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RESEARCH

A Multidisciplinary Research Agenda for Artificial Intelligence, Education, Learning, and Instruction

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Abstract

Artificial Intelligence (AI) is reshaping education, learning, and instruction, yet current research in this area is fragmented, often tool-specific, and dominated by short-term perspectives. This article develops a broader research agenda for AI and Education (AI&ED), bringing together Artificial Intelligence in Education (AIED) and AI literacy within an educational ecology framing. Using a collective writing methodology, an expert panel of eleven internationally recognised scholars from various disciplines within computer and learning sciences contributed ten standalone reflections on the challenges, opportunities, and transformations of AI&ED. Two additional leading scholars provided critical commentaries to strengthen the analysis. A thematic analysis of the contributions identifies five main challenges (learning and instructional practices and curricula, access and ethics, assessment and evaluation, research capacity, and stakeholder readiness), five areas of opportunity (enhanced pedagogies, innovation in design and research, support for learning processes, critical skills, and hybrid knowledge), and four transformational themes (AI technologies and the design of education, human-AI interplay, lifelong learning, and organisation of AI&ED research). The article proposes an educational ecology research agenda across macro (policy, research ecosystem, society), meso (curricula, institutions, leadership), and micro (instructors, learners, learning processes) levels. We argue for a future-oriented, critical, and inter- or multidisciplinary approach that recognises AI as a socio-technical assemblage and sustains educational values such as equity, democracy, and human dignity in postdigital societies.

Keywords Artificial Intelligence · AI in education · AI literacy · AI and education · Education · Educational technology · Generative Artificial Intelligence · Instruction · Learning · Lifelong learning · Multidisciplinary approach · Working life · Postdigital

In loving memory of Lars Svensson who passed away before this work was published.

Introduction

Researching Artificial Intelligence (AI) began in the mid-1950s, focusing on studying and replicating human problem-solving methods, in a field known as cognitive simulation (Dreyfus and Dreyfus 1986). AI has since developed, yet a common definition still describes AI as machines performing tasks that would require human intelligence if done by a person (McCarthy 1960; Minsky 1961). Today's research on AI and its intersection with educational, learning, and instructional themes has been discussed under several names such as AI literacy, AI in education (AIED), and AI and education (AI&ED). For the sake of simplicity, this article applies the concept of AI&ED to include issues related to both AIED and AI literacy.

Research agendas in the field of AI&ED (e.g. Bhullar et al. 2024; Hwang et al. 2020; Lodge et al. 2023; Mustafa et al. 2024; Peters and Tukdeo 2025; Sahar and Munawaroh 2025; Wong and Looi 2024; Woolf et al. 2013) emphasise the increasing significance of AI technologies and their impact on education, learning, and instruction, especially in higher education. Most of these agendas stress that earlier research is rather short-term, tool-specific, and limited to specific areas such as language learning. Together, they call for inter- or multidisciplinary, equitable, and future-oriented approaches for AI&ED.

With a few exceptions (see Hwang et al. 2020; Peters and Tukdeo 2025; Woolf et al. 2013), most earlier research agendas were built on extensive systematic literature reviews, or aggregated from a collection of papers in special issues. These research methodologies have their limits, so there is a need to identify current trends in AI&ED on a different basis. Based on insights from an expert panel consisting of highly ranked and experienced researchers, this paper responds to that need. The article addresses the following research questions:

> RQ1: Which challenges, opportunities, and transformations do experts identify as crucial for researching Artificial Intelligence, education, learning, and instruction?
> RQ2: According to experts, what should be included in a sustainable and broad multidisciplinary research agenda for the study of Artificial Intelligence, education, learning, and instruction?

After a brief introduction, the expert panel contributed ten standalone reflections on the challenges, opportunities, and transformations of AI&ED, followed by an analysis on an aggregated level. Two additional experts each contributed a commentary. The final section includes concluding remarks focused on the key themes and the micro, meso, and macro levels of the suggested research agenda for AI&ED, followed by three open reviews.

Critical Issues in the Research of AI, Education, Learning, and Instruction

AI technologies are claimed to support instructors in various tasks, from automating tedious administrative work to assisting in teaching and learning (e.g. Rahm 2023). However, the immaturity of both the technologies and their applications requires more research to justify such claims. Most of this research struggles to keep up with the rapid pace of technological advancements and dissemination (Holmes and Tuomi 2022; Hwang et al. 2020).

AI&ED is not discussed without critical concerns. Its development has been accused of eroding key features of education, such as human values, and weakening the links between instructors and learners as complementary agents in educational activities. AI technologies are described as limited in enabling the development of empathy, judgment, and socio-emotional support. One obvious risk is that overreliance on AI technologies may lead to a loss of essential skills in assessment, content generation, and providing learners relevant feedback (e.g. Holmes et al. 2022).

Another critique focuses on the corporatisation and commercialisation of public education (e.g. Holmes et al. 2022; Williamson et al. 2023). This trend may lead to pedagogies that teach to the algorithm instead of allowing for dialogue and inquiry learning. Moreover, commodification overemphasises the significance of measurable outputs at the expense of processes such as the development of democratic citizenship, creativity, critical thinking, and collaborative skills (see Hayes 2020).

There are further concerns around instructor accountability and responsibility in AI&ED. Who is accountable if AI generates incorrect grading decisions or does not meet the needs of learners (e.g. Kahr and Snijders 2023)? Issues related to responsibility also concern the lack of clarity in roles—between, for example, developers, instructors, leaders, policymakers, and researchers—which may lead to ethical grey zones (e.g. Holmes 2024).

Another critical issue is digital equity. This critique is linked to digitalisation in general and concerns the uneven access to AI technologies among socioeconomic groups and geographical areas (e.g. Utterberg Modén et al. 2025). It also relates to potential inequalities and inequitable implementations linked to potential biases and discrimination in AI algorithms (e.g. Fischer 2024). Surveillance is yet another common critical issue discussed by scholars (e.g. Gidiotis and Hrastinski 2024), as the application of AI technologies may include extensive data collection by monitoring instructors' and learners' behaviours, engagement, and performance.

AI&ED needs to ensure the protection of educational values such as democratic participation, equity, and human dignity. These critical issues and educational values are also linked to what Biesta (2020) refers to as the three main purposes of education: qualification, socialisation, and subjectification. These three educational purposes constitute the micro (instructors, learners, learning processes), meso (curricula, institutions, leadership), and macro (policy, research,

and society) levels, respectively (Schuelka and Engsig 2022). Current research approaches have left the field fragmented, and there is a need for research that ensures that the human aspects of education, learning, and instruction in the context of AI&ED will be sustained. This research needs to build on expertise from several disciplines, using multidisciplinary, interdisciplinary, and transdisciplinary approaches (Jandrić et al. 2023a, b).

The Collective Approach to Writing

In recent years, collective writing has emerged as a genre of academic writing (Jandrić et al. 2023c). Although collective writing may not follow academic norms, many collectively written papers are organised in much the same way as conventional papers, with distinct sections such as an introduction, methodology, results, discussion, and conclusion. However, the results section may be structured quite differently from conventional research articles. Collective writing of the results section may be cooperative, with each participating author contributing their own reflection or discussion around a theme or goal (e.g. Jandrić et al. 2023c; Zeivots et al. 2025a). Alternatively, the results may be written collaboratively, with the participating authors crafting a joint discussion around a theme or goal (e.g. Hrastinski et al. 2019; Networked Learning Editorial Collective et al. 2021). Thus, a key difference between cooperative writing and collaborative writing is the division of labour (Sundgren and Jaldemark 2020).

This study mainly applied the cooperative approach, meaning that most contributions were written separately by one (or two) authors. The remaining sections of the article were mainly written by the first author, with the introductory sections co-written with the second author. Each contribution includes a 500-word response to the following three empirical questions:

1. From your perspective and research, what challenges do you see regarding research on Artificial Intelligence in education, learning, and instruction?
2. From your perspective and research, what opportunities do you see for research on Artificial Intelligence in education, learning, and instruction?
3. From your perspective and research, how can research on Artificial Intelligence contribute to the transformation of education, learning, and instruction?

This study was inspired by the expert panel methodology (e.g. Tiberius et al. 2021). The authors' panel consists of eleven scientific experts who work at the intersection of digital technologies, education, instruction, and learning, and who are members of a European Association for Learning and Instruction Centre for Excellence in Research.[1] Two additional scholars, selected due to their strong reputation

[1] See https://www.earli.org/. Accessed 24 September 2025.

as top scholars in the field of AI&ED, were invited to comment upon the study's results.

The Expert Panel

AI, Learning Science Theory, Empirical Data, and Designing New Technologies Informed by Research (Justin Edwards and Sanna Järvelä)

Research on AI&ED faces a technical bottleneck introduced by the resource cost of conducting robust, situated, empirical studies of AI systems in classrooms. These resource costs include both time resources as well as human resources. To understand the deep and long-term impact of AI&ED, time must be spent implementing and adapting tools in authentic settings. But as technological capabilities rapidly develop, this longitudinal research must focus on the pedagogical value of new affordances brought by AI systems rather than on rapidly changing surface-level features of new technologies. Likewise, the skillset needed by a research team in this area must be multidisciplinary, with skills in human-AI interaction design and data analysis supporting a core expertise around learning science and pedagogy. This challenges research teams to collaborate and share expertise across disciplines and across institutions to efficiently combine the necessary skills to research this area.

Regulation of learning, both in terms of individual level self-regulation of learning (SRL) and group-level socially shared regulation of learning (SSRL), represents critical skills for learners to develop to thrive in the modern world (Järvelä et al. 2018). However, these processes, particularly SSRL, have traditionally been challenging to detect and support, as traces of SSRL processes occur across a variety of modalities, from dialogue to physiological signals to gestures and facial expressions (Molenaar and Järvelä 2014). Research on AI&ED offers a tremendous opportunity in supporting these processes, both in terms of multimodal data analysis of SSRL processes in naturalistic learning contexts as well as in real-time detection of these processes and supportive prompting in contexts in which AI technologies are used as an intervention (Järvelä et al. 2023a, b). Harnessing AI in these manners for empirical research in learning sciences further enables the renewal and advancement of the deep theoretical basis of the discipline.

A transformation in education, learning, and instruction research is already underway. Empirical research on AI&ED serves as a critical testbed for novel theoretical constructs in learning science research, like the trigger events concept in SSRL research, in which challenging events within the learning process invite regulatory responses from learners (Järvelä and Hadwin 2024; Järvelä et al. 2023a, b). Research centred on novel theoretical concepts like regulatory triggers has, in turn, begun to crystallise approaches for understanding learning processes, motivated by the multimodal detection affordances of AI (Lämsä et al. 2024). Likewise, the trigger concept has motivated iterative design research on emerging technologies such as AI conversational agents, enhancing the effectiveness of AI research and design within new learning contexts (Edwards et al. 2024).

This cycle of AI enabling empirical data collection, empirical data renewing theory, and theory informing the design of new AI technologies, represents a transformative cycle by which the understanding of learning as well as the technological support of learning develop symbiotically. This tight coupling of learning science theory, empirical research around AI in learning, and design science around AI for education, is crucial to ensure that research in this area is impactful and meaningful, contributing to education, learning and instruction rather than simply chasing technological trends.

AI Research and the Horizontal Transition of Expertise Using a Multidisciplinary Approach (Andreas Gegenfurtner)

Many professions—and our profession as professors is no exception—undergo recurring transformations as they face rapid and constant change. This change is often introduced by frequent technological innovations that challenge the way we as experts work in our domain (Damşa et al. 2017; Gegenfurtner et al. 2019; Lehtinen et al. 2020). From this perspective, it is interesting to ask how AI changes our work practices; how we adapt our domain-specific practices of researching, teaching, collaborating, and communicating to AI-associated shifts; and how AI challenges what constitutes 'expert performance' in our domain. If we understand expertise in our profession to be hybrid, situated at the confluence of human agency, minds, bodies, and digital technological artifacts (including, but not limited to AI), then a major question is how we, experienced professors, manage this horizontal transition of expertise as the representativeness of our domain is challenged (Gegenfurtner et al. 2024; Lehtinen et al. 2020; Säljö 2023). A related challenge is how to support our less experienced learners in their vertical transition of expertise from apprentice to master amidst dynamically changing constraints.

In research on education, learning, and instruction, AI can be both an object of and an instrument for research. First, AI can be an object of research if we study how people adapt to novel contexts. Research questions can address, for example, how instructors use GenAI tools to prepare their teaching and how learners integrate AI into their social lives. Research questions can also adopt the notion of horizontal transition of expertise (Gegenfurtner et al. 2024) to study how workers adapt their routines when AI cha(lle)nges the domain-specificity of their workplaces.

Second, AI can be an instrument for research if we use existing and yet-to-be-developed AI tools for data collection and analysis. For data collection, we can use GenAI for producing textual and pictorial stimuli, for example, when studying teachers' attitudes toward learners' diversity in implicit association tests (Just 2024). For data analysis, we can use AI in eye-tracking research to automate area-of-interest creation and complex scanpath analysis (Keskin et al. 2024; Sümer et al. 2018); we can also use AI-produced rapid feedback to inform teachers about the equity of their professional vision in the classroom and how their gaze is distributed among diverse social groups of learners (Mendez and van Es 2024; Szulewski et al. 2018).

To deeply understand the effects of AI on the transformation of education, learning and instruction, a multidisciplinary approach seems viable and promising, for

example by connecting expertise found in the computer sciences and social sciences. Multidisciplinarity is certainly not unique to studying AI: arguably, research on education, learning, and instruction has always flourished when we have considered multiple perspectives and crossed disciplinary boundaries (Lehtinen 2012; Säljö 2009). An interest in understanding how humans and machines coevolve is not new (Hutchins 1995; Suchman 2007), and we can suspect that AI will not be the last iteration. Still, research on AI may produce new theoretical frameworks and develop novel methods to study the hybrid nature of learning, and how these innovations might be used in future research.

Going Beyond the Generative AI Boom: The Transformative Potential of Research from a Lifelong Learning Perspective (Jimmy Jaldemark)

Researching AI in education, learning, and instruction brings challenges similar to those encountered in implementations of earlier digital technologies. These challenges relate to understanding how humans perceive the studied technologies (Hrastinski et al. 2019). They also relate to ethical issues and regulations regarding data collection (Cerratto Pargman et al. 2023; Lundin et al. 2023). Another challenge is the acceptance of AI technologies without a supporting organisation and proper professional development for instructors. There is also a challenge in how researchers can build on earlier studies in the educational technology (EdTech) field.

AI technologies, compared to earlier implementations, such as the recent broad implementation of videoconferencing, bring a more complex challenge to the table. The wide range of technologies in the AI field differs in complexity and usability for a learner or instructor and, therefore, in their potential impact on education, learning, and instruction. AI-based recognition algorithms in search engines and GenAI seem to be easier to apply in education, learning, and instruction than applying deep learning or learning analytics. It is also a big challenge to go beyond the GenAI boom.

History of EdTech shows that new technologies will be involved in try-outs in various educational settings with the intention of supporting education, learning, and instruction (Anderson and Garrison 1998; Jaldemark 2010). Such try-outs bring opportunities to study the implementation of AI from learners' and instructors' perspectives and embrace the design of educational settings and leadership issues. Studies need to focus on formal and informal settings and include a lifelong perspective to understand the impact of AI in various contexts and levels of educational systems (Jaldemark 2023; Jaldemark et al. 2021; Poquet and De Laat 2021). Addressing organisational issues of leadership, support, and professional development for leaders and workers may unlock the true values of AI implementation.

A much-debated potential of AI is to support personal learning pathways. These might benefit many learners and arrange and adapt learning processes to individual needs (Holmes and Littlejohn 2024; Järvelä et al. 2023a, b). Nevertheless, personal learning pathways might be a double-edged sword if they over-emphasise individual learning. Studies that build on AI-powered tools to support both personalisation and collaboration have the potential to enhance lifelong learning (Sonderegger and

Seufert 2022). Research on and supported by AI can, combined with other digital technologies, address earlier constraints of time and space. Examples include adaptive systems, automation of assessment, collaborative tools, learning analytics, personalised tutoring, and recognition.

Many Studies on AI and Education Appear to be Relatively Small and Fragmented (Maarten de Laat)

AI, similar to other digital technologies, will continue to disrupt education, and some of the more profound challenges to research will be the speed by which these changes will keep on coming. Understanding the capabilities of AI and its impact on education, learning, and instruction will put pressure on our ability to conduct high-quality research in a much shorter timeframe. Setting known challenges with research funding procedures and timeframes aside, there is an urgent need to accelerate research to keep pace with the introduction of AI&ED. The introduction of GenAI in classrooms, for example, has been largely done without well-informed research evidence; the scale of uptake is probably unprecedented, and instructors, school leaders, and policy makers are in need of guidance and transparent frameworks in order to be able to make ethical decisions about AI.

While implications of AI are largely unknown, evaluating AI capability in itself has also become challenging. Current shortcomings of AI, like the known hallucinations (or forthcoming new types) of GenAI chatbots (Alkaissi and McFarlane 2023), are likely to be reduced when the next version or update becomes available. This might mean that research should focus more on understanding the practices, contexts, and cultures in which the introduction of AI will take place. What are people's needs and expectations of AI? How will AI change the way in which human and non-human intelligence work together to solve real-world problems, create ideas, and build new knowledge? These questions have a profound impact on learning design and learner participation and will infuse the debate about education in postdigital societies. How does education prepare our citizens to participate successfully in an AI-based economy/society? This raises questions about equity and inclusivity and how AI introduces new challenges on this front, as well as its potential ability to help reduce them.

Many studies on AI&ED appear to be relatively small and fragmented. Review studies are on the rise, but it would be beneficial if there were more opportunities for coordinated larger, longitudinal studies to establish a coherent evidence base to understand and describe the processes involved when introducing AI in classroom practice. When based on Open Science principles, these studies can be made available for other researchers to work on as well, which helps to reduce fragmentation and enables them to share and interrogate findings. This approach will create scale at an accelerated pace, which is what is needed to keep up with the rapid change in the field of AI&ED.

In Australia, for example, when working with departments for education and other education systems, it becomes apparent that there is a clear need to understand what instructors and school leaders know about AI, what their needs and capabilities

are to work with AI, and how this translates to effective and equitable AI&ED processes. A federal parliamentary inquiry into the use of GenAI in the Australian education system (Standing Committee of Employment et al. 2024) recommends for research to be organised in cooperation with public and private partners, such as education systems, EdTech industries, and universities as the challenges are complex and of a national priority. A coordinated effort increases the opportunities for applied research at scale with a focus on the needs of and supports for learners, instructors, and school leaders. Such applied research must address the introduction of AI capability that is secure from a technical and data point of view, trusted by its users, and fit-for-purpose. It must be able to make valid claims about AI's impact on pedagogy and practice.

Human-Centred AI Research, Cultural Values, Future Literacy Skills, and the Overlook of Aesthetic Norms (Ylva Lindberg)

In an AI era, cultural, linguistic, and aesthetic norms and funds of knowledge are being transformed by what data is considered and how, when, and for what it is used, thus further challenging traditional literacy skills (Merchant 2021). How to approach the changing status and standards of creativity, aesthetics, and authorship in education, instruction, and learning due to AI is a central question and challenge for research in future literacy skills.

As the rapid development of GenAI technologies taps into the core of language learning and instruction, several opportunities are presented for exploring designs for collaborative writing and conceptualisations of *algorithmic authorships* (Henrickson 2021). Research on practices and skills engaged and required in knowledge production and understanding wherein AI is positioned, for example, as an actor, assistant, collaborator, evaluator or trigger, call for attention. In parallel with advancements in AI and cognition, AI&ED offers opportunities to enhance the focus on aesthetic dimensions through critical and creative means, i.e. how learning is entangled with multi-sensory experiences of abstract and material conditions (Dewey 1994).

Rapid AI developments shift the temporal focus away from pasts and presents, pushing research on education, learning, and instruction to explore anticipatory and futures-oriented methods and perspectives (Ross 2023). AI possesses tremendous power for prediction, generating alternative solutions, and ways of thinking while producing ready-made interpretations of facts, and predetermined answers (Vallor 2024). This problematic augmentation and mirroring of human intelligence is an opportunity for arts and humanities education to critically engage with AI development.

A research agenda focused on AI collaborations and co-authorships would support continuous learning and foster critical and creative practices in a society increasingly shaped by AI tools and solutions. These goals could help align educational practices with future skills and knowledge requirements (Lindberg and Haglind 2024). While adjusting instruction is important, the broader transformation of literacy must also be addressed. As different AI technologies become available to

a wider audience and are increasingly embedded in everyday life, opportunities to explore and assess these tools are accumulating.

For example, it is still an open question how AI technologies, such as GenAI, chatbots, smart cameras, automated decision-making for grading, natural language processing for translation, explainable AI, can enhance language education, and learning in the arts and humanities. Engaging with AI transformations in these subjects requires a critical view of how the availability and use of media and technology shape literacy practices and cultural expressions (Bolter and Grusin 1999). Therefore, it is paramount to include both learners and instructors in AI development to adequately address what it means to read and write in the educational settings of the future.

Renewed practices and standards for reading, writing, and knowledge creation imply that ethical and aesthetic norms explored in the humanities and the arts should be central to these AI research ambitions (Cerratto Pargman et al. 2023). This focus would ensure that AI developments support human-centred instruction and uphold cultural and linguistic values (Lindberg 2025).

Guidelines Are Not Enough in Designing and Employing AI to Education's Grand Challenges (Johan Lundin)

An overreliance on generic policies, guidelines, and metrics for the fair and safe use of AI—for example, the EU AI act (European Union 2024)—risks stifling innovation and limiting the effectiveness of applying AI technologies in education. While such frameworks are designed to uphold important values, they may only partially succeed. Poorly designed AI systems can violate these values, but even well-designed systems can lead to unintended and undesirable outcomes (Utterberg Modén et al. 2025). Ensuring that key educational and human values are consistently upheld requires active engagement from stakeholders.

Fairness and safety must be understood as dynamic concepts, situated within educational practices, and continuously shaped, interpreted, and maintained by practitioners (Lundin et al. 2023). A significant challenge is transitioning from merely automating tasks to empowering users with control and involvement not only in the design but also in the practical application of AI systems. Thus, an important research task is both investigating relevant dimensions within which users could control AI systems in practice, as well as exploring design solutions for these. Such an approach would also act as a remedy to much research on AI&ED, that often falls short in addressing the multidimensional and transformative aspects of the rapid developments in the field. It frequently lacks visionary narratives that explore what education could and should become in the face of these transformations. True transformational change will inevitably involve trade-offs, not just incremental improvements to existing practices (Fischer et al. 2020).

A more ambitious research approach should not disengage with attempts to integrate AI in more straightforward educational tasks. There are ample opportunities to explore possibilities to alleviate instructors and learners from administrative tasks and other less engaging aspects of their current practices. Such attempts could be

part of addressing pressing global educational challenges, such as the significant shortage of teachers worldwide. Multidisciplinary research, incorporating critical and design-oriented perspectives, holds the potential to imagine, test, and responsibly redesign new educational futures. The redistribution of tasks between humans and machines requires the development of new models and methods, as well as a broader discussion on responsible change. Practitioners must be actively involved in these processes to gain insights into potential futures and to ensure they have agency in guiding these changes (Lundin et al. 2023).

An intriguing avenue for future research lies in the development of methods and tools that address often-overlooked aspects of educational technology use. AI could be leveraged to enhance creativity, boost learner confidence, foster diverse interests among learners, and increase the overall sense of meaningfulness in education. By focusing on these areas, AI research could contribute significantly to the transformation of education, learning, and instruction, going beyond traditional metrics to enrich the educational experience in profound ways.

Unlocking the Transformative Potential of Generative AI: From AI Literacy to Hybrid Human-AI Co-pilots (Sabine Seufert)

From a learner perspective, there is a risk of overreliance on AI, which could undermine the development of learners' critical thinking and problem-solving skills. Ensuring that learners have the necessary competencies to use AI tools effectively (Ng et al. 2021), such as the ability to formulate theoretically sound questions and to critically evaluate AI-generated content, is crucial. Moreover, adapting university curricula to include these competencies remains a significant challenge, requiring ongoing adjustments to educational programmes (Albadarin et al. 2024; Koh and Doroudi 2023). From the perspective of instructors, a major hurdle is the rapid pace of technological change, which requires instructors to continuously update their skills, but often leaves them with insufficient time for training. This requires a shift in the understanding of the role of instructors from mere users to active designers and co-creators of technology-enhanced educational settings (Ausat et al. 2023), which requires a deep integration of technological, pedagogical, and content knowledge (Seufert et al. 2021).

In higher education, a key opportunity lies in exploring how AI can be used as a tool to enhance genre-based academic writing and research. This involves investigating how AI tools like Large Language Models (LLMs) can serve as personal tutors or research assistants, particularly in helping learners develop specific writing competencies within different academic disciplines. Research can explore the effectiveness of AI in improving the feedback process and to support learning and development effectively (Spirgi et al. 2024). Another opportunity is to explore the integration of GenAI tools into teacher training and curriculum design. Research can explore how AI can be used as a conversational agent—teacher co-pilot—to support teachers' ongoing professional development and classroom practice. To integrate AI in the classroom, research can explore different roles of AI (e.g. AI as assessor, discussant, teammate) and how to design and evaluate AI agents in the classroom. A

research topic to explore focuses then on 'Human-AI co-orchestration': how the task of managing a learning scenario can be shared across multiple agents in educational contexts, including both human and AI agents (Holstein and Olsen 2023).

In the area of assessment, AI could bring about the most profound change, from providing personalised feedback for learning purposes to carrying out summative assessment in a natural language and evidence-based manner ('assessment as learning'). However, due to the limitations of LLMs, it is necessary to adapt the systems to ensure the quality of the application. Hybrid architectures that extend LLMs and retrieval-augmented models (such as knowledge graphs to provide the logic of knowledge domains) show potential to advance conventional language models, increase their contextual understanding, incorporate private data, and reduce instances of hallucination (Xia et al. 2023). Educational researchers should be active partners in this interdisciplinary research.

AI can automate repetitive tasks such as grading and feedback, allowing instructors to focus on more complex and creative educational activities. In addition, AI can enhance instructors' ability to deliver personalised pathways to learning and engaging classroom experiences (Holstein and Olsen 2023; Seufert et al. 2021). AI can analyse vast amounts of educational data to provide insights that help instructors improve teaching strategies and educational settings. Research in this area can investigate how such AI technologies affect instructors workload and teaching quality, and how data analysis and predictive models can be used to improve decision-making in education policy and classroom management.

Hybrid Groups of Agents Forms AI&ED to be a Unique Research Field (Marcus Specht)

One of the main challenges for integrating AI, and especially GenAI, into education, learning, and instruction is finding a safe space for experimentation for instructors and learners. This challenge includes how we can enable educational organisations to experiment on what works and how. Instructors have a lot of uncertainty and hesitation about using or banning GenAI from their courses as it is unclear what the consequences may be for grading and lecturing. This leads to more banning than embracing the technology to understand the actual issues and needs.

Learners use AI continuously, which leads to serious problems and challenges for instructors and the system. For example, assessment cannot be constructed and implemented as in the past (Swiecki et al. 2022). Essay questions are very difficult to assess, and plagiarism detection does not work as before. The dependency of learners on AI technologies grows within a grading/summative assessment mindset, so they just use AI technologies to get a good grade instead of moving the bar and becoming more productive or curious. Another challenge is equal access to AI technologies and the ability to use them; AI technologies may split society into those who just consume and those who reflect and critically use them.

I think there is an urgent need for consideration of what factors must be addressed to enable instructors to embrace GenAI. The way learners interplay with GenAI components in course designs is essential for the outcomes. Similar to research on

topics such as peer review, we need to research the effects and learning outcomes of different integrations of GenAI instructional design among learners and instructors. We also need to research what kinds of learner interplay and help-seeking are actually contributing to learner motivation and knowledge gain as opposed to dependency. We need research on how to develop critical thinking and AI literacy to understand what GenAI skills people need to work with. This includes evaluating and critically using these AI technologies as well as developing their own perspective (Walter 2024).

The biggest opportunity is in an interdisciplinary research culture in the sense of transferring learning science principles into research on AI and machine learning models. A core question is if new forms of AI will lead to more equity and support human diversity or if old models of personalised education (optimising local performance) and the digital divide (Dieterle et al. 2024) will lead to more subgroups in society.

AI and the World of Work (Lars Svensson)

AI services such as ChatGPT are rapidly stirring up conditions that frame what is valid knowledge and competencies for the future. On a conceptual level, it should be noted that scholars and practitioners are vague when it comes to defining AI. Aanestad (2024) contributes to this discussion by framing AI as a Horizon Concept, i.e. it makes sense to talk about AI as something that might affect our near or far future, but when it comes to actual implementations and professional use of said services, we no longer label them as AI, but rather label them in direct relation to what services the AI actually provides.

In the world of work, some sectors are more affected than others (Grüning et al. 2023; Lebovitz et al. 2022; Raftopoulos and Hamari 2023). For instance, in the IT-sector many software developers are relying on GenAI to solve wicked code problems. In a small-scale case study of full-stack developers (Gutmanowitz and Westlund 2024), it was found that the amount of prior professional experience affects the ability to use GenAI in a productive way, and that experience also helps in the art of phrasing 'prompts' for AI tools. However, the art of skilful prompting and re-prompting (Anichini et al. 2024) requires a nose for detecting hallucinating responses and avoiding the bias of re-prompting AI, and by this deliver pre-conceived solutions that reduce the potential of AI services' provision of radical and expansive learning opportunities that enable lifelong learning (Engeström and Sannino 2010).

In (higher) education, the conditions for preparing students for work-life are at a conundrum (Neumann et al. 2023). Should students learn to master GenAI services through skills of prompting and the ability to detect when AI is hallucinating, or should traditional methods of instruction, supervision, and assessment be protected through regulation and strict control (Chiu 2024)? At present, many experiments with instructional design, syllabus, and curriculum are conducted—some promising, others less so. AI is creating new distances between intended, enacted, and experienced curricula (Billett 2015).

Research on the impact of AI can contribute to the transformation of education, learning, and instruction in several ways. Firstly, it will help us identify the meta-skills needed for competent acting in a future world of work and secondly, it can provide a critical lens for analysing how higher education can be designed to address the delicate interplay between professional demands, technological development, and the values of becoming an academic scholar.

AI and the Hybridity of the Human Mind and Know-How (Roger Säljö)

Since the days of the ancient Greeks, and reinforced by Cartesian dualism, human knowledge has been seen primarily as a property of the mind of the individual, i.e. knowledge has been seen as localised in the brain/mind. This conception underpins much of contemporary research on learning and human know-how, for instance in the neurosciences where knowing is often reduced to brain functions. In an alternative perspective, human know-how lies at the intersection between the mind, evolving socio-material resources, and our capacity to collaborate (Laland 2017).

As humans, we have an incredible, and almost unique, talent for externalising our experiences and insights, and for transforming them into artifacts that help us remember (texts, search engines), organise information (tables, diagrams), move around in space (maps, navigators), and think and solve problems in all walks of life. In almost every human activity, there is a cultural invention involved at some stage. Thus, our minds are better conceived as hybrids (Donald 2010) or as extended minds (Clark and Chalmers 1998); knowing is a matter of being able to use the cultural tools—intellectual as well as physical—of our society that have evolved over time and that are part of a rapidly expanding cultural memory. Since the emergence of *Homo Sapiens* (and in fact even earlier), we are apprenticed to evolutionary processes that are cultural in nature (Sterelny 2012).

In this perspective, what we now call AI, brought into the public eye through ChatGPT in 2022, is another example of our capacity for externalising, and repurposing information. It is obvious that AI of this kind has implications for education, learning, and instruction as we have practised these activities so far. Chat robots of this kind can scan vast amounts of data to produce answers and essays that, at least in standardised situations, make sense (Choi et al. 2022; Herbold et al. 2023).

Several interesting questions emerge from this development if we acknowledge the hybrid nature of human knowing. One interesting feature of tools of this kind is how we can develop tests of knowledge and skills that are relevant in an era where people increasingly rely on resources of this kind. We are no longer able to show what we know, if we do not have access to such infrastructures of know-how (and this has been the case for some time through the role played by the Internet as a cultural memory and as a shared resource for finding solutions to problems). A second issue along the same lines is recognising learning as innovation and problem-solving, and not just as a matter of repetition. Central to both the challenges and the opportunities of AI is the very interesting issue of the design of *feedback* to learners.

Table 1 Key challenges for researching AI and Education

Themes	Identified challenges
1. Learning and instructional practices and curriculum	Overreliance on AI may hinder critical thinking Rapid technological change requires continuous professional development Need to adapt curricula for AI integration
2. Access and ethical issues	Unequal access to AI tools and infrastructure Need for fair and regulated data collection and usage Ensuring responsible AI deployment
3. Assessment and evaluation of learning	Traditional assessments may no longer be adequate Need for new assessment methods aligned with AI capabilities
4. AI capabilities, research, and resource constraints	Shortage of robust empirical studies High cost of research implementation Risk of conceptual fragmentation and lack of clarity
5. Readiness of instructors, leaders, and learners	Hesitancy and uncertainty about AI among educational leaders and instructors Lack of safe environments for experimentation Need for professional development and leadership training

Analysis

The analysis of the ten contributions was performed by the first author and was inspired by the six steps in thematic analysis (Braun and Clarke 2006). In the first step, familiarisation with the data, the ten contributions were read through in order to learn the content of the contributions. The second step included highlighting phrases in the contributions and allocating them a code. The third step aggregated the codes to overarching themes. In the fourth step, themes were reviewed and compared to the ten contributions to make sure that themes represent the data. The fifth step defined and named the themes. This was followed by the writing up. In this final step, the results were ordered according to the article's research questions.

The contributions identified 14 challenges aggregated into five themes (see Table 1) that should be addressed in a research agenda for AI&ED.

The contributions identified 16 opportunities aggregated into five themes (see Table 2) that a research agenda for AI&ED should address.

A research agenda for AI&ED may focus on 18 transformational ideas around four themes (see Table 3).

The synthesis of the three analytical layers—challenges, opportunities, and transformational ideas—reveals both the complexity and the transformative potential of AI&ED. Across Tables 1, 2, and 3, there is a clear tension between uncertainty and innovation: while Table 1 highlights systemic challenges such as inequitable access, limited readiness, and conceptual fragmentation, Table 2 and Table 3 demonstrate how these same issues become springboards for reimagining education, learning, and instruction. For instance, the challenge of rapid technological change directly aligns with opportunities in innovation in design and research and with

Table 2 Key opportunities for researching AI and Education

Themes	Identified opportunities
1. Enhanced pedagogies and educational design	Apply AI to improve academic writing and inter- and multidisciplinary research Use GenAI as conversational agents to support instruction and learning Link AI with leadership and curriculum design
2. Innovation in design and research	Conduct ambitious design-driven research Transform educational culture through AI Explore AI in collaborative writing and algorithmic authorship Embrace future-oriented methodologies
3. Support for learning processes	Support regulation of learning through multi-modal analytics Enable real-time learning detection Improve feedback processes with AI
4. Development of critical skills	Foster AI literacy and critical thinking Prepare learners for AI-integrated work-life contexts Support both learners and instructors in critical skill development
5. Hybrid knowledge and innovation	Recognise hybrid human-AI knowledge structures Use AI for externalising and repurposing knowledge Treat learning as innovation and problem-solving

transformational ideas under AI technologies and the design of education, learning, and instruction. This indicates a dialectical relationship in which challenges and opportunities are co-constitutive rather than oppositional—a pattern that resonates with earlier findings in the literature suggesting that educational transformations driven by AI emerge precisely from navigating tensions between control and openness (e.g. Holmes et al. 2022).

The thematic interplay also underscores a shift in the epistemic orientation of educational research. As identified in the literature review (e.g. Bhullar et al. 2024; Lodge et al. 2023), AI&ED research must move beyond technological determinism toward a human-centred and pedagogically grounded understanding. The data from the ten contributions extend this argument by articulating how empirical and conceptual work can be integrated across design, ethics, and professional development. For example, the theme 'interplay between humans and AI technologies' captures a movement toward hybrid epistemologies that blend human and machine intelligence—echoing theoretical calls for human-AI partnerships in education (e.g. Hwang et al. 2020; Peters and Tukdeo 2025). Similarly, the theme 'organisation and conduct of AI&ED research' links directly to critiques in the literature about the field's fragmentation and the need for large-scale, interdisciplinary collaboration to establish robust evidence bases (e.g. Jandrić et al. 2023a, b).

Taken together, the results contribute to an emerging research agenda that positions AI not as an external disruptor but as a catalyst for rethinking educational purpose and design. By connecting the practical challenges of readiness, access, and assessment with opportunities for innovation, critical skill

Table 3 Key transformational ideas for researching AI in Education

Theme	Transformational ideas
1. AI technologies and the design of education, learning and instruction	Promote inclusive, equitable, and accessible AI-enhanced learning Develop creative and meaningful instructional designs Address diverse learner needs and close educational gaps Redefine success beyond academic performance, fostering motivation and learner engagement
2. Interplay between humans and AI technologies	Advanced hybrid models of human and AI knowledge interplay Shift from rote learning to critical thinking and creativity Embrace human-centred, culturally sensitive AI systems Emphasise the aesthetic, social, and cultural alignment of AI with education Promote AI literacy to empower instructors and learners for effective AI use and co-creation
3. A lifelong learning perspective on AI&ED	Align education with AI-impregnated work-life realities Develop future-ready curricula for employability Enable personalised learning pathways while maintaining collaboration and organisational alignment Promote lifelong relevance of education by tailoring it across stages and professional contexts
4. Organisation and conduct of AI&ED research	Foster empirical-theoretical integration for AI research Apply inter- and multidisciplinary approaches bridging technology and education Coordinate large-scale and longitudinal studies Develop data-driven, adaptive, and human-centred AI applications Generate evidence-based resources to inform policy and leadership for scalable AI implementation in education

development, and hybrid knowledge creation, the findings suggest a future-oriented vision of AI&ED that aligns with a lifelong learning paradigm. This perspective aligns with the broader literature's call for sustainable, equitable, and participatory AI development in education, learning, and instruction (e.g. Holmes et al. 2022; Utterberg Modén et al. 2025; Zeivots et al. 2025a). The three layers of analysis—challenges, opportunities, and transformational ideas—illustrate how AI can simultaneously unsettle and strengthen the foundations of educational research and practice, providing both the conceptual scaffolding and the empirical grounding for a renewed agenda in the field.

External Commentaries

The Vulnerable Interplay Between Humans and AI Technologies: A Research Perspective on AI and Education (Allison Littlejohn)

The contributions to this article underscore the complexity of integrating AI within education, learning, and instruction. AI is transforming ways of knowing across different areas of society, stimulating opportunities, while at the same time bringing about challenges. Each contribution highlights a set of diverse themes that need to be brought together to create the kind of infrastructure needed to overcome these challenges. The integration of AI in different areas of society engenders a range of vulnerabilities experienced by humans (Durán del Fierro et al. 2024). Some of these vulnerabilities are evident in the commentaries and analysis.

For example, the commentary by Gegenfurtner explains the reflexivity between the use of AI in academic work and the impact on 'expert performance'. The technology changes the ways humans—in this case academics—work. These changes are mediated by the culture, values, identities, and knowledge of each professional (Eteläpelto et al. 2013), triggering emotional as well as cognitive and behavioural reactions, engendering agentic responses. These responses will reflect the vulnerabilities professionals feel as well as the opportunities perceived. Yet there is a tendency to privilege AI by focusing on the opportunities afforded by these technologies and the ways these shape society, overlooking affective responses from professionals. To understand and minimise human vulnerabilities, we need to consider changes starting from a human perspective.

Säljö emphasises the hybrid nature of knowing and the importance of social interplay as a fundamental way humans build knowledge. Systems built around LLMs have been purposefully designed to behave in a humanoid way: robots, chatbots, or ChatGPT interfaces are designed to give learners the appearance that they interplay with another human (Gourlay 2024). These systems are designed to mirror human conversations by asking and answering questions. Answers are presented in such a way that users may feel that reasoning processes, similar to human reasoning, are taking place. In reality, rather than engaging in social and hybrid forms of knowing, humans may simply be sourcing information through a sophisticated interface. This makes humans vulnerable to believing that they are actively building knowledge through their interplay with the system, when, in fact, they may simply be accessing information that has been reproduced from the cloud.

To reduce this vulnerability, humans should be able to navigate new forms of human–computer interplay in ways that allow them to differentiate between interplay with an AI system and interplay with other humans. Seufert suggests that if human learners are AI literate they will understand these boundaries and limitations of using AI to support human knowledge development. New literacies are needed not only to understand how to interface and use AI systems but also to appreciate the consequences and outcomes. Without these literacies humans will remain vulnerable in terms of not being able to actively develop knowledge.

Learners' overreliance on AI was identified as a challenge that impacts their ability to develop forms of critical thinking. Fostering an understanding that interplay with AI cannot replace interplay with other humans is a critical part of reducing this vulnerability. As Lundin points out, guidelines are not a sufficient way to make sure learners can use AI in ways that help them think critically and build knowledge. Edwards and Järvelä comment on how learners can be supported to regulate their learning through individual (self-regulation) and social interplay (social-regulation). As they do so, they receive responses from digital technology systems and from other humans (e.g. instructors or learners). Edwards and Järvelä emphasise the importance of capturing and analysing all kinds of social interplay in ways that not only support learners to build knowledge, but also enable them to (at a meta-level) question new forms of human–computer interplay and use this meta-level knowledge to navigate interplay within human-AI systems. By continually nurturing these forms of social and self-regulation, learners can overcome potential vulnerabilities that would reduce their capacity to build knowledge.

Human vulnerabilities are difficult to identify for a number of reasons related to the diversity of humans, the context in which they operate, and the technologies themselves. Lundin highlights that AI is a collection of diverse and varied digital tools, rather than a single technology. Jaldemark notes the varied contexts, ranging from formal education to non-formal learning, and de Laat emphasises that all these variations make it difficult to evidence the effectiveness of AI&ED. Perhaps a way forward is to start by focusing on the impact on human learners and use this evidence to then consider how to adapt AI, rather than designing AI for humans to adapt to.

The human vulnerabilities highlighted in this article cannot be reduced through 'effective AI-driven education, learning and instruction'. The examples point toward forms of 'effective human-driven education, learning and instruction, supported by AI'. Inter- and multidisciplinary, scientific collaboration that brings together education, learning and instruction, computer science, and informatics is an essential part of addressing some of the world's most pressing social issues. It is critical to address the challenges of AI&ED by identifying human vulnerabilities and finding ways to reduce these issues.

A Critical Studies Perspective on Researching AI and Education (Wayne Holmes)

Following the public unveiling of ChatGPT, and the myriad other GenAI chatbots and applications that have since followed, rarely a day goes by without some unsubstantiated and hyperbolic claim about AI's capabilities or putative benefits appearing in the media. This is especially true for AI and education. Words such as transformational, augmented, personalisation, and time-saving, pepper today's educational narratives—often being promoted by BigTech, by some governments and international agencies, and all too often by some academics.

For example, OpenAI (the developers of ChatGPT) write: 'ChatGPT can help with various tasks across campus, such as providing personalized tutoring for

students and assisting faculty with grading and feedback'.[2] Similarly, the OECD writes: 'As AI rapidly advances, it's becoming evident that it is starting to outpace humans in critical areas such as reading, mathematics and scientific reasoning'.[3] And Google writes: 'Educators, students, and staff can use Gemini to kickstart lesson planning, brainstorm and research new ideas, and learn with confidence'.[4]

However, as noted by many contributors to this article, the evidence for most such claims is weak. The claims are anecdotal (i.e. very small scale), speculative (e.g. 'AI technologies could…'), or based on questionable assumptions (e.g. that education is all about individual learning and that 'personalised learning' is worth having; for a discussion see Säljö). In fact, despite their framing, such claims usually have more to do with marketing and commerce than with robust academic research—which is why this article, and the research it heralds, is extremely welcome.

However, building on the contributions in this article, I would contend that, for the proposed research agenda to be both successful and useful, many of its assumptions need to be re-examined. For example, it is important to recognise that AI is not simply 'another' digital technology. Instead, AI systems are the first and only technologies to successfully mimic human behaviours, communications, and decision-making processes. AI systems are being sold to us as, appear as, and are perceived as being human-like, often leading to the misperception that they operate with human-like intentions or understanding.

AI is also not simply a set of technologies, but rather a socio-technical assemblage (Holton and Boyd 2021). In other words, what we call AI is a complex system that integrates both technical and social components—with the social components including the people who design, use, and are affected by AI, as well as the organisational, political, and economic structures, and the societal and ethical norms that shape its development, deployment and impact (Eynon and Young 2021).

Next, the application of AI in education (AIED) has been researched for at least 50 years (Holmes et al. 2019). Long before the arrival of GenAI, there were already more than fifty multimillion-dollar-funded AIED companies selling their software into education systems around the world. For this alone, as Jaldemark explains, it is important not to conflate GenAI with AI, or the impact of GenAI on education with the impact of AI on education (especially given that AIED applications are mainly knowledge-based rather than data-based) (Holmes and Tuomi 2022). GenAI-enabled AIED does have important consequences for education, but we should not forget the more than 20 other types of AIED (Holmes 2023).

In addition, the language that we use is important. As I have written before, by uncritically anthropomorphising AI with words such as 'intelligence', 'learning', and 'hallucinations' (e.g. Svensson), 'we can all too easily [allocate to AI technologies] capabilities that they do not actually have' (Holmes 2024: 9). Instead of 'intelligence', we would be better off talking about its predictive capabilities (even 'generative' AI works by predicting); instead of learning, 'adaptation' (no machines learn

[2] See https://openai.com/chatgpt/education. Accessed 24 September 2025.
[3] See https://www.oecd.org/en/publications/pisa-2022-results-volume-i_53f23881-en.html. Accessed 24 September 2025.
[4] See https://edu.google.com/intl/ALL_uk/ai/gemini-for-education. Accessed 24 September 2025.

as humans do); and instead of 'hallucinations' (which require a consciousness), my favoured term is 'bullshit' (while many claim that AI systems are continuing to improve, so that they will produce far less bullshit in future, others contend that they are beginning to hit a ceiling) (Marcus 2022). It is true that, initially, anthropomorphisms can be helpful, because they build on familiar concepts and make things more understandable. However, they can quickly lead to the dangerous assumption that the interplay between technology and humans is symmetric. For related reasons, I also argue that Artificial Intelligence should always be capitalised, 'to highlight that it is a specific field of inquiry and development, and not simply a type of intelligence that is artificial' (Holmes and Tuomi 2022: 2).

We also must recognise that, despite the innumerable claims (such as AI will 'personalise learning' and 'save teachers work') first made, but never evidenced, by B. F. Skinner (see Watters 2023), we actually have no robust independent evidence at scale for the effectiveness, or safety, or positive impact of AI systems in education (see Edwards and Järvelä). Consequently, it is not clear why 'there is an urgent need for technology acceptance' (Specht). Instead, I would contend that we should be clear about when AI should not be used, as much as when it might be, and we should reject the standard but unevidenced claim that AI is inevitable and worth having—partly because, as de Laat points out, AI&ED research is typically small and fragmented.

We do not even have an agreement about what constitutes 'good' evidence. There is, on the other hand, growing evidence of some harms: 'when access [to GenAI] is subsequently taken away, students actually perform worse than those who never had access' (Bastani et al. 2024). This is why it is worrying that AI systems are being deployed in educational settings worldwide without the effectiveness and safety evidence that is basic in medicine, and with very little research into the unintended consequences, and why we need, as Gegenfurtner points out, multidisciplinary approaches.

It is also important to be clear about what we mean by education. In fact, despite its name, AI&ED has always focused not on education but on attempting to automate Bloom's '2 Sigma Effect' (the now disputed claim that individual tuition can achieve 2 standard deviations higher learning outcomes than group tuition) (von Hippel 2024). However, education is about far more than learning (getting stuff into young people's heads, or self-regulated learning or lifelong learning), or far more than what the education philosopher Biesta (2011) calls the 'qualification function'. The other two key functions of education are socialisation, which 'has to do with the many ways in which, through education, we become part of particular social, cultural and political "orders"' (Biesta 2011: 20), and subjectification, the process 'that allow[s] those educated to become more autonomous and independent in their thinking and acting' (Biesta 2011: 21). These two latter functions have received little if any attention from AI&ED researchers.

In fact, AI&ED is only part of the story (Holmes et al. 2022). In my view, and at least partly shared by Seufert, we also need to take responsibility for developing young people's critical AI literacy (education *about* AI). To that end, we need to help instructors develop critical AI literacy too (the umbrella term AI&ED references both AIED and AI literacy) (Holmes et al. 2022). For more than a decade,

there has been a wide range of online courses that set out to teach AI, many developed by BigTech, others developed independently (e.g. 'Elements of AI'[5]). However, such courses usually address AI solely as a technology, rather than the socio-technical assemblage. Accordingly, they focus almost exclusively on the 'technological dimension' of AI (its algorithms, data and statistics) (Council of Europe 2025).

More recently, since the public debut of GenAI, a huge number of websites and courses have appeared dedicated to instruction and learning how to use GenAI (the 'practical dimension' of AI), focused mainly on the writing of prompts. However, there remain few courses that properly address the 'human dimension' of AI (when, in my view, being AI literate means being literate mainly, but not exclusively, in the human dimension of AI). Topics include the impact of AI on human well-being, gender, dignity, inclusion, trust, education, culture (see Lindberg), and the digital divide; the implications of AI for human agency, autonomy, privacy, equity, diversity, and discrimination; 'fake' news, the history of AI (including the role of the military), the ghost workers of AI, surveillance, election interference, and the impact on jobs; the implications for sustainable development and the impact on both the environment and the climate; and the broader implications of AI for human rights, social justice, democracy and the rule of law.

Finally, it's important to recognise, as mentioned by Lundin, that we need more than ethical guidelines for the effective and safe use of AI in educational settings (Holmes and Porayska-Pomsta 2023). We need appropriate regulation. As the Council of Europe explains:

> Just as drugs and medical treatments are mostly designed to impact on the human body, so AI-enabled education technologies are designed to impact on the human mind and especially on a child's developing cognition ... Before being available for use, medicines undergo a rigorous stepped safety trial process, which evaluates both efficacy and safety. Inevitably, that process is not perfect ... However … for AI-enabled education technologies, almost no such testing takes place, which means that teachers must rely on anecdotal evidence or marketing claims. (Havinga et al. 2024: 7)

I very much welcome the proposed research agenda. This kind of inter- or multidisciplinary research, grounded in such diversity of expertise, is essential for multiple reasons: to determine what evidence we need and how to go about getting that evidence and using it effectively; to contribute to robust regulations that ensure young people are protected whenever they use AI systems, and that they remain in control of their education and their whole lives; and to help ensure that all members of society (beginning with instructors and learners) become critically AI literate (especially in the human dimension of AI), so that they can make properly informed choices about whether, when, and how to use AI systems (Holmes et al. 2025). And, as a first step toward all that, we need to begin by using language carefully, by avoiding the unevidenced speculative claims, and challenging the hype.

[5] See https://www.elementsofai.com. Accessed 24 September 2025.

Conclusion

A research agenda for AI&ED needs to take a holistic perspective (e.g. Wong and Looi 2024) and a multifaceted educational ecology approach. Such an agenda should investigate how AI suits the purposes of education, learning, and instruction. At the same time, it should critically study the ethical and societal aspects that may lead to mismatches and concerns. In terms of Littlejohn's commentary, AI&ED research should position humans at the centre and reflect on vulnerable aspects of the interplay between humans and AI technologies. This notion is also echoed in earlier studies (e.g. Gidiotis and Hrastinski 2024; Holmes et al. 2022; Kahr and Snijders 2023) that alert learners and instructors to the potential risks of being overly reliant on AI technologies.

As Holmes mentions in his commentary, the research agenda should include a critical perspective to avoid reproducing speculative claims and inform both practice and future research. Holmes echoes resistance to commercialisation, commodification, and corporatisation of education (e.g. Fischer 2024; Hayes 2020; Williamson et al. 2023) and its emphasis on measurement. To ensure criticality, the research agenda may embrace the ecological complexity of micro, meso, and macro levels and the educational purposes of qualification, socialisation, and subjectification (Biesta 2020; Gibson et al. 2023; Schuelka and Engsig 2022). This includes that research should not assume that AI&ED is inherently good.

Many earlier agendas underline the dominance of cognitive sciences and computer sciences (e.g. Lodge et al. 2023; Wong and Looi 2024). This conclusion is also shared by Holmes et al. (2025), who emphasise the need for AI&ED research to align AI systems with the complexity of education, learning, and instruction. This study confirms these views by demonstrating and suggesting that the research field may benefit from adopting an approach that integrates theories and research methods from multiple disciplines, in addition to cognitive sciences and computer sciences. Moreover, such an approach may lead to the development of new and innovative research methods by fostering disciplinary collaboration. A multidisciplinary agenda should contribute to developing relevant frameworks, models, and theories for AI&ED that impact educational practices and inform educational leaders, instructors, and learners on the benefits and pitfalls of the application of AI technologies.

Many of the recently suggested agendas have a narrow perspective, focusing on a single AI application and/or a particular level of the educational system (e.g. Bhullar et al. 2024; Lo et al. 2024; Lodge et al. 2023; Sahar and Munawaroh 2025). However, such narrow perspectives are too limited (Mustafa et al. 2024). This study takes a broader approach that aligns with the grand challenges outlined by Woolf et al. (2013) and the Global South perspective presented by Peters and Tukdeo (2025). Suggested research agenda for AI&ED encompasses all educational levels and extends beyond formal education by adopting a lifelong and lifewide perspective, including learners, instructors, and leaders who govern educational systems.

Considering both formal and informal learning may contribute to a deeper understanding of the intersection of AI, education, learning, and instruction. Such a hybrid agenda needs to emphasise cultural, ecological, historical, and social

aspects to develop deeper insights into how contextual conditions in educational settings impact the use of AI technologies. This includes the impact that AI technologies have on learning and the performance of instruction and leadership in formal educational systems (e.g. Hwang et al. 2020; Peters and Tukdeo 2025; Sahar and Munawaroh 2025) as well as workplace learning in its many shapes and forms (see Jaldemark 2023; Jaldemark et al. 2024).

As suggested by Woolf et al. (2013) and Hwang et al. (2020), among others, the research agenda needs to include collaboration with practitioners to update curricula and rethink assessment methods, enabling the development of new learning and instructional practices, supporting learning processes, and developing critical skills. It may enable research that contributes to more effective and equitable educational settings that prepare learners for the complexities of living in a world imprinted with AI.

This suggests the need to build a research agenda for AI&ED that embraces an educational ecology approach. As such, it should include macro, meso, and micro levels of AI&ED (Biesta 2020; Gibson et al. 2023; Schuelka and Engsig 2022). Table 4 expands on these three levels by building on the challenges, opportunities, and transformational ideas presented in this study.

The macro level of the research agenda for AI&ED focuses on issues of policy, research ecosystems, and society. At this level, key themes include organising and conducting AI&ED research that fosters large-scale, multidisciplinary, and longitudinal studies. Such studies need to integrate empirical and theoretical frameworks and create adaptive applications. At the macro level, research needs to focus on the relationship between education and the role and impact of AI applications in work-life settings. The macro level also encompasses researching the promotion of access and equity through national and global policies, as well as the assurance of ethical and responsible governance of AI in education.

The meso level concerns issues of curricula, institutions, and leadership. At this level, research addresses the transformation of instructional design and how it can integrate creative, inclusive, and meaningful AI-supported pedagogies. The meso level needs to cover curriculum development and leadership that support AI literacy and innovation. Other themes at the meso level are how institutions can support the professional development of instructors and leaders; how experiments with GenAI applications can be safely enabled in educational settings; and how evaluation systems for applying AI technologies can be assessed and redesigned.

At the micro level, the research agenda concerns instructors, learners, and learning processes. Researching AI&ED needs to address if and how learners' experiences can be enhanced through critical thinking, personalisation, and AI-supported feedback. The micro level addresses how human-AI interplay can be supported. Three important micro-level themes are the encouragement of AI literacy among instructors and learners; the promotion of engagement and motivation through creative and innovative ways of learning; and how individuals can make themselves ready to adopt AI as a tool for learning.

A research agenda for AI&ED is a constantly moving target. Built on the educational purposes of qualification, socialisation, and subjectification, and the three levels of educational ecology (macro, meso, and micro) (Biesta 2020; Gibson et al.

Table 4 An educational ecology approach built on macro-, meso-, and micro-level considerations for a research agenda on AI, education, learning, and instruction

Educational ecology level	Focus area	Key themes
Macro	Policy, Research ecosystems, Society	Organising and conducting AI&ED research: fostering large-scale and longitudinal multidisciplinary studies; integrating empirical-theoretical frameworks; creating adaptive AI applications Aligning education with AI-related changes in work-life settings Promoting equity and access through national/global policy measures Ensuring ethical and responsible AI governance in education
Meso	Curricula, Institutions, Leadership	Instructional design transformation: integrating creative, inclusive, and meaningful AI-supported pedagogies Leadership and curriculum development supporting AI literacy and innovation Institutional support for professional development of instructors and leaders Enabling safe experimentation with AI tools in educational settings Assessing and redesigning systems that evaluate the application of AI technologies
Micro	Instructors, Learners, Learning processes	Enhancing learner experiences through critical thinking and AI-supported feedback Supporting human-AI interplay at the classroom level Encouraging AI literacy among instructors and learners Promoting motivation and engagement through creative and innovative learning Addressing the readiness of individuals to adopt AI

2023; Schuelka and Engsig 2022), the research agenda for AI&ED developed in this article lends itself to perpetual development.

Open Review 1: Artificial Intelligence and the Recursive Logic of Education (Chrysi Rapanta)

As Bass and Good (2004), citing Craft (1984), observed, the word *education* etymologically encompasses two contrasting notions: one derived from *educare*, meaning 'to train' or 'to mold', and another from *educere*, meaning 'to lead out'. This dual logic, inherent in all educational systems, may help to explain the evolving relationship between AI and education, particularly as learning systems become increasingly recursive and adaptive.

AI and education together form what may be described as an *ontological feedback loop* (see Liew et al. 2025). Humans 'educate' machines through the design of training datasets, algorithmic architectures, and evaluative feedback, nurturing artificial systems toward specific capacities (Bryson 2019; Mitchell 2020). Yet these same systems subsequently 'educate' humans by mediating knowledge, extending cognitive reach, and reshaping the epistemic conditions of learning (Popenici and Kerr 2017). This recursive process suggests that AI is not merely an artifact of human design but an interlocutor within a broader ecology of intelligence (see also Seufert's and Säljö's contributions). Through such reciprocity, both human and machine evolve as co-learners in a distributed network of cognition (Clark and Chalmers 1998).

However, the *educere* challenge becomes particularly evident in this ecosystem, as part of the responsibility gap (Matthias 2004) may be expressed in terms of *who transforms whom* when humans and machines learn together through mutual instruction. This challenge is reciprocal—both for humans as learners with AI and for humans as teachers *of* and *with* AI. Human learners should be encouraged to take AI's outputs a step further, transforming information into new knowledge and insight. Likewise, human designers and educators should be challenged to develop AI systems and learning activities that draw forth human creativity, ethical discernment, and critical reflection.

Only when both *educare* and *educere* are realised can we meaningfully speak of AI&ED as a coherent paradigm. The ultimate *telos* of AI&ED lies in flourishing through co-evolution: a pedagogical ecosystem in which *educare* unfolds as an ongoing dialogue between the human and the artificial, continually leading out (*educere*) the still-unrealised possibilities of both (Holmes et al. 2019; Selwyn 2019). The micro, meso, and macro levels of consideration in the current and future AI&ED research agenda, as discussed in this collective article, add further complexity and meaning to this goal.

Note: The author intentionally limited the cited sources to those published up to 2020 to show that the challenges identified over the past three decades remain unresolved even after the recent 'boom' of GenAI.

Open Review 2: Retaining 'Clouded' Judgement or Disruptive Research for an Equitable 'Cloud'? (Sarah Hayes)

My cryptic title is inspired by the work of Sergio Carvajal-Leoni (2025), who asks: 'who is paying the price for AI power?', 'who is benefitting from automation?', 'what kind of humans do we become when our learning is shaped by algorithms we didn't choose and barely understand?' These questions alone call for a critical, inclusive macro, meso, and micro research agenda for AI&ED. So, I thank these collective authors for their insights and for, as Säljö suggests, positioning AI not as an external disruptor, but a catalyst for rethinking educational purpose and design. Disruptive research, as suggested by Lundin, can go beyond traditional metrics and undermine a dangerous assumption, highlighted by Holmes, that the interplay between technology and humans is symmetric.

Säljö notes that human activity, unlike technology, draws on our diverse cultural experiences, so we cannot reduce 'knowing' to the confines of brain/mind alone. Our 'postdigital positionalities' (Hayes 2021, 2023) intersect between our minds, bodies, cultural contexts, socio-material resources, creativity and innovation, local language, skin colour, disability, 'data-ableism' (Charitsis and Lehtiniemi 2022), levels of disadvantage or privilege. Specht asks if AI will bring more equity and support human diversity, or simply reinforce old models, digital divides, and subgroups in society. The analytical layers presented in this article—challenges, opportunities, and transformational ideas—only reveal some complexities currently, because, as Holmes observes, this is a constantly moving target.

Table 4 presents a valuable educational ecology approach, but there remains room to reflexively interrogate *who* is missing in any static representation. For example, many diverse cross-sector stakeholders who might collaborate with academia in these endeavours (Hayes et al. 2025). Which charities, businesses, schools, cultural and environmental organisations, activists and artists might become equitable partners in any research agenda into AI&ED?

Carvajal-Leoni's (2025) AI-generated artistic depiction of a cloud, not made of vapor, but of circuitry, provokes reflection on the huge environmental and human costs behind cloud computing. He argues that making space for voices beyond academic texts prompts otherwise overlooked ethical discussions. This addresses the socialisation and subjectification aspects of education (Biesta 2011). Svensson calls for a redesign of higher education to address a delicate interplay across professional demands, technological development, and the values of becoming an academic scholar. We can begin by discarding clouded judgments that limit how we perceive academia and instead take an educational ecology approach of close collaboration with local and global communities, in working toward a more equitable cloud.

Open Review 3: Toward Multidisciplinary Co-Design (Sandris Zeivots)

This article is a timely intervention that helps us recognise the (need for) shifting research paradigms of education, learning, instruction and AI. It captures a moment

of transition where entanglements of actors, perspectives, and epistemologies reconfigure in new arrangements, and does so with coherence. The proposed three-layered educational ecology shows how micro, meso, and macro processes are distinct, yet interlinked. These levels cannot be understood in isolation.

What I find particularly compelling is how several contributions—Lundin, Säljö, Littlejohn, among others—foreground the ontological and epistemic reconfiguration of knowing-through-research. The metaphor of 'vulnerabilities experienced by humans' (Littlejohn) is provoking, reminding us that our discomfort with AI reflects deep shifts in how knowledge is embodied and experienced. Säljö's observation that humans can no longer 'show what we know' further points to the changing reality of learning as innovation and problem-solving rather than repetition. These examples illustrate that learning and knowing are increasingly approached as relational, distributed, and affective.

This ontological shift is accompanied by a pressing methodological shift. The paper positions AI as an unfamiliar-yet-familiar catalyst for rethinking educational purpose and design. I support the authors' call for a multidisciplinary research agenda, and would extend it through multidisciplinary design-oriented perspectives, particularly co-design. Such approaches acknowledge multidisciplinary stakeholders and their role in sustained, design-driven inquiry. Co-design is not a one-off collaboration but a practice of attunement—making sense, researching, and designing educational futures collectively (Zeivots et al. 2025b). It ensures futures of the research agenda are not left to unfold on their own terms but are intentionally shaped with care, democratic participation, and ethical responsibility (Wardak et al. 2024).

The paper asks us to stay with tensions rather than resolve them quickly, to design with and through difference. This orientation matters because research on AI in education cannot remain a 'catch-up' exercise—the futures of learning are shaped now, and how we design together will influence which futures become possible. As de Laat notes, we need coordinated, longer-term, and situated research efforts that engage with practice and policy. Here, co-design can offer a methodological bridge—linking diverse expertise, fostering shared responsibility, and aligning innovation with values such as equity, sustainability, and human dignity.

This paper opens an urgent conversation about how we imagine and design educational futures. Its contribution is a blueprint and a provocation: a reminder that to rethink AI and education, we must rethink what it means to know, to learn, and to collaborate.

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Declarations

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