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Empowering K-12 Education with AI

Preparing for the Future of Education and Work

First published 2025

ISBN: 978-1-032-81155-0 (hbk)
ISBN: 978-1-032-81154-3 (pbk)
ISBN: 978-1-003-49837-7 (ebk)

Reform, Challenges, and Future Research on AI for K-12 Education

Eight

DOI: 10.4324/9781003498377-8

Routledge
Taylor & Francis Group
LONDON AND NEW YORK

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Eight

Let's shake up education with a splash of AI magic! Imagine classrooms where creativity soars, collaboration thrives, and learning feels like an adventure. With smart tech by our side, we can turn the ordinary into the extraordinary and prepare students to tackle the future with confidence and flair!

Thomas K. F. Chiu

8.1 INTRODUCTION

AI has transformed K-12 education in many ways (Chiu, 2023; Crompton et al., 2022). Students can use generative AI (GenAI) tools to obtain real-time feedback on their work, receive recommended learning content and assessment items, and visualize their thoughts (Chiu, 2024; Kong & Yang, 2024; Law, 2024; Mintz et al., 2023). Teachers can use learning analytics and performance predictors to monitor the development of their student learning. They can employ GenAI tools to generate innovative teaching ideas (Chiu, 2024; Chiu, Xia, et al., 2023; Moreno-Marcos et al., 2020), and collaborate with Gen AI tools to teach students effectively (Chiu, Moorhouse, et al., 2024). Parents may use AI systems as teaching aides to facilitate their children's learning process. In order to promote ethical, healthy, responsible, and productive usage of AI among kids, teachers, and parents, it is necessary for the government and schools to review and update the curriculum and policies (Chiu, 2023). While AI technologies offer advantages to K-12 education, they also pose issues that necessitate significant educational reforms. (Arantes, 2023; Chiu, 2023; Mintz et al., 2023).

This chapter examines the necessary actions that different stakeholders, including educational technology developers, students, teachers, parents, schools, policymakers, and educational researchers,

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should take to reform the integration of AI in education. In addition, we provide an analysis of the challenges they encounter and the future research directions they contemplate.

8.2 AI EDUCATIONAL TECHNOLOGY DEVELOPERS

In K-12 education, students are adolescents, and most of them require teacher guidance as well as well-designed digital resources to succeed in learning, particularly for low achievers (An & Reigeluth, 2011; Chiu, 2023; Zawacki-Richter et al., 2019). The quality of AI education applications influences how well students and teachers learn and teach. Some applications are failing to recommend content that is appropriate for student needs (Zafari et al., 2022; Zawacki-Richter et al., 2019). Students may get disengaged and struggle to understand the content because what the applications can do is not what they expect (Bergdahl et al., 2020; Chiu, Xia, et al., 2023). For instance, an AI application in mathematics that was created with an inadequate knowledge structure may present mathematics questions that are either too complex or too elementary. An AI application for learning English, constructed using data from native speakers, may present unsuitable context for non-native speakers, as their approach to learning English may differ. Inadequate applications may fail to accommodate the unique learning needs of particular students, resulting in both student and teacher frustration. High-quality applications have the ability to efficiently offer pertinent resources and monitor student advancement, thereby actively engage students in their learning process (Chiu, Xia, et al., 2023; Pham & Sampson, 2022). The success of AI education applications is strongly reliant on their capacity to personalize content and adapt to individual student requirements (Moreno-Marcos et al., 2020; Pham & Sampson, 2022).

The large language model-driven chatbot ChatGPT might not be able to adapt to the learning needs of young children (Chiu, 2024). The GenAI technology has been developed for general use and is not specifically designed for education or any other particular purpose (Bommasani et al., 2021; Chiu, 2024; Pal et al., 2024). ChatGPT should be viewed as a foundational model rather than an educational technology. It may be more useful for higher education than K-12 education students, particularly for getting new ideas and completing essay-based assignments (Chiu, 2024; Fauzi et al., 2023).

A plausible explanation is that higher education students who are more knowledgeable (in terms of both content knowledge and critical thinking) can make better judgments on the output. This implies ChatGPT may not adequately address the learning needs of students in K-12. Therefore, the literature calls for researchers and developers to redevelop ChatGPT into EdGPT (Bommasani et al., 2021; Kasneci et al., 2023; UNESCO, 2023). EdGPT models undergo training using curated datasets specifically designed for educational applications, as stated by UNESCO in 2023. The model training should use education data that is both high quality and specialized to the relevant topic (Bommasani et al., 2021; Kasneci et al., 2023). For optimal training of EdGPT models, it is recommended to use data that pertains to Shulman (1986) and Kasneci et al.'s (2023) pedagogical content knowledge. EdGPT is anticipated to generate outputs with reduced general biases and errors, resulting in more favorable content compared to ChatGPT. ChatGPT can be seen as a standard version of GPT, whereas EdGPT is specifically designed for educational purposes. The development of EdGPT is in its early stages (Arefeen et al., 2024; Kasneci et al., 2023; Pal et al., 2024). Hence, the present progress of AI instructional technology needs significant enhancement.

Actions you should take to reform

- **Co-design process:** A collaborative effort among students, teachers, and educational researchers is necessary to design and create high-quality AI educational applications (Hutchins & Biswas, 2024; Kyza & Agesilaou, 2022; Lee, 2008; Matuk et al., 2016). Developers ought to use a co-design process in order to incorporate perspectives from various stakeholders, thereby augmenting their understanding of educational data. For instance, educational data includes the various interactions that occur among students, teachers, and content. Developers engage in a genuine co-design process to create applications that specifically cater to the needs of students and teachers, rather than building them solely for their own convenience.
- **Domain-specific:** Developers should co-design AI educational applications with teachers and students for a specific domain (Arefeen et al., 2024; Hutchins & Biswas, 2024; Kasneci et al., 2023; Pal et al., 2024). They should use data that is more pertinent

for the purpose of training the model. In order to produce appropriate and relevant learning materials such as content and tests, the applications must be in accordance with the curriculum (Arefeen et al., 2024; Pal et al., 2024). AI tools should primarily be used by teachers and students to prevent irrelevant users from introducing data that could compromise the accuracy of the model training.

- **Learning sciences:** To optimize the efficacy and value of their artificial intelligence applications for student learning outcomes, it is essential for developers to incorporate learning theories and principles into the development process. For instance, developers can apply learning theories such as Mayers' multimedia learning to create high-quality educational material (Chiu & Churchill, 2015; Chiu & Mok, 2017; Chiu et al., 2020). It is also important to expand beyond just content knowledge and incorporate more pedagogical strategies, and to foster positive connections between teachers and students, as well as among students themselves (Luckin & Cukurova, 2019). Developers should take into account psychological elements including motivation, needs satisfaction, and social learning to increase the educational value of AI applications (Chiu, 2024; Chiu, Moorhouse et al., 2024).
- **Transferability:** The primary objective of most contemporary AI education applications is to facilitate student learning and enhance teacher instruction. The data and trained model used in the applications can be applied to other educational domains, such as counseling, educational psychology, and parenting. For instance, they can be used to screen for the risk of dyslexia (Chen & Perez, 2023) and provide career counseling (Muhammad, 2023; Zaidi et al., 2021).
- **Ethics:** To create AI education applications of high quality, a substantial volume of data from both students and teachers is necessary (Nguyen et al., 2023). Developers ought to ethically gather data pertaining to students and teachers. This entails obtaining sufficient consent and safeguarding the privacy and security of the acquired data. Furthermore, it is crucial for developers to be open regarding the utilization of the data and establish clear guidelines for its keeping and safeguarding (Griffin et al., 2024; Rhodes et al., 2003). Developers may cultivate trust among users and create AI educational applications that are advantageous to both students and teachers by following ethical data collection standards.

Co-design brings together educational technology developers, teachers, students, and researchers to develop better solutions based on direct user feedback (Hutchins & Biswas, 2024; Kyza & Agesilaou, 2022; Matuk et al., 2016) (i.e., the users are involved in the design and development). This co-design process highlights common goals, shared values, equity of voice, and a commitment to ongoing enhancement while taking into account student and teacher experiences. This process will shift from "technology for education" to "educational technology": technology for education expects teachers to incorporate what technology can do into education, whereas educational technology expects technology to match the demands of education. However, user opinions may not be feasible in development, and conflicting opinions from various people involved in the development make decision-making more complicated. So, it could be time-consuming, resource-intensive, and cost-ineffective (Lee, 2008). Thus, the big questions include: How can developers effectively co-design AI apps for education purposes? How can developers protect students and teachers when their data are collected during the development?

Challenges you may face

- **Educational gap in application:** Most AI applications are not specifically designed for educational purposes and do not sufficiently cater to the learning needs of K-12 students.
- **Inauthentic co-design process:** The design and development of AI educational technology does not sufficiently consider educational perspectives in a comprehensive manner. We may be lacking a genuine co-design process.
- **Lack of data protection procedures for K-12 education:** Student and teacher data are required for the development process. The data protection measures require enhancement.

Future research directions you could pursue

- **Co-design framework:** Co-design may lack equal involvement and representation of all stakeholders due to the possibility of a cost-ineffective and time-consuming approach (Hutchins & Biswas, 2024; Kyza & Agesilaou, 2022; Matuk et al., 2016). Future studies are needed to build a co-design framework for the development of

AI educational technologies, so as to promote genuine collaboration. Incorporating transparency and accountability into the co-design process is recommended to address power imbalances and guarantee that all perspectives are acknowledged and respected.

- **Ethical guidelines for schools:** There exist multiple ethical standards; however, they are not exclusive to schools (Nguyen et al., 2023). The standards can offer broad direction; yet, school environments should be more protected and distinct from the commercial realm. Further investigation is required to comprehend the ethical procedures by which developers and schools might gather and analyze data.

8.3 STUDENTS

By leveraging AI, educational technology has the potential to transform one-size-fits-all learning into customized learning that caters to the unique needs of each student. AI has the capability to examine data regarding students' progress, accomplishments, and preferences. It may provide personalized feedback and challenges to engage each student (Chiu, Xia, et al., 2023; Moreno-Marcos et al., 2020). It also can uncover or predict students' strengths and areas for improvement through the examination of learning patterns, namely by recognizing and recommending what students are knowledgeable about and what they lack knowledge in. For instance, in the field of language, there is a platform called Amira that uses AI to aid students by offering guidance, resources, and immediate assistance in case of misreading (Chen & Perez, 2023). The platform produces a comprehensive report on the students' reading skills and needs. Intelligent tutors in mathematics generate personalized and diverse problems by considering students' knowledge, interests, and experiences (del Olmo-Muñoz et al., 2023; Walkington & Bernacki, 2019), resulting in enhanced student engagement. Personalized mathematics problems have the potential to promote positive emotional states and discourage negative ones in all students. The main benefit of AI-powered learning platforms for students is personalized learning (Ayeni et al., 2024).

GenAI tools enhance human-like interaction compared to traditional AI, hence expanding possibilities for student self-regulated learning (Chiu, 2023; Chiu, Moorhouse, et al., 2024). These resources are readily accessible for students. Students can directly request solutions,

feedback, and digital resources from GenAI tools according to their own needs and preferences (Chiu, 2024; Fauzi et al., 2023; Kasneci et al., 2023). These tools enable students to get new perspectives and ideas from other fields of study, while also empowering them to produce multimedia resources that they believe they cannot develop on their own. Nevertheless, the majority of these tools are not specifically tailored for K-12 education and yield biased, inaccurate, or inappropriate outcomes (Kasneci et al., 2023; UNESCO, 2023). To use these tools effectively for educational purposes, students must possess a strong understanding of the subject matter and acquire various literacies and abilities, including AI literacy, critical thinking, and fact-checking (Chiu, 2023; Ciampa et al., 2023; Xia et al., 2023). Hence, AI educational technologies have the potential to revolutionize student learning by enhancing self-regulated and integrated learning in K-12 education and adding more prerequisite knowledge.

Actions you should take to reform

- **Self-regulated learning:** Students have the opportunity to receive recommendations from adaptive and predictive learning systems, feedback from GenAI, as well as access to articles and questions generated by GenAI (Chiu, 2024; Kong & Yang, 2024; Molenaar et al., 2023; Wang & Lin, 2023). Consequently, AI applications function as round-the-clock student learning partners and advisors during the process of self-regulated learning. Additional information was provided in Chapter Four.
- **Interdisciplinary learning:** Although interdisciplinary education, including sustainability and STEM education, has been advocated for in K-12 schools, there is still a lack of explicit recommendations for integrating many disciplines (Chiu & Li, 2023; Gibson et al., 2023; Hopcan et al., 2023). One potential reason is that students may not be able to obtain prompt and relevant feedback to break the subject boundaries, leading to confusion and a perception of the process as being time-consuming. Teachers in classrooms are knowledgeable and authoritative in their specific subjects. They may lack the capacity to offer comprehensive guidance to students across several fields of study. Moreover, being human, they are unable to provide regular and ongoing feedback to students due to physical constraints. AI educational tools operate tirelessly, providing

students with round-the-clock access. These technologies can facilitate students in acquiring diverse concepts and knowledge during interdisciplinary learning (Chiu, 2023; Chiu & Li, 2023; Gibson et al., 2023; Hopcan et al., 2023). For further details, refer to Chapter Four. Interdisciplinary learning entails the synthesis and integration of unfamiliar content and theories from other fields. Thus, this learning approach fosters the acquisition of students' advanced problem-solving abilities, enabling them to effectively tackle intricate real-world challenges spanning multiple fields of study. Moreover, it equips them with the necessary skills to excel in their future professional endeavors and academic pursuits.

Although AI tools have the potential to support self-regulated and interdisciplinary learning, students frequently have difficulties in understanding the information they receive. For example, students may have insufficient prerequisite subject knowledge and digital competencies to effectively learn with AI chatbots (Chiu, Moorhouse, et al., 2024). In addition to acquiring knowledge and skills, it is crucial for students to cultivate ethical behavior and maintain good physical and mental well-being in the era of AI. They can develop excessive dependence on AI and unquestioningly embrace the information provided by AI. These pertain to the beliefs and attitudes of students regarding the use of AI, as well as their comprehension of AI and ethics. The issue of student well-being in AI-powered learning environments needs to be acknowledged and dealt with (Ayeni et al., 2024). Thus, the big questions include: What prerequisite or prior knowledge should students have before learning with AI? How do students gain AI competencies? How do students avoid becoming addicted to AI? How can students be ethical, responsible, healthy, and productive learners in the AI era?

Challenges you may face

- **Insufficient prerequisites or prior knowledge:** Students must possess a solid understanding of the relevant prior subject knowledge to properly regulate their learning with AI or engage in interdisciplinary learning. The challenge is in the extensive and comprehensive understanding of prerequisites knowledge, which can be overwhelming for students with low academic performance.

- **Balancing AI use:** Preventing addiction involves setting boundaries and balancing AI use with human interaction and independent problem-solving. Exercising self-discipline and being conscious of one's actions can be challenging, particularly in light of the growing integration of AI into everyday routines.
- **Ethical considerations:** Ethical considerations in the field of AI, such as privacy, prejudice, transparency, and responsibility, present a challenge. Students must be taught to analyze these areas in a critical manner, necessitating thorough and subtle curriculum design.
- **Productivity and health:** Maintaining productivity and health involves balancing screen time, managing stress, and ensuring physical activity. The challenge is to integrate these learning practices into an AI-heavy learning environment without compromising their outcomes.

Future research directions you could pursue

- **Models for self-regulated or socially regulated learning using AI:** Several established models of self-regulated learning have been proposed in the literature (Greene & Azevedo, 2007; Hadwin & Oshige, 2011; Molenaar et al., 2023; Panadero, 2017). These were designed using psychological perspectives and have a significant influence on student learning; however, AI tools have provided new opportunities for advancement in self-regulated learning. Consequently, future studies should see AI as learning partners of students. Future research should explore the functions of AI in student-led learning (e.g., self-regulated learning), considering both individual and social perspectives. It also aims to develop the models that can assist teachers and researchers in designing AI-empowered learning environments that promote self-regulation and social interaction.
- **AI-powered interdisciplinary learning:** AI revolutionizes interdisciplinary learning, just like self-regulated learning does (Chiu & Li, 2023; Gibson et al., 2023; Hopcan et al., 2023). Future studies should examine the roles of AI in promoting interdisciplinary learning among students. Specifically, we suggest exploring how students use AI to establish connections across different study fields and effectively express their interdisciplinary concepts.

- **Student well-being:** Further research should be undertaken to investigate the impact of AI technology on the well-being of students. The proposed research areas include balancing AI support with human interaction, the roles of ethical awareness in student well-being, the examination of mental health in AI learning, and the creation of inclusive learning environments.

8.4 TEACHERS

In K-12, teacher instruction has a significant impact on the academic achievements of students. Teacher support is necessary for most students, especially those who have lower academic performance (An & Reigeluth, 2011; Chiu et al., 2024). Teachers should use AI-powered learning analytics to accurately identify a student's academic strengths and weaknesses, enabling them to design a personalized learning that addresses their individual needs and intervene proactively before the student becomes overwhelmed with frustration and stress. Furthermore, teachers should transition from being experts in their subjects to assuming the role of facilitators and mediators in student-centered learning, using GenAI (Chiu, 2024). Please refer to Chapter Four for more information. To facilitate student self-regulated learning with GenAI tools, teachers should assume several roles, including observer, co-learner, co-designer, advisor, and endorser (Chiu et al., 2024). The GenAI tools serve as facilitators, providers of alternative intelligence, and developers of material to promote interdisciplinary learning among students (Chiu, 2023).

Actions you should take to reform

- **Changing teacher roles:** AI technology can work as teaching assistants, delivering step-by-step solutions to mathematical problems, explaining how things work, and giving feedback on written articles. They can also serve as learning partners for students. Teachers should expand their duties beyond being only providers of resources, instructors, and facilitators. AI serves as a catalyst for the transformation of teacher instruction and mindsets.
- **Designing interdisciplinary teaching:** AI applications enable teachers to transcend disciplinary barriers and generate a greater number of interdisciplinary assignments (Chiu & Li, 2023). They

enhance their competencies and convictions toward interdisciplinary education.

- **Using new assessments:** AI tools have the capacity to autonomously offer solutions and responses to students, reducing teacher workloads in grading and marking written work (Chiu, 2023). Teachers should prioritize student engagement through increased use of student verbal sharing and oral presentation, as opposed to relying heavily on written assignments, examinations, and tests. Interdisciplinary teaching frequently incorporates real-life situations, and it requires authentic assessment. Consequently, teachers should enhance their assessment literacy to foster greater collaboration with AI in evaluating student performance.
- **Using learning analytics:** AI-driven learning analytics offers objective suggestions to teachers by detecting patterns and trends, identifying students requiring support, giving feedback, and tailoring instruction to meet their specific needs. Teachers are encouraged to acquire the skills necessary to use learning analytics to deliver highly effective, tailored instructions to their students.
- **Engaging in the co-design process:** Teachers who engage in the co-design process to develop AI educational technology might enhance their understanding of student learning by analyzing comprehensive and varied data. This interaction with educational technology developers has the potential to improve teacher AI competency.
- **Screening tools for special education needs:** Identifying students with special education needs is a challenge for teachers (Chen & Perez, 2023; Hopcan et al., 2023). A diagnosis system enhanced with AI could assess students who may be at risk of dyslexia or who exhibit exceptional intellectual abilities (Mullet & Rinn, 2015). This system has the capability to examine the performance of students on tests and detect patterns that may suggest the necessity for additional assessment. Teachers can use the system as a screening tool to identify students who have specific needs.

Implementing AI technologies in education has the promise to transform the way teachers teach and assess students. Technologies can efficiently perform certain teaching responsibilities, such as grading and prediction, allowing teachers to allocate their time to more

important duties that enhance student learning. Teachers should adapt their responsibilities to engage in collaboration with technology in effort to enhance student learning experiences and performance. Nevertheless, teachers are not ready to transform their own practices (Chiu, 2023). Thus, the big questions include: What competencies should teachers have in the AI era? Do teachers have the competencies to use AI? How do teachers design appropriate assessments in AI-empowered environments? What are the roles of teachers in these environments?

Challenges you may consider

- **Defining and assessing teacher AI competency:** Defining a defined set of teacher AI competencies can be challenging due to the ever-changing and interdisciplinary nature of AI. The competencies include technical skills, pedagogical knowledge, and ethical understanding. Various subjects may also necessitate specific AI competencies. Moreover, we lack reliable and validated assessment tools to evaluate the ability of teachers to use AI for education and are unable to establish a baseline for this competency.
- **Redefining teacher roles:** Teachers should shift from being providers of knowledge to being facilitators. They should adjust to a role that prioritizes guiding students in collaborating with AI tools rather than serving as the primary repository of information. To maintain a harmonious balance, it is essential to ensure that AI enhances rather than replaces critical teacher–student relationships.

Future research directions you could pursue

- **Teacher assessment literacy:** Increased use of self-evaluation and authentic assessment methods is expected to evaluate student progress in self-regulated and interdisciplinary learning. Teachers should acquire the skills to effectively collaborate with GenAI to assess student learning. Future research should undertake a redefinition of the concept of teacher assessment literacy, accompanied by illustrative examples.
- **Teacher AI competency:** In Chapter Three, we provided a definition of teacher AI competency and proposed a matrix for evaluating it. This field of research is now in its nascent stage and undergoing

continuous development. Additional empirical investigations are required to further enhance the definition and matrix in the future.

- **Teacher roles:** We proposed the roles of a teacher in AI-powered learning environments in Chapter One. Similarly, this research area is still in its infancy. Additional empirical studies are required to validate or modify the roles.

8.5 PARENTS

The literature provides limited discussion on the impact of AI on parenting; yet, parents play a crucial role in the development of students. AI tools facilitate parental involvement by (i) acting as teaching assistants for parents, thereby extending classroom learning to the home environment, (ii) providing improved visibility of student academic progress for continuous monitoring and support, and (iii) granting access to personalized learning resources.

Actions you should take to reform

- **Using AI in supporting your children:** Parents can use AI tools and systems to facilitate their children's learning at home. For example, parents can enhance their children's mathematical skills by using an AI-powered mathematics application, such as Photomath, which offers comprehensive explanations for each step of a math problem. Similarly, parents can enhance their children's English pronunciation skills by using an AI-powered English-speaking application like ELSA, which assesses and helps improve pronunciation.
- **Seeking help or collaboration from schools:** Parents should consult with schools to obtain guidance on effectively using AI to enhance their children's educational experience and explore opportunities for collaboration. Children's learning is influenced by their school environment.

We believe that studies on how parents might collaborate with AI to boost student learning are overlooked. Thus, the big questions include: What competencies should parents have in the AI era? Do parents have the competencies to use AI? What are the roles of teachers in the environments? How do parents identify appropriate applications for their children?

Challenges you may consider

- **Developing parents' AI competency:** Many parents have a limited understanding of AI and its applications in education. They might face difficulties keeping abreast of the rapid advancements in AI.
- **Changing parental roles:** AI systems facilitate more parental involvement in education, necessitating a significant investment of time and effort to successfully participate. Parents must adapt to new learning paradigms.
- **Collaborating with teachers:** Parents may struggle to align their understanding and use of AI with teachers' approaches and expectations. Inconsistent integration of AI across schools can lead to confusion for parents.

Future research directions you could pursue

- **Parent AI competency:** This research area is infrequently explored in literature. Future study should establish a clear definition of the competencies that parents require.
- **Parent roles:** Similarly, this research area is less discussed. Future study should investigate the specific responsibilities that parents play in facilitating AI e learning.
- **Home–school collaboration:** This research area is not novel. Nevertheless, AI transforms the way parents understand their children's learning progress. Consequently, schools should proactively engage in communication with parents regarding the methods to assist children's use of AI. Further research should explore the impact of AI on the collaboration between homes and schools.

8.6 SCHOOLS AND UNIVERSITIES

AI will be integrated into a wide range of digital devices, including computers and mobile phones. In the future, it will be essential for everyone to possess skills in effectively collaborating with AI. This may entail employing AI to analyze data for the purpose of generating reports, proofreading articles before publication, composing email responses, and predicting customer behaviors. Schools are intended to provide students with the essential skills and knowledge for their personal and professional lives. Schools must rethink the learning outcomes that students require, while teacher training institutions

(universities) must rethink the competencies that teachers need to attain these student learning outcomes.

Actions you should take to reform

- **Revising lifelong learning outcomes:** The advent of AI has led to a reevaluation of the skills that our future workforce must possess, prompting a need to reconsider the desired lifelong learning outcomes that should be cultivated in schools. It is recommended that learning outcomes prioritize 21st-century skills, specifically creativity and critical thinking. Additionally, it is suggested that new abilities such as fact-checking, learning, and working with AI in certain fields should be included (Bukartaite & Hooper, 2023; Chiu, 2023; George, 2023).
- **Redesign teacher education:** Pre- and in-service teacher education programs should incorporate AI competencies, necessitating the restructuring of professional development programs and teacher training by universities and providers (Chiu, 2023; Falloon, 2020). For instance, the current pedagogy may not be sufficient for classrooms that rely on AI. To address this, teacher education programs should provide AI training to all teachers and incorporate innovative pedagogy and assessment (Celik, 2023; Kim et al., 2021).
- **Redesigning curriculum redesign:** Schools ought to redesign their existing curriculum framework by including AI literacy, data literacy, media literacy, and applied mathematics, and fostering greater transdisciplinary learning (George, 2023).

The school curriculum and policies related to AI are not well established (Chiu, 2023; Schiff, 2022). The big questions include: What are the future skills needs in the AI era? What are effective curricula for teaching AI in schools and teacher training institutions? How should effective professional development for AI competencies be designed?

Challenges you may consider

- **Identifying future skills:** Striking a balance between technical expertise and essential soft skills, while also ensuring that education

keeps up with the industry's expectations for AI-related skills, is a formidable challenge.

- **Developing effective AI curricula:** The challenges include a deficiency of standardized curricula and assessments for AI education, a shortage of competent teachers to teach AI, and a need for effective methods to integrate AI across various subjects (interdisciplinary teaching).
- **Designing professional development for AI competencies:** The challenges include the necessity of addressing the varied backgrounds and proficiency levels of teachers, guaranteeing that professional development translates into efficient classroom practices, and providing comprehensive training within limited timeframes and financial resources.

Future research directions you could pursue

- **Curriculum revamp:** The current teacher training activities primarily emphasize specific subjects, and there is a need to enhance teachers' competence in AI through an interdisciplinary approach (Chiu, 2023; Chiu et al., 2021; Falloon, 2020). Future research should investigate the implementation of interdisciplinary methods to overhaul the curriculum for pre-service teachers and the programs for professional development of in-service teachers. The research should suggest criteria and structures for integrating different disciplines in the context of enhancing the professional growth of teachers. The standards and guidelines should include AI education in several topics, ensuring that teachers possess the necessary knowledge and abilities to integrate AI concepts into their teaching methods.
- **Future skills:** AI changes the essential competencies required for the future workforce. For future research, it is recommended that schools engage in partnerships with universities and industry to get insight into the requirements of prospective students and employees (Bukartaite & Hooper, 2023; Chiu, 2023). Schools might utilize the discoveries to adapt school missions and learning accordingly.
- **21st-century skills assessment:** Evaluating the 21st-century abilities of students is frequently carried out in a subjective manner, relying on rubrics provided by students or observations made by

teachers (Chiu, 2023). This suggests that schools do not have a reliable and widely accepted approach for evaluating students. Future research should include scenarios as a method for developing self-assessment tests. Through the use of scenarios, students can showcase their aptitude in applying 21st-century abilities in practical contexts, thereby offering a more precise evaluation of their competence (Darling-Hammond et al., 2010). This strategy can also foster students' self-reflection and enable them to discern areas in which they might enhance their skills.

8.7 POLICYMAKERS AND EDUCATION RESEARCHERS

Policymakers engage in collaboration with educational researchers to formulate and execute policies pertaining to AI. Educational researchers contribute to policy decisions by generating empirical evidence and formulating innovative methodologies through research. Policymakers utilize the evidence to revise policies. The policies are implemented through the identification and elimination of barriers, ensuring that the integration of AI in education is fully and effectively achieved with high quality. Policy development is essential for sustaining this initiative.

Actions you should take to reform

- **Collaboration between policymakers and educational researchers:** They should establish regular channels of communication and collaboration, such as joint working groups or advisory panels to develop and revise AI policies in education. They also should work together to develop frameworks for evaluating the effectiveness of AI policies in education.
- **Professional teacher standard:** Professional standards for teachers and leaders should explicitly include AI competency (Chiu, 2023). These standards provide valuable benchmarks for the teaching profession in the areas of school leadership development, teacher training, and continuous professional development. It is crucial for the standards to provide positive and forward-thinking expectations for how teachers and leaders may fulfill the requirements of modern education. The requirements should encompass AI, computational, and media literacy, which involve critical thinking and the ability to understand and utilize information and communication effectively.

They would encourage school organizations to design professional development on AI and teacher training institutions to include teacher AI competencies in their curriculum. These standards would benefit school and teacher development.

Developing policies is crucial for ensuring the continued integration of artificial intelligence (AI) in K-12 education. The policy should explicitly focus on ensuring the provision of education of high quality. Therefore, the big questions include: Will AI widen student education inequity (the digital divide)? How do we measure AI literacy internationally? How do we make sure that students and teachers are ethical, responsible, healthy, and productive AI users?

Challenges you may consider

- **Ensuring equitable education:** AI has the potential to widen education inequity, such as the digital divide. Students from disadvantaged schools or low-income families may not derive any advantages from the integration of AI in education. This discrepancy can worsen existing educational inequity.
- **Developing standardized metrics for AI literacy and competency:** Developing comparable and culturally relevant metrics for assessing AI literacy and competency across various nations and educational systems poses a significant challenge. The challenge of developing standardized criteria for testing AI literacy arises from differences in curriculum, educational agendas, and the usage of technology. Moreover, cultural and linguistic differences must be considered to ensure that AI literacy assessments are inclusive and relevant to diverse populations.
- **Promoting ethical and responsible AI use:** It is essential to integrate ethics education and promote digital well-being among students and teachers. Ensuring that both students and teachers understand the ethical implications of AI use, such as data privacy, algorithmic bias, and responsible usage, is crucial. Moreover, promoting healthy and balanced use of AI technologies to prevent over-reliance and potential addiction is essential for maintaining digital well-being. Designing comprehensive ethics education for students and continuous professional development for teachers poses a challenge.

- **Digital divide:** AI tool is a form of digital resource. The integration of AI technology in education may either worsen or alleviate the digital divide, a widely discussed topic (Celik, 2023; Shakina et al., 2021). Therefore, it is crucial for future studies to investigate the effects of AI on the digital divide by identifying the influential factors that have an impact. Several factors that should be considered are the availability of AI technology, the level of digital competence, the socioeconomic situation, the education level of parents, and the geographic location (Timotheou et al., 2023).
- **Education inequity:** AI is typically considered a field within STEM or engineering, and its educational programs can worsen educational inequity (Celik, 2023; Xia et al., 2023). Further investigation is necessary to examine approaches for enhancing the involvement of underrepresented populations, including girls and those of African origin, in the domain of AI education.
- **AI careers:** AI generates novel employment prospects that necessitate proficiency in AI (Chen et al., 2022; Zhang et al., 2023). The prediction of students' choice in AI careers is influenced by their interest and identity toward AI. Future studies should investigate how to effectively cultivate student interest and identity by role models, mentorship programs, community engagement, and exposure to practical applications of AI (Chiu, Ismailov et al., 2023). By fostering curiosity and a sense of belonging in the field of AI at an early stage, we can facilitate students to gain the necessary expertise and enthusiasm to pursue prosperous AI-related careers.
- **International AI literacy assessment:** AI literacy is a newly developed proficiency that is crucial for every student. The evaluation of mathematics, language, science, and digital literacy was carried out using well-established international assessments such as the Programme for International Student Assessment (PISA), the Trends in International Mathematics and Science Study (TIMSS), and the International Computer and Information Literacy Study (ICILS) to measure mathematics, language, science, and digital literacy. Hence, it is essential to build an international assessment framework to assess AI literacy (Chiu & Sanusi, 2024).

- **Human-centered mindset:** AI is a disruptive technology that has the potential to pose risks to human well-being (UNESCO, 2023). Students should emphasize the well-being of humans over AI technologies and embrace the idea that AI is to be used for the betterment of society. Guidelines are essential for educational technology developers and teachers to proficiently build and use AI solutions in education. Future studies should put out explicit recommendations for the application of AI in education. The findings could guarantee that students develop into ethical, healthy, responsible, and productive learners of AI.

8.8 FINAL THOUGHTS

To examine the impact of AI on education, we thoroughly analyzed the available research, a sample of curricula and professional development programs, and offered empirical evidence. As this final chapter reveals, there is still much to learn about the design, development, and deployment of integrating AI in education. We hope this chapter will inspire you to take actions to reform your practices, schools, universities, and communities, and to conduct more studies to advance our knowledge. We acknowledge that positive transformation is challenging and time-consuming. Teachers, parents, government officers, researchers, developers, and other stakeholders should collaborate to empower K-12 education with AI to prepare for the future of education and work.

REFERENCES

An, Y. J., & Reigeluth, C. (2011). Creating technology-enhanced, learner-centered classrooms: K–12 teachers' beliefs, perceptions, barriers, and support needs. *Journal of Digital Learning in Teacher Education*, 28(2), 54–62. https://doi.org/10.1080/21532974.2011.10784681

Arantes, J. A. (2023). Personalization in Australian K-12 classrooms: How might digital teaching and learning tools produce intangible consequences for teachers' workplace conditions?. *The Australian Educational Researcher*, 50(3), 863–880. https://doi.org/10.1007/s13384-022-00530-7

Arefeen, M. A., Debnath, B., & Chakradhar, S. (2024). Leancontext: Cost-efficient domain-specific question answering using LLMs. *Natural Language Processing Journal*, *7*, 100065. https://doi.org/10.1016/j.nlp.2024.100065

Ayeni, O. O., Al Hamad, N. M., Chisom, O. N., Osawaru, B., & Adewusi, O. E. (2024). AI in education: A review of personalized learning and educational technology. *GSC Advanced Research and Reviews*, 18(2), 261–271. https://doi.org/10.30574/gscarr.2024.18.2.0062

Bergdahl, N., Nouri, J., Fors, U., & Knutsson, O. (2020). Engagement, disengagement and performance when learning with technologies in upper secondary school. *Computers & Education*, *149*, 103783. https://doi.org/10.1016/j.compedu.2019.103783

Bommasani, R., Hudson, D. A., Adeli, E., Altman, R., Arora, S., von Arx, S., … & Liang, P. (2021). On the opportunities and risks of foundation models, arXiv preprint. arXiv:2108.07258.

Bukartaite, R., & Hooper, D. (2023). Automation, artificial intelligence and future skills needs: An Irish perspective. *European Journal of Training and Development*, *47*(10), 163–185. https://doi.org/10.1108/EJTD-03-2023-0045

Celik, I. (2023). Exploring the determinants of artificial intelligence (AI) literacy: Digital divide, computational thinking, cognitive absorption. *Telematics and Informatics*, *83*, 102026. https://doi.org/10.1016/j.tele.2023.102026

Chen, D. C., You, C. S., & Su, M. S. (2022). Development of professional competencies for artificial intelligence in finite element analysis. *Interactive Learning Environments*, *30*(7), 1265–1272. https://doi.org/10.1080/10494820.2020.1719162

Chen, J. J., & Perez, C. (2023). Enhancing assessment and personalized learning through artificial intelligence. *Childhood Education*, *99*(6), 72–79. https://doi.org/10.1080/00094056.2023.2282903

Chiu, T. K. F. (2023). The impact of generative AI (GenAI) on practices, policies and research direction in education: A case of ChatGPT and Midjourney. *Interactive Learning Environments*, Advance online publication. https://dx.doi.org/10.1080/10494820.2023.2253861

Chiu, T. K. F. (2024). A classification tool to foster self-regulated learning with ChatGPT by applying self-determination theory from a teacher perspective. *Educational Technology Research & Development*, *72*, 2401–2416. https://doi.org/10.1007/s11423-024-10366-w

Chiu, T. K. F., Chai, C. S., Williams, J., & Lin, T. J. (2021). Teacher professional development on self-determination theory-based design thinking in STEM education. *Education Technology & Society*, *24*(4), 153–165. www.jstor.org/stable/48629252

Chiu, T. K. F., & Churchill, D. (2015). Exploring the characteristics of an optimal design of digital materials for concept learning in mathematics: Multimedia learning and variation theory. *Computers & Education*, *82*, 280–291. https://doi.org/10.1016/j.compedu.2014.12.001

Chiu, T. K. F., Ismailov, M., Zhou, X-Y, Xia, Q., Au, D., & Chai, C. S. (2023). Using self-determination theory to explain how community-based learning fosters student interest and identity in integrated STEM education. *International Journal of Science and Mathematics Education*, *21*, 109–130. https://doi.org/10.1007/s10763-023-10382-x

Chiu, T. K. F., Jong, M. S. Y., & Mok, I. A. C. (2020). Does learner expertise matter when designing emotional multimedia for learners of primary school mathematics? *Educational Technology Research and Development*, *68*, 2305–2320. https://doi.org/10.1007/s11423-020-09775-4

Chiu, T. K. F., & Li, Y. (2023). How can emerging technology impact STEM education? *Journal of STEM Education Research*, 6, 375–384. https://doi.org/10.1007/s41979-023-00113-w

Chiu, T. K. F., & Mok, I. A. C. (2017). Learner expertise and mathematics different order thinking skills in multimedia learning. *Computers & Education*, 107, 147–164. http://dx.doi.org/10.1016/j.compedu.2017.01.008

Chiu, T. K. F., Moorhouse, B. L., Chai, C. S., & Ismailov, M. (2024). Teacher support and student motivation to learn with artificial intelligence (AI) chatbot. *Interactive Learning Environments*, 32(7), 3240–3256. https://doi.org/10.1080/10494820.2023.2172044

Chiu, T. K. F., & Sanusi, I. T. (2024). Define, foster, and assess student and teacher AI literacy and competency for all: Current status and future research direction. *Computers and Education Open*, 6, 100182. https://doi.org/10.1016/j.caeo.2024.100182

Chiu, T. K. F., Xia, Q., Zhou, X-Y, Chai, C. S., & Cheng, M.-T. (2023). Systematic literature review on opportunities, challenges, and future research recommendations of artificial intelligence in education. *Computer & Education: Artificial Intelligence*, 4, 100118. https://doi.org/10.1016/j.caeai.2022.100118

Ciampa, K., Wolfe, Z. M., & Bronstein, B. (2023). ChatGPT in education: Transforming digital literacy practices. *Journal of Adolescent & Adult Literacy*, 67(3), 186–195. https://doi.org/10.1002/jaal.1310

Crompton, H., Jones, M. V., & Burke, D. (2022). Affordances and challenges of artificial intelligence in K-12 education: A systematic review. *Journal of Research on Technology in Education*, 56(3), 248–268. https://doi.org/10.1080/15391523.2022.2121344

Darling-Hammond, L., Adamson, F., & Abedi, J. (2010). *Beyond basic skills: The role of performance assessment in achieving 21st century standards of learning*. Stanford Center for Opportunity Policy in Education.

del Olmo-Muñoz, J., González-Calero, J. A., Diago, P. D., Arnau, D., & Arevalillo-Herráez, M. (2023). Intelligent tutoring systems for word problem solving in COVID-19 days: Could they have been (part of) the solution?. *ZDM–Mathematics Education*, 55(1), 35–48. https://doi.org/10.1007/s11858-022-01396-w

Falloon, G. (2020). From digital literacy to digital competence: The teacher digital competency (TDC) framework. *Educational Technology Research and Development*, 68(5), 2449–2472. https://doi.org/10.1007/s11423-020-09767-4

Fauzi, F., Tuhuteru, L., Sampe, F., Ausat, A., & Hatta, H. (2023). Analysing the role of ChatGPT in improving student productivity in higher education. *Journal on Education*, 5(4), 14886–14891. https://doi.org/10.31004/joe.v5i4.2563

George, A. S. (2023). Preparing students for an AI-driven world: Rethinking curriculum and pedagogy in the age of artificial intelligence. *Partners Universal Innovative Research Publication*, 1(2), 112–136. https://doi.org/10.5281/zenodo.10245675

Gibson, D., Kovanovic, V., Ifenthaler, D., Dexter, S., & Feng, S. (2023). Learning theories for artificial intelligence promoting learning processes. *British Journal of Educational Technology*, 54(5), 1125–1146. https://doi.org/10.1111/bjet.13341

Griffin, T. A., Green, B. P., & Welie, J. V. (2024). The ethical wisdom of AI developers. *AI and Ethics*, 2024, 458. https://doi.org/10.1007/s43681-024-00458-x

Greene, J. A., & Azevedo, R. (2007). A theoretical review of Winne and Hadwin's model of self-regulated learning: New perspectives and directions. *Review of Educational Research*, 77(3), 334–372. https://doi.org/10.3102/003465430303953

Hadwin, A., & Oshige, M. (2011). Self-regulation, coregulation, and socially shared regulation: Exploring perspectives of social in self-regulated learning theory. *Teachers College Record*, 113(2), 240–264. https://doi.org/10.1177/016146811113001204

Hopcan, S., Polat, E., Ozturk, M. E., & Ozturk, L. (2023). Artificial intelligence in special education: A systematic review. *Interactive Learning Environments*, 31(10), 7335–7353. https://doi.org/10.1080/10494820.2022.2067186

Hutchins, N. M., & Biswas, G. (2024). Co-designing teacher support technology for problem-based learning in middle school science. *British Journal of Educational Technology*, 55(3), 802–822. https://doi.org/10.1111/bjet.13363

Kasneci, E., Seßler, K., Küchemann, S., Bannert, M., Dementieva, D., Fischer, F., … & Kasneci, G. (2023). ChatGPT for good? On opportunities and challenges of large language models for education. *Learning and Individual Differences*, 103, 102274. https://doi.org/10.1016/j.lindif.2023.102274

Kim, S., Jang, Y., Choi, S., Kim, W., Jung, H., Kim, S., & Kim, H. (2021). Analyzing teacher competency with TPACK for K-12 AI education. *KI-Künstliche Intelligenz*, 35(2), 139–151. https://doi.org/10.1007/s13218-021-00731-9

Kong, S. C., & Yang, Y. (2024). A human-centred learning and teaching framework using generative artificial intelligence for self-regulated learning development through domain knowledge learning in K-12 settings. *IEEE Transactions on Learning Technologies*, 17, 1588–1599. https://doi.org/10.1109/TLT.2024.3392830

Kyza, E. A., & Agesilaou, A. (2022). Investigating the processes of teacher and researcher empowerment and learning in co-design settings. *Cognition and Instruction*, 40(1), 100–125. https://doi.org/10.1080/07370008.2021.2010213

Law, L. (2024). Application of generative artificial intelligence (GenAI) in language teaching and learning: A scoping literature review. *Computers and Education Open*, 6, 100174. https://doi.org/10.1016/j.caeo.2024.100174

Lee, Y. (2008). Design participation tactics: The challenges and new roles for designers in the co-design process. *Co-design*, 4(1), 31–50. https://doi.org/10.1080/15710880701875613

Luckin, R., & Cukurova, M. (2019). Designing educational technologies in the age of AI: A learning sciences-driven approach. *British Journal of Educational Technology*, 50(6), 2824–2838. https://doi.org/10.1111/bjet.12861

Matuk, C., Gerard, L., Lim-Breitbart, J., & Linn, M. (2016). Gathering requirements for teacher tools: Strategies for empowering teachers through co-design. *Journal of Science Teacher Education*, 27(1), 79–110. https://doi.org/10.1007/s10972-016-9459-2

Mintz, J., Holmes, W., Liu, L., & Perez-Ortiz, M. (2023). Artificial Intelligence and K-12 education: Possibilities, pedagogies and risks. *Computers in the Schools*, 40(4), 325–333. https://doi.org/10.1080/07380569.2023.2279870

Molenaar, I., de Mooij, S., Azevedo, R., Bannert, M., Järvelä, S., & Gašević, D. (2023). Measuring self-regulated learning and the role of AI: Five years of research using multimodal multichannel data. *Computers in Human Behavior*, 139, 107540. https://doi.org/10.1016/j.chb.2022.107540

Moreno-Marcos, P. M., Pong, T. C., Muñoz-Merino, P. J., & Kloos, C. D. (2020). Analysis of the factors influencing learners' performance prediction with learning analytics. *IEEE Access*, 8, 5264–5282. https://doi.org/10.1109/ACCESS.2019.2963503

Muhammad, R. (2023). Barriers and effectiveness to counselling careers with artificial intelligence: A systematic literature review. *Ricerche di Pedagogia e Didattica. Journal of Theories and Research in Education*, 18(3), 143–164. https://doi.org/10.6092/issn.1970-2221/18250

Mullet, D. R., & Rinn, A. N. (2015). Giftedness and ADHD: Identification, misdiagnosis, and dual diagnosis. *Roeper Review*, 37(4), 195–207. https://doi.org/10.1080/02783193.2015.1077910

Nguyen, A., Ngo, H. N., Hong, Y., Dang, B., & Nguyen, B. P. T. (2023). Ethical principles for artificial intelligence in education. *Education and Information Technologies*, 28(4), 4221–4241. https://doi.org/10.1007/s10639-022-11316-w

Pal, S., Bhattacharya, M., Lee, S. S., & Chakraborty, C. (2024). A domain-specific next-generation large language model (LLM) or ChatGPT is required for biomedical engineering and research. *Annals of Biomedical Engineering*, 52(3), 451–454. https://doi.org/10.1007/s10439-023-03306-x

Panadero, E. (2017). A review of self-regulated learning: Six models and four directions for research. *Frontiers in Psychology*, 8, 250270. https://doi.org/10.3389/fpsyg.2017.00422

Pham, S. T., & Sampson, P. M. (2022). The development of artificial intelligence in education: A review in context. *Journal of Computer Assisted Learning*, 38(5), 1408–1421. https://doi.org/10.1111/jcal.12687

Rhodes, S. D., Bowie, D. A., & Hergenrather, K. C. (2003). Collecting behavioural data using the world wide web: Considerations for researchers. *Journal of Epidemiology & Community Health*, 57(1), 68–73. https://doi.org/10.1136/jech.57.1.68

Schiff, D. (2022). Education for AI, not AI for education: The role of education and ethics in national AI policy strategies. *International Journal of Artificial Intelligence in Education*, 32(3), 527–563. https://doi.org/10.1007/s40593-021-00270-2

Shakina, E., Parshakov, P., & Alsufiev, A. (2021). Rethinking the corporate digital divide: The complementarity of technologies and the demand for digital skills. *Technological Forecasting and Social Change*, 162, 120405. https://doi.org/10.1016/j.techfore.2020.120405

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, 15(2), 4–14. https://doi.org/10.3102/0013189X015002004

Timotheou, S., Miliou, O., Dimitriadis, Y., Sobrino, S. V., Giannoutsou, N., Cachia, R., … & Ioannou, A. (2023). Impacts of digital technologies on education and factors influencing schools' digital capacity and transformation: A literature review. *Education and Information Technologies*, 28(6), 6695–6726. https://doi.org/10.1007/s10639-022-11431-8

UNESCO (2023) *Guidance for generative AI in education and research*. The United Nations Educational, Scientific and Cultural Organization. Retrieved from www.unesco.org/en/articles/guidance-generative-ai-education-and-research

Walkington, C., & Bernacki, M. L. (2019). Personalizing algebra to students' individual interests in an intelligent tutoring system: Moderators of impact. *International Journal of Artificial Intelligence in Education*, 29, 58–88. https://doi.org/10.1007/s40593-018-0168-1

Wang, C. Y., & Lin, J. J. (2023). Utilizing artificial intelligence to support analyzing self-regulated learning: A preliminary mixed-methods evaluation from a human-centered perspective. *Computers in Human Behavior*, 144, 107721. https://doi.org/10.1016/j.chb.2023.107721

Xia, Q., Chiu, T. K. F., Chai, C. S., & Xie, K. (2023). The mediating effects of needs satisfaction on the relationships between prior knowledge and self-regulated learning through artificial intelligence chatbot. *British Journal of Educational Technology*, 54(4), 967–986. https://doi.org/10.1111/bjet.13305

Zafari, M., Bazargani, J. S., Sadeghi-Niaraki, A., & Choi, S. M. (2022). Artificial intelligence applications in K-12 education: A systematic literature review. *IEEE Access*, 10, 61905–61921. https://doi.org/10.1109/ACCESS.2022.3179356

Zaidi, D., Raza, S., & Sharma, L. (2021). Artificial intelligence based career counselling chatbot a system for counselling. *Annals of the Romanian Society for Cell Biology*, 25(6), 11732–11735. Retrieved from http://annalsofrscb.ro/index.php/journal/article/view/7695

Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education: Where are the educators?. *International Journal of Educational Technology in Higher Education*, 16(1), 1–27. https://doi.org/10.1186/s41239-019-0171-0

Zhang, H., Lee, I., Ali, S., DiPaola, D., Cheng, Y., & Breazeal, C. (2023). Integrating ethics and career futures with technical learning to promote AI literacy for middle school students: An exploratory study. *International Journal of Artificial Intelligence in Education*, 33(2), 290–324. https://doi.org/10.1007/s40593-022-00293-3