Solving**

    de Laat, M., Joksimovic, S., & Ifenthaler, D. (2020). Artificial intelligence, real-time feedback and workplace learning analytics to support in situ complex problem-solving: A commentary. *The International Journal of Information and Learning Technology*. https://doi.org/10.1108/IJILT-03-2020-0026

    In this resource, authors argue that the increased digitization of work and social interaction, combined with recent research on workplace learning analytics and AI, make it possible to design automated, real-time feedback systems to support complex problem-solving at work. This resource may be helpful for those interested in developing AI-driven systems of feedback.

14. **Privacy-Driven Learning Analytics**

    Joksimović, S., Marshall, R., Rakotoarivelo, T., Ladjal, D., Zhan, C., & Pardo, A. (2022). Privacy-driven learning analytics. In E. McKay (Ed.), *Manage Your Own Learning Analytics: Implement a Rasch Modelling Approach* (pp. 1–22). Springer International Publishing. https://doi.org/10.1007/978-3-030-86316-6_1

    With the rise of data science applications in education, there is a growing need for strong data privacy solutions. Despite this need, many organizations working on education and learning analytics still depend on inconsistent, makeshift measures for data privacy. This resource explores the literature on measuring and reducing data privacy risks. This literature could help decrease risks to data privacy and improve the use of online learning data. This resource is for those who are looking to implement learning analytics while consistently and reliably protecting against data privacy risks.

15. Six Human-Centered Artificial Intelligence Grand Challenges

Ozmen Garibay, O., Winslow, B., Andolina, S., Antona, M., Bodenschatz, A., Coursaris, C., Falco, G., Fiore, S. M., Garibay, I., Grieman, K., Havens, J. C., Jirotka, M., Kacorri, H., Karwowski, W., Kider, J., Konstan, J., Koon, S., Lopez-Gonzalez, M., Maifeld-Carucci, I., … Xu, W. (2023). Six human-centered artificial intelligence grand challenges. *International Journal of Human–Computer Interaction*, *39*(3), 391–437. https://doi.org/10.1080/10447318.2022.2153320

One unintended consequence of AI is that its algorithmic decisionmaking can perpetutate existing social inequities and divisions. The authors of this paper provide six important areas of improvement in order to create ethical, fair, human-centered AI technologies. These challenges require an approach to AI that is centered in human well-being, is designed responsibly, respects privacy, follows human-centered design principles, is subject to appropriate governance and oversight, and interacts with individuals while respecting human's cognitive capacities. This is a useful resource for those interested in building ethical, equity-minded AI systems.

16. Algorithmic Bias in Education

Baker, R., & Hawn, A. (2021). Algorithmic bias in education. *International Journal of Artificial Intelligence in Education*, *32*. https://doi.org/10.1007/s40593-021-00285-9

This paper discusses algorithmic bias—systematic and repeatable errors in computer systems that lead to inequitable outcomes. The authors review the evidence and various causes of algorithmic bias in education, and they discuss which groups are known to be impacted, which parts of the system are responsible, and how to measure algorithmic bias to better understand it. The authors then offer four areas where mitigating the negative effects of algorithmic bias in education could be addressed. This is a great resource for people who want to understand how systems of inequity translate to AI and technology, and what we can do to address them.

17. Closing the Loop: Automated Data-Driven Cognitive Model Discoveries Lead to Improved Instruction and Learning Gains

Liu, R., & Koedinger, K. (2017). Closing the loop: Automated data-driven cognitive model discoveries lead to improved instruction and learning gains. *Journal of Educational Data Mining*, *9*(1), 25–41. https://doi.org/10.5281/zenodo.3554625

Educational data mining analyzes and models the enormous learning data produced by educational technology. The best evaluation of a discovery made from educational data mining is whether or not it improves student learning when applied, which is sometimes referred to as "closing the loop." This resource presents a case of closing the loop and discusses how an interpretation of brand-new data might be used to make impactful changes to classroom-deployed educational technology. This resource is useful for those interested in understanding how to build data-driven models to improve instruction and learning.

18. Empowering Learners for the Age of Artificial Intelligence

Gašević, D., Siemens, G., & Sadiq, S. (2023). Empowering learners for the age of artificial intelligence. *Computers and Education: Artificial Intelligence*, 100130. https://doi.org/10.1016/j.caeai.2023.100130

This resource is a collection of 11 papers that explores how learners can be empowered for the age of AI. These articles discuss how AI and humans coordinate, the risks and rewards of using AI in educational assessment, why understanding and navigating AI will be important future-oriented skills for humans, how to design AI-driven educational systems, predictive analytics, and different applications of AI currently in use. This resource is for those who want a comprehensive deep dive into AI's presence in education and how to prepare learners to adapt to an AI-driven world.

19. AI and Education: Guidance for Policy-Makers

Miao, F., & Holmes, W. (2021). *AI and education: Guidance for policy-makers*. United Nations Educational, Scientific and Cultural Organization. https://unesdoc.unesco.org/ark:/48223/pf0000376709

AI has the potential to address major challenges and accelerate innovation in education. However, rapid technological developments create risks and challenges that policy and regulations struggle to keep up with. This resource guides policymakers on how to balance AI's potential benefits against its risks. It provides an overview of the essential concepts of AI and provides an analysis of emerging trends. It then discusses how educators can ensure ethical, inclusive, equitable AI use; how education can prepare humans for an AI-integrated world; and how AI can enhance education. This resource is useful for those seeking to build a foundation of knowledge about AI in education or for those in need of recommendations for planning policies and programs for AI in local educational contexts.

20. The Relationship Between Trust in AI and Trustworthy Machine Learning Technologies

Toreini, E., Aitken, M., Coopamootoo, K., Elliott, K., Zelaya, C. G., & van Moorsel, A. (2020). The relationship between trust in AI and trustworthy machine learning technologies. *Proceedings of the 2020 Conference on Fairness, Accountability, and Transparency*, 272–283. https://doi.org/10.1145/3351095.3372834

This article explores the relationship between machine learning technologies in AI systems and human societal values such as trust, benevolence, and fairness. This resource is useful for those interested in building ethical AI systems.

21. AI Guidance for Schools Toolkit

AI guidance for schools toolkit. https://www.teachai.org/toolkit

This toolkit is designed to help education authorities, school leaders, and teachers create thoughtful guidance to help their communities realize the potential benefits of incorporating artificial intelligence (AI) in primary and secondary education while understanding and mitigating the potential risks.

22. A Research Agenda for Hybrid Intelligence: Augmenting Human Intellect with Collaborative, Adaptive, Responsible, and Explainable Artificial Intelligence

Hoos, H., Hung, H., Jonker, C., Monz, C., Neerincx, M., Oliehoek, F., Prakken, H., Schlobach, S., van der Gaag, L., van Harmelen, F., Welling, M. (2020). A research agenda for hybrid intelligence: Augmenting human intellect with collaborative, adaptive, responsible, and explainable artificial intelligence. *Computer*, *53*(8), 18–28. https://doi.org/10.1109/MC.2020.2996587

This article explores the potential of synergistic, collaborative teams of humans and AI in education. For example, a classroom-deployed, interactive Nao Robot could collaborate with teachers and educational therapists to design and refine personalized learning programs, monitor progress, and engage and encourage children experiencing learning difficulties. This is a great resource for those who want to learn more about the potential uses for collaborative, hybrid human–AI systems.

Theoretical information

23. Conceptualizing Hybrid Human–Machine Systems and Interaction

Buxbaum-Conradi, S., Redlich, T., & Branding, J.-H. (2016). Conceptualizing hybrid human-machine systems and interaction. *2016 49th Hawaii International Conference on System Sciences (HICSS)*, 551–559. https://doi.org/10.1109/HICSS.2016.75

This article discusses hybrid human–machine systems, exploring the history and evolution of human–AI interactions and analyzing modern day systems where humans and machines are integrated. This resource may be useful for those interested in conceptualizing or developing hybrid human–machine systems.

24. AI & Human Values: Inequalities, Biases, Fairness, Nudge, and Feedback Loops

Devillers, L., Fogelman-Soulié, F., & Baeza-Yates, R. (2021). AI & human values: Inequalities, biases, fairness, nudge, and feedback loops. *Reflections on Artificial Intelligence for Humanity*, 76-89. http://doi.org/10.1007/978-3-030-69128-8_6

This article provides an overview of key concepts and definitions relevant for the study of inequalities and AI. It then presents and discusses concrete examples of inequalities produced by AI systems, highlighting their variety and potential harmfulness. It concludes by discussing how putting human values at the core of AI requires answering many questions still open for further research.

25. Domain-General Problem Solving Skills and Education in the 21st Century

Greiff, S., Wüstenberg, S., Csapó, B., Demetriou, A., Hautamäki, J., Graesser, A. C., & Martin, R. (2014). Domain-general problem solving skills and education in the 21st century. *Educational Research Review*, *13*, 74–83.

Domain-general problem-solving is a cross-curricular skill that encompasses other skills needed to address problems in a wide range of contexts. This article argues that modern educational systems do not sufficiently foster the domain-general problem-solving skills that students in the 21st century must have. This resource may be useful for those interested in preparing students with future-oriented skills.

26. Artificial Intelligence and Communication: A Human–Machine Communication Research Agenda

Guzman, A. L., & Lewis, S. C. (2020). Artificial intelligence and communication: A Human–Machine Communication research agenda. *New Media & Society*, *22*(1), 70–86. https://doi.org/10.1177/1461444819858691

This article provides a starting point for explaining the differences between communicative AI and previous technologies. This resource may be helpful for those who want to better understand AI applications in communication and explore the philosophy of what it means to be communicating with an AI as a human.

27. A New Framework for Understanding Cognition and Affect in Writing

Hayes, J. R. (1996). A new framework for understanding cognition and affect in writing. *The Science of Writing: Theories, Methods, Individual Differences, and Applications* (pp. 1-27) https://www.researchgate.net/publication/271429714_A_new_framework_for_understanding_cognition_and_affect_in_writing

This resource presents a model that explores the cognitive aspects of writing and explores components such as the role of working memory, visual-spatial awareness, the role of motivation, and the mental processes that interpret text. This resource may be useful for those who are interested in thinking more deeply about the cognitive aspects of writing and language education.

28. State of the Art and Practice in AI in Education

Holmes, W., & Tuomi, I. (2022). State of the art and practice in AI in education. *European Journal of Education*, *57*(4), 542–570. https://doi.org/10.1111/ejed.12533

This article reviews existing systems of AI in education and explores different practices in the field. The authors also show how these AI practices have been grounded in different interpretations of what AI is or could be. This resource is for those who want an overview of AI practices in education, and the assumptions behind them.

29. The AI Index 2023 Annual Report

Maslej, N., Fattorini, L., Brynjolfsson, E., Etchemendy, J., Ligett, K., Lyons, T., Manyika, J., Ngo, H., Niebles, J. C., Parli, V., Shoham, Y., Wald, R., Clark, J., & Perrault, R. (2023). *The AI index 2023 annual report*. AI Index Steering Committee, Institute for Human-Centered AI, Stanford University. https://aiindex.stanford.edu/report/

The AI Index is an annual report that tracks, summarizes, and displays data about AI, providing background information and recommendations to help decisionmakers ethically and responsibly advance AI usage. This resource is useful for those looking for an overview of the landscape of AI in a range of fields, including K–12 education.

30. **Rethinking the Entwinement Between Artificial Intelligence and Human Learning: What Capabilities Do Learners Need for a World With AI?**

    Markauskaite, L., Marrone, R., Poquet, O., Knight, S., Martinez-Maldonado, R., Howard, S., Tondeur, J., De Laat, M., Shum, S. B., Gašević, D., & Siemens, G. (2022). Rethinking the entwinement between artificial intelligence and human learning: What capabilities do learners need for a world with AI? *Computers and Education: Artificial Intelligence*, *3*, 100056. https://ro.uow.edu.au/test2021/4204/

    What kinds of skills and capabilities do people need in a world infused with AI? This resource is a pool of ideas about how education can help people develop essential skills and capabilities needed to succeed in an AI-driven future. This resource is useful for those interested in understanding how to create learners and education systems that are adaptive to technological advancement.

31. **Partners in Cognition: Extending Human Intelligence With Intelligent Technologies**

    Salomon, G., Perkins, D. N., & Globerson, T. (1991). Partners in Cognition: Extending human intelligence with intelligent technologies. *Educational Researcher*, *20*(3), 2–9. JSTOR. https://doi.org/10.2307/1177234

    This article explores the question, "How do technologies support people's intellectual performance and enrich their minds?" The authors explain the difference between the intellectual effects that happen while interacting with technology, and the intellectual effects that continue afterward. They also explore how human-AI partnerships can leave an "educationally valued cognitive residue" and how computer tools might extend the human mind in a variety of theoretical and practical contexts.

32. **Four Responsibility Gaps With Artificial Intelligence: Why They Matter and How To Address Them**

    Santoni de Sio, F., & Mecacci, G. (2021). Four responsibility gaps with artificial intelligence: Why they matter and how to address them. *Philosophy & Technology*, *34*(4), 1057–1084. https://doi.org/10.1007/s13347-021-00450-x

    When an AI causes harm, who is responsible? This article analyzes this question of the AI "responsibility gap" in detail, exploring the different types of responsibility gaps in AI systems, and what the respective consequences could be. The paper also outlines a comprehensive strategy for building accountability into AI systems by aligning them with human reasons and capacities. This is a great resource for people interested in building ethical AI systems.

33. **Human and Artificial Cognition**

    Siemens, G., Marmolejo-Ramos, F., Gabriel, F., Medeiros, K., Marrone, R., Joksimovic, S., & de Laat, M. (2022). Human and artificial cognition. *Computers and Education: Artificial Intelligence*, *3*, 100107. https://doi.org/10.1016/j.caeai.2022.100107

    This article compares, contrasts, and connects human and AI cognition, first by evaluating how humans and AI handle different tasks and then by considering the ways in which humans and AI interact with each other as two separate cognitive systems. This resource may be helpful for those interested in the cognitive aspects of AI, and human–AI interactions.

34. Assessment in the Age of Artificial Intelligence

Swiecki, Z., Khosravi, H., Chen, G., Martinez-Maldonado, R., Lodge, J. M., Milligan, S., Selwyn, N., & Gašević, D. (2022). Assessment in the age of artificial intelligence. *Computers and Education: Artificial Intelligence, 3*, 100075. https://www.sciencedirect.com/science/article/pii/S2666920X22000303

This article concludes that traditional assessments can be onerous for educators to design and implement; they may only provide discrete snapshots of performance rather than nuanced views of learning; they may be uniform and thus unadapted to the particular knowledge skills and backgrounds of participants; they may be inauthentic, adhering to the culture of schooling rather than the cultures schooling is designed to prepare students to become members of; and they may be antiquated, assessing skills that humans routinely use machines to perform. This resources may be useful for those interested in how AI may improve assessment practices.

35. The Singularity Principles: Anticipating and Managing Cataclysmically Disruptive Technologies

Wood, D. (2022). *The Singularity principles: Anticipating and managing cataclysmically disruptive technologies*. Delta Wisdom. https://books.google.com.au/books?id=qCdNzwEACAAJ

This book defines and explores the concept of the Singularity—the emergence of a hypothetical type of AI that can perform any task a human can and that can surpass human capabilities. The author discusses how this AI may come to be and how it could transform what it means to be human. This may be a useful resource for those who wish to learn more about the philosophy of AI and its presence in human society.

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