

## UNESCO Chairs / UNITWIN Networks Policy Brief Template

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### AI in teaching and learning in Higher Education

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### Abstract

Recognizing that the role and function of Artificial Intelligence (AI) in learning is a very complex issue, the task of this policy brief is to analyse AI in Higher Education (HE) from two inquiry perspectives: (1) What new opportunities can AI bring to teaching and learning in HE, and (2) What risks and ethical challenges should be recognized when AI is implemented in teaching and learning in HE. Recommendations with examples are also presented. They focus on how AI can contribute to solving global challenges and raise the quality and relevance of HE, and how AI can support student' learning processes and well-being and be an important tool in skill and competence learning. The recommendations also underline the importance of AI literacy for all HE teachers and students and call HE institutions to be responsible actors in lifelong learning reforms ensuring that all people will have basic understanding and social responsibility for the use of AI.

This policy brief is mainly focused on pedagogical and educational themes even though AI can provide strong methods in many disciplines for research and knowledge production in HE. The policy brief is based on intensive collaboration of the authors, who have worked with their research groups and networks in China, Finland, and USA, to explore how AI can serve learning and education, and to examine what are the main risks. The culmination has been a joint book, *AI in Learning – Designing the Future* (2022), which contributes to the substance of this policy brief.

## Content

<b>Abstract .....</b>	<b>1</b>
<b>1. Introduction and the purpose of the policy brief.....</b>	<b>3</b>
<b>2. New opportunities – AI is changing teaching and learning in Higher Education...4</b>	
<b>3. What are risks and ethical challenges in integrating AI into human learning environments and socio-technical systems for education .....</b>	<b>6</b>
<b>4. Recommendations and conclusions .....</b>	<b>7</b>
<b>References.....</b>	<b>10</b>

## 1. Introduction and the purpose of the policy brief

Artificial intelligence (AI) is changing the world radically. It impacts societies, organizations, work, and education, and it is becoming more and more part of educational systems including also Higher Education (HE). The Organisation for Economic Co-operation and Development (OECD) launched 2020 “AI Policy Observatory” (OECD, 2020). It tracks policy areas where AI is driving changes in the workforce, transportation, and healthcare sectors. It follows up trends and AI data use and provides a forum for national AI policies and global initiatives of different stakeholders including business, academia, and civil society. HE institutions are part of national strategies, but they are also academies preparing future experts, leaders, and decision-makers. HE institutions are responsible for the competences of their graduates and they face AI at different levels: individual students, study and degree programs, tools and practices of pedagogical methods, and responsibility for sustainable development in societies.

The United Nations (UN) see AI as one important tool for sustainable development. In April 2021, UN published its Resource Guide on Artificial Intelligence AI Strategies (UN, 2021). It introduces how AI can provide resources to achieve sustainable development goals (SDGs) that are related to big challenges such as climate change, hunger, poverty, inequalities, and other severe global threats. UNESCO, as a United Nations agency, has a special mandate for education and culture. UNESCO published its 2021 AI guidelines for policymakers, introducing and reviewing AI technologies in educational applications and their ethical challenges (UNESCO, 2021a). In November 2021, UNESCO launched a report *Reimagining our futures together: a new social contract for education* (UNESCO, 2021b). This future report is a strong appeal for the importance of education and sustainability in education (SDG 4). The report covers all educational levels including HE and expresses a strong concern about teaching and pedagogy in HE. The main message of the report is that a new social contract for education needs pedagogy that is rooted in cooperation and solidarity, building the capacities of students and teachers to work together in trust to transform the world (p. 50), and further recommending these principles should be implemented also in Higher education.

We may ask what roles digital tools and environment play in the call for a new social contract of education. The report admits (p. 9) that “the digital transformation of our societies is impacting our lives in unprecedented ways. Computers are quickly changing the ways in which knowledge is created, accessed, disseminated, validated, and used. Much of this is making information more accessible and opening new and promising avenues for education”. But it continues with warnings that the risks are many: learning can narrow as well as expand in digital spaces; technology provides new levers of power and control which can repress as well as emancipate; and, with facial recognition and AI, our human right to privacy can contract in ways that were unimaginable just a decade earlier. The report emphasizes that we need to be vigilant to ensure that ongoing technical transformations help us thrive and do not threaten the future of diverse ways of knowing or of intellectual and creative freedom (UNESCO, 2021, p. 9). It also draws undesirable scenarios that in the future universities will follow this path by delegating teaching tasks to other institutions or to special centres equipped with sophisticated AI-infused technologies.

Based on the introduced scenarios and contradictions, we may see that the role and function of AI in learning is a very complex issue. The task of this policy brief is to analyze AI in Higher Education from two inquiry perspectives:

- (1) What new opportunities can AI bring to teaching and learning in higher education, and
- (2) What risks and ethical challenges should be recognised when AI is implemented in teaching and learning in higher education.

After the analysis, several recommendations with examples will be presented for future actions in HE. This policy brief is mainly focused on pedagogical and educational themes even though AI can provide strong methods in many disciplines for research and knowledge production in HE.

The policy brief is based on intensive collaboration of the authors, who have worked with their research groups and networks in China, Finland, and USA, and shared their research and findings of the last three years in joint activities. The main aim has been to explore how AI can serve learning and education, and to examine what are the main risks. The culmination has been a joint book, **AI in Learning – Designing the Future** (2022) in which the cutting-edge researchers describe their cases, analyses, and reflections about AI in Learning. The authors of the policy brief are the editors of the book. The agreement of book was signed in 2021 and the manuscript has been submitted in January 2022. This policy brief is based on the common intellectual product.

## **2. New opportunities – AI is changing teaching and learning in Higher Education**

Recent AI technologies provide several options for learning and educational services which can be summarized (UNESCO, 2021a; Roschelle, Lester and Fusco, 2020):

- Natural language processing (NLP) for the use of AI to automatically interpret texts, including semantic analysis, used in translations, and for generating texts of learning contents, and supporting personalization processes.
- Speech recognition covers the application of NLP to spoken words, including smartphones, and provides AI personal assistants within games and intelligent tutoring systems, and for conversational bots in learning platforms.
- Image recognition and processing employs AI for facial recognition (e.g., for smart phone and computer login, and involving electronic documents and processes in classroom situations), handwriting recognition, text analysis (e.g. to detect plagiarism), image manipulation (e.g. for recognizing deep-fakes), and for autonomous scoring and grading.
- Autonomous agents use AI in computer game avatars, software bots, virtual learning spaces, smart robots.
- Affect detection employs AI to analyze sentiment in text, behavior and facial expressions.
- AI underlies data mining algorithms for predictive learning diagnoses, progress forecasting, socio-emotional wellbeing analysis, financial predictions, and fraud detection.
- Artificial creativity uses AI in systems that can create new kinds and exemplars of photographs, music, artwork, or stories.

We have reviews and ongoing research on how AI has been implemented in education and learning (Bransford et al. 2006; Niemi, 2020; 2021; Popenici and Kerr, 2017).). AI has already entered education and schools in different forms. Learning sciences has introduced for decades how learning analytics can help to recognize and facilitate learning processes with intelligent tools (Baker and Inventado, 2014; Fisher et al. 2020; Niemi, D. et al. 2018). Chen, Chen and Lin (2020) reviewed research on AI published in education in international journals between 2009-2019. The review provides evidence that AI has been extensively adopted and used in administration, instruction and learning. In administration, AI applications such as reviewing and grading students' assignments were seen as very useful and, in some cases, even more accurate than human-based assessments. Important implementations were also

applications for teachers which help them improve instruction with more knowledge about students' learning and with interactive tools for learners' knowledge construction and sharing.

In the context of higher education, AI can help students learning by **tutoring and personalization**. New technological systems have leveraged machine learning and adaptability. Curriculum and contents can be **customized** and personalized in line with students' needs. Reviews and analyses of current state of the art (Chen, Chen and Lin, 2020; Stone et al., 2016; Timms, 2016; Roschelle, Lester and Fusco, 2020) also reveal that a transformation has happened from computer and computer-related technologies to web-based and **online intelligent education systems**. Often with the use of embedded computer systems but also together with other technologies, we also note the use of humanoid robots and web-based chatbots to perform instructors' duties and functions independently or jointly with instructors. AI-related themes, such as **teaching robots, intelligent tutoring systems (ITS), online learning, and learning analytics**, have become common over the past several years (see e.g., Roschelle, Lester and Fusco, 2020; Stipancic et al. 2021). In many studies, **big data, learning analytics, and data mining** techniques have become major tools for personalized learning.

Roschelle et al. (2020) describes the recent development on the **multimodality of data**, which goes beyond observing what students type on a computer or how they answer questions. This kind of data can help HE students in multiple ways. Newer research-based systems can listen to recordings or watch videos of classrooms, finding events that are significant for learning outcomes (e.g., Suresh et al., 2019). Automated essay scoring is another longstanding application of AI (Page, 2003). It is also now rapidly expanding to **include assistive systems for peer grading, student collaboration**, and other educational applications of AI-based learning. New AI technologies, along with other emerging technologies, can produce learning innovations that include **rigorous performance assessment, virtual reality, voice-based systems, gesture-based systems, social, and educational robots, collaborative learning, mobile learning**, and more. In addition, for HE students, interactive e-books can be a great help for improving their learning (Jiang et al. 2022).

Many Higher Education programs have close connections with **professional competences**. In these tasks, AI techniques can be used, e.g., in healthcare education and training. AI has potential to help healthcare professionals to improve their clinical reasoning. Simulation games have been proven effective for learning clinical reasoning skills and AI with game metrics can be utilized in nursing simulation games (Koivisto et al. 2022). The game metrics provide an important on-line feed-back system for demonstrating learning outcomes.

New AI technology is multi-modal that allows the use of several data collection methods simultaneously. It is possible to train forthcoming professionals to learn how to cope in stressful situations in a simulation-based learning environments, while also collecting biomarkers about participants' physiological states in those critical incidents (Ruokamo et al, 2022). AI technology can also be used for **learning demanding hard skills situated in virtual reality (VR)** (Korhonen, et al. 2022). Learners can be provided with scaffolding by an AI Tutor within VLE to advance their learning.

Learning is a broad concept encompassing non-cognitive mental processes. Often, cognitive and non-cognitive elements are integrated, and AI can even help to connect cognitive and non-cognitive processes in learning. This integration opens many opportunities for supporting higher education students that have motivational or socio-emotional problems in their learning. AI based systems to gauge and intervene to contribute to students' wellbeing is critical as it marks their positive development in academic studies and ensures their future

growth. Tang et al. (2022) have introduced an automated scoring **wellbeing system**—featured as dynamic and real-time in giving immediate feedback at multiple organization layers (person, class, school). Task performance and emotion regulation skills were the most consistent skills to promote psychological wellbeing, academic wellbeing, and health-related outcomes.

Contemporary AI-based authentic and engaging learning environments transcend the traditional teacher-centric lecturing, incorporating types of learning experiences that are embodied, **project-based, inquiry-driven, collaborative, and open-ended**. AI-based tools and sensing technologies can help researchers and practitioners navigate and enact these novel approaches to learning with **new analytic techniques and interfaces**. Such socio-technical systems help researchers collect and analyze different types of multimodal data across contexts, while also providing a meaningful lens for student reflection and inquiry (e.g., Haber, 2022; Niu et al. 2022; Worsley, 2022).

In summary, we conclude that AI has brought and will continue to bring to HE several new ways to support individual students by intelligent tutoring, personalization of learning, providing augmented and virtual reality environments to professional competence learning in high-skill professional tasks, and helping students in socio-emotional wellbeing issues. Furthermore, AI has also brought methods to support cooperative and collaborative learning because many applications are suitable for **teamwork and team learning**, as they provide data that helps to understand the complicated interactive processes involved in multi-party project-based inquiry and learning tasks.

An expert panel (Roschelle et al., 2020, pp. 19-20) has discussed how AI could support teaching and learning. They conclude that the prospect is more like “orchestrating complex learning activities with multiple people and resources, augmenting human abilities in learning contexts, expanding naturalistic interactions among learners and with artificial agents, broadening the competencies that can be assessed, and revealing learning connections that are not easily visible.” They stressed that these approaches go beyond familiar design concepts for individualized, personalized, or adaptive learning.

### 3. What are risks and ethical challenges in integrating AI into human learning environments and socio-technical systems for education

AI has a huge potential in teaching and learning. However, the more we reflect on it, the clearer it becomes that the ethics of AI in education is a keystone issue which will ramify the future of AI-augmented learning (e.g., Coeckelbergh, 2020; Floridi et al. 2018; Henein et al. 2020; Joksimović et al., 2022). We have challenges around how these technologies may be re-shaping human development, we can already recognize risks of algorithmic biases and access inequities and acknowledge the need for learners’ critical consciousness concerning their data privacy.

Floridi et al. (2018) reviewed several guidelines for ethically sustainable AI policy that lay the foundations for a “Good AI Society.” First, they concluded the following value basis for what beneficial AI use is about: enabling human self-realization without devaluing human abilities, enhancing human agency without removing human responsibility, increasing societal capabilities without reducing human control, and cultivating societal cohesion without eroding human self-determination. Based on these concepts, they summarized the common principles that can be seen in most ethical guidelines, and that also should be followed. These principles can be summarized: AI *beneficence* means useful, reliable technology generously supporting the diversity of human well-being. AI *non-maleficence* would guarantee data security, accuracy, reliability, reproducibility, quality, and integrity. AI with *human autonomy* has

humans free to make decisions and choices regarding AI use. AI *with justice* operates in a fair and transparent manner, not obstructing democracy or harming society. *Explicable* AI enables clear explanation and interpretation of system functioning for humans and corresponding accountability and responsibility. These principles provide leading frames for AI, but how they can be applied in K-12 education and higher education teaching and learning would need more discussion and concrete examples.

Many applications have positive aims but also dark sides. Pea et al. (2022) has introduced ‘Four surveillance technologies creating challenges for education’, now being embraced by universities and preK-12 schools. These are: Location Tracking, Facial Identification, Automated Speech Recognition, and Social Media Mining. As such, ubiquitous AI is becoming infrastructural to cultural practices, embodied in cloud computing web services, and in sensors in phones and the physical world, creating a surveillance society, it is essential for education stakeholders, from policymakers to school leaders, teachers, parents, legislators, regulators, and industry itself, to tackle together the ethical issues of AI in education which these surveillance technologies foreground.

Many ethical issues are related to everyday life in HE. Learning always happens in social and cultural contexts, and teachers need more understanding of how they can integrate AI-based tools into their pedagogy in such a way that learners have agency and teachers have the capacity to orchestrate different digital tools, AI included. AI in learning is also a big societal issue and relates to how people’s privacy is ensured, how they understand what AI in learning is, and what the consequences are when life-wide and life-long multimodal data are gathered.

We need much more research and research-based discussion for making AI more trustworthy for users and to prevent misconceptions. The issues of privacy and ownership are essential. Who owns the data in multimodal environments? Who can use the information and for what purposes? Who is responsible for decisions with AI tools and services? Who can explain what happens in human and machine learning and decision making? These are big questions that should be urgently answered in educational settings, and we need much cross-disciplinary research cooperation. We also have experience suggesting that technology companies that develop systems for learning need a more theoretical basis for learning and pedagogy. In this regard, many more cooperative efforts between researchers, practitioners, and companies are needed.

#### **4. Recommendations and conclusions**

UNESCO (2021b) has presented the demand that digital technologies should aim to support—and not replace—schools. The report also claims that we should leverage digital tools to enhance student creativity and communication. When AI and digital algorithms are brought into schools and HE, we must be vigilant to ensure that they do not simply reproduce existing stereotypes and systems of exclusion. AI must not increase the digital gap and deepen inequities in education. Based on wide cooperation with its member states, the recommendations for AI policy were adopted by UNESCO’s General 24 November 2021 (UNESCO, 2021c). The consensus reaffirms a humanistic approach to the use of AI with a view towards protecting human rights and preparing all people with the appropriate values and skills needed for effective human–machine collaboration in life, learning and work, and for sustainable development. It advocates for human-controlled and human-centered AI development, where the deployment of AI should be in the service of people and to enhance human capacities. It recommends that the impact of AI on people and society should be monitored and evaluated throughout value chains. We may also ask critically how ethics relates to law—whether the different parties in AI system development and commerce will

voluntarily comply with ethically sustainable AI policy guidelines to provide the foundations for a “Good AI Society” or whether policies, laws and sanctions will be required to regulate the activities of the legal entities behind AI products and services in education.

AI is not a new thing in computing sciences, but its use in schools and HE is still under a developing phase. We need more understanding about what AI is, how to use it and what are its ethical premises. Ng et al. (2021) have reviewed how AI literacy has been conceptualized in recent research. They conclude and remind us that AI becomes a fundamental skill for everyone, not just for computer scientists and that it should be added as an element of every learner’s twenty-first century technological literacy in work settings and throughout everyday life (see also Nouri et al, 2019).

**Based on these humanistic approach values in AI use, and our analysis and recent discussion on AI in education, we recommend the following recommendations and actions in HE:**

**1. More exploration of the potential of AI for reshaping education and quality in HE**

AI must be used as a tool for raising quality and relevance of HE. HE plays a special role in educational systems. On the one hand, it relates to K-12 in that pre-college, secondary education prepares students for HE, and on the other hand, HE is responsible for the highest-level expertise in societies globally. In addition, in most countries, K-12 teachers have their preparatory education in HE institutions, and the quality of learning contents and pedagogy in HE has consequences for K-12 future schools.

Examples for future actions:

- **Interdisciplinary modules with AI.** The HE programs and teaching should prepare students to take high-level responsibility in societies and globally. HE should have courses or modules in how to explore and contribute to innovative new solutions of the grand challenges introduced as the UN’s strategic goals (Climate change, clean water, hunger etc.). AI can be part of these solutions, and e.g., big data, datamining, machine learning, alternative and virtual reality, simulations and games can all be used as AI-based methods.
- **AI as the tool for supporting professional competences.** Simulation, game metrics, augmented reality and virtual reality tutors can help students to practice skills and competences that would be otherwise difficult to achieve.
- **New pedagogy for students’ collaboration, engagement, and creativity with AI.** Students are not only the end users of AI, but potentially also problem-solvers in how to creatively use AI technologies (e.g., Ng et al. 2021). Students should learn together how to use, apply, and evaluate AI-based tools and methods in different kinds of collaborative and project-based learning tasks.

**2. Connecting AI with human development, learning and students’ well-being**

Examples for future actions:

- **AI tutoring systems** with virtual agents using reinforcement learning and natural language processing techniques, automatic scoring services with AI assistance can be used for enhancing students’ development of competences for work and participation in society.

- **Automized, dynamic and real-time feedback** systems for students' socio-emotional well-being can support individual students. As anonymized, they can help HE institutions to identify students' needs and to provide student services.
- **Online chatbots** for multiple HE modules as the teaching assistant can help students in learning.
- **HE teachers need to update their AI knowledge.** Teachers need knowledge concerning how AI-enhanced technologies such as adaptive learning systems can facilitate their daily teaching practice and management and promote personalized learning to understand students' learning progress and needs (see also Ng et al. 2021; Roschelle et al., 2020).

### 3. Promoting HE students' and teachers' AI literacy

AI literacy consists of basic competencies to know about and to critically understand, use, and apply AI in studying, but also widely in life and work. It also includes ethical awareness and responsible uses of AI, such as inclusiveness, fairness, accountability, and transparency. HE teachers and students alike need to equip themselves cognitively for future technological challenges and changes in their working life conditions and foster their social responsibility and uses of AI for societal good.

Examples for future actions:

- Organizing easily available and accessible training incorporating AI and how to apply it pedagogically and ethically in HE teaching and learning.
- Developing and providing multi-language, MOOC courses to introduce the fundamental knowledge and applications of AI for HE students and professionals in different disciplines without prior knowledge in this field. Free courses already available e.g., <https://www.elementsofai.com/> by the University of Helsinki & Reaktor.
- Launching international AI competitions and summer schools for the HE students from different countries and universities

### 4. AI for lifelong learning reform in a civil society – HE as a responsible actor

HE relates to the whole educational system and is part of continuous learning and education. HE should be a frontier to ensure that graduates have knowledge of AI. However, it also has responsibilities through preparing K-12 teachers so that the whole education system provides critical understanding of AI for learners of all ages.

HE should work in close cooperation with the whole educational ecosystem as well as with informal learning settings. HE should also promote critical awareness through research and discussion of why and how AI can be used for equity in teaching and learning. Globally, we have big differences in who has access to AI based tools and environments. AI can deepen digital gaps and UNESCO has been worried that vulnerable groups, e.g., refugees and girls, who will be easily excluded in AI policy and practices. There are also many warnings that algorithms in AI based environments can be biased and confound justice for different minoritized groups, such as people of color.

HE cannot solve all AI challenges alone but needs multilevel cooperation with other partners in civil societies, including policymakers, companies, industry, working life representatives and NGO organizations.

## References

- Baker, R.S., & Inventado P.S. (2014). Educational data mining and learning analytics. In J. Larusson, & B. White (Eds.), *Learning Analytics* (pp. 61–75). New York, NY: Springer. [https://doi.org/10.1007/978-1-4614-3305-7\\_4](https://doi.org/10.1007/978-1-4614-3305-7_4).
- Bransford, J., Stevens, R., Schwartz, D., Meltzoff, A., Pea, R., Roschelle, J., Vye, N., Kuhl, P., Bell, P., Barron, B., Reeves, B., & Sabelli, N. (2006). Learning theories and education: Toward a decade of synergy. In P. A. Alexander & P. H. Winne (Eds.), *Handbook of educational psychology* (pp. 209–244). Mahwah, NJ: Lawrence Erlbaum Associates Publishers.
- Chen (2020) L. , Chen, P. Chen, & Z. Lin (2020) Artificial Intelligence in Education: A Review. *IEEEAI Access*. 8, 75264-75278. <https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9069875>
- Coeckelbergh, M. (2020). Artificial intelligence, responsibility attribution, and a relational justification of explainability. *Science and Engineering Ethics*, 26, 2051–2068. <https://doi-org.libproxy.helsinki.fi/10.1007/s11948-019-00146-8>
- Fischer, C., Pardos, Z. A., Baker, R. S., Williams, J. J., Smyth, P., Yu, R., Slater, S., Baker, R., & Warschauer, M. (2020). Mining big data in education: Affordances and challenges. *Review of Research in Education*, 44(1), 130–160. <https://doi.org/10.3102/0091732X20903304>
- Floridi, L., Cowls, J. , Beltrametti, M., Chatila, R., Chazerand, P., Dignum, V., Luetge, C., Madelin, R., Pagallo, U., Rossi, F., Schafer, B., Valcke, P. & Vayena E. (2018). AI4People—An ethical framework for a good AI society: Opportunities, risks, principles, and recommendations. *Minds and Machines*, 28, 689–707. <https://doi.org/10.1007/s11023-018-9482-5>.
- Haber, N., (2022, submitted). Curiosity and Interactive Learning in Artificial Systems. In H. Niemi, R. Pea, and Y. Lu (Eds.), *AI in Learning. Designing the future*. Springer Nature.
- Henein, N., Willemsen, B., & Woo, B. (2020). The state of privacy and personal data protection, 2020–2022. *Gartner Report*.
- Jiang, B., Gu, M., & Ying Du, Y.,(2022, submitted) Recent Advances in Intelligent Textbooks for Better Learning. In H. Niemi, R. Pea, and Y. Lu (Eds.), *AI in Learning. Designing the future*. Springer Nature.
- Joksimović, S., Marshall, R., Rakotoarivelo, T., Ladjal, D., Zhan, C., & Pardo, A. (2022). Privacy-Driven Learning Analytics. In *Manage Your Own Learning Analytics* (pp. 1-22). Springer, Cham.
- Koivisto, J-M., Havola, S., Mäkinen, H. & Haavisto, H.(2022, submitted). Learning clinical reasoning through gaming in nursing education – Future scenarios of game metrics and AI. In H. Niemi, R. Pea, and Y. Lu (Eds.), *AI in Learning. Designing the future*. Springer Nature.
- Korhonen, T., Timo Lindqvist, T., Laine, J., & Hakkarainen (2022, submitted). Training Hard Skills in Virtual Reality: Developing a Theoretical Framework for AI-based Immersive Learning. In H. Niemi, R. Pea, and Y. Lu (Eds.), *AI in Learning. Designing the future*. Springer Nature.
- Ng, D.T.K., Leung, J.K.L., Chu, S.K.W., Qiao, M.S. (2021). Conceptualizing AI literacy: An exploratory review. *Computers and Education* (2).

- Niemi, D., Pea, R., Saxberg, B., & Clark, R.E. (2018). (Eds.). *Learning Analytics in Education*. Charlotte, NC: Information Age Publishing (Published in Chinese Translation, 2020).
- Niemi, H. (2020), Artificial intelligence for the common good in educational ecosystems. In *Humanistic futures of learning: Perspectives from UNESCO Chairs and UNITWIN Networks* (pp. 148–152). Paris: Ediciones UNESCO. Retrieved from <https://researchportal.helsinki.fi/en/publications/artificial-intelligence-for-the-common-good-in-educational-ecosys>
- Niemi, H. (2021) AI in learning: Preparing grounds for future learning. *Journal of Pacific Rim Psychology*, 15. <https://doi.org/10.1177/18344909211038105>
- Niemi, H., Pea, R., and Lu, Y. (Eds.) (2022, submitted). *AI in Learning. Designing the future*. Springer Nature.
- Niu, S.J. Li, X., and Jutong Luo, J. (2022, submitted). Multiple users' experiences of an AI-aided educational platform for teaching and learning. In H. Niemi, R. Pea, and Y. Lu (Eds.), *AI in Learning. Designing the future*. Springer Nature.
- Nouri, J., Zhang, L., Mannila, L., & Norén, E. (2019) Development of computational thinking, digital competence and 21<sup>st</sup> century skills when learning programming in K-9. *Education Inquiry*, 11(1), 1–17. <https://doi.org/10.1080/20004508.2019.1627844>
- OECD (The Organisation for Economic Co-operation and Development) (2021) OECD.AI. Policy observatory. *OECD AI Principles overview*. <https://oecd.ai/en/ai-principles>
- Page, E. B. (2003). Project essay grade: PEG. In M. D. Shermis & J. Burstein (Eds.), *Automated essay scoring: A cross-disciplinary perspective* (p. 43). Mahwah, New Jersey: Lawrence Erlbaum Associates.
- Pea, R., Biernacki, P., Bigman, M., Boles, K., Coelho, R., Docherty, V., Garcia, J., Lin, V., Nguyen, J., Pimentel, D., Pozos, R., Reynante, B., Roy, E., Southerton, E., Suzara, M., & Vishwanath, A. (2022, submitted). Four surveillance technologies creating challenges for education. In H. Niemi, R. Pea, and Y. Lu (Eds.), *AI in Learning. Designing the future*. Springer Nature.
- Popenici, S., & Kerr, S. (2017). Exploring the impact of artificial intelligence on teaching and learning in higher education. *Research and Practice in Technology Enhanced Learning*, 12(1), 1-13.
- Roschelle, J., Lester, J., & Fusco, J. (Eds.) (2020). *AI and the future of learning: Expert panel report*. Digital Promise. Retrieved from <https://circls.org/reports/ai-report>
- Ruokamo, H., Kangas, M., Vuojärvi, H., Sun, L., & Qvist, P. (2022, submitted) AI-Supported Simulation-Based Learning: Learners' Emotional Experiences and Self-Regulation in Challenging Situations. In H. Niemi, R. Pea, and Y. Lu (Eds.), *AI in Learning. Designing the future*. Springer Nature.
- Stipancic, T., Koren, L., Korade, D., & Rosenberg, D. (2021, ). PLEA: A social robot with teaching and interacting capabilities. *Journal of Pacific Rim Psychology*, <https://doi.org/10.1177/18344909211037019>

Stone, P., & 16 Study Panel members (2016). *Artificial intelligence and life in 2030, one hundred year study on artificial intelligence report of the 2015*. Stanford, CA: Stanford University. Retrieved from [https://ai100.stanford.edu/sites/g/files/sbiybj9861/f/ai100report10032016fnl\\_singles.pdf](https://ai100.stanford.edu/sites/g/files/sbiybj9861/f/ai100report10032016fnl_singles.pdf)

Suresh, A., Sumner, T., Jacobs, J., Foland, B., & Ward, W. (2019). Automating analysis and feedback to improve mathematics teachers' classroom discourse. *Proceedings of the AAAI Conference on Artificial Intelligence*, 33(01), 9721–9728.

Tang, X., Upadaya, K., Toyama, H., Kasanen, M., and Salmela-Aro, K. (2022, submitted) · Assessing and Tracking Students' Wellbeing through an Automated Scoring System: Schoolday Wellbeing Model, In H. Niemi, R. Pea, and Y. Lu (Eds.), *AI in Learning. Designing the future*. Springer Nature.

Timms, M.J. (2016). Letting artificial intelligence in education out of the box: Educational cobots and smart classrooms", *Int. J. Artif. Intell. Edu.*, 26, (2), 701-712. <https://link.springer.com/content/pdf/10.1007/s40593-016-0095-y.pdf>

UN (United Nations). (2021). *Resource Guide on Artificial Intelligence (AI) Strategies*. <https://sdgs.un.org/documents/resource-guide-artificial-intelligence-ai-strategies-25128>

UNESCO (United Nations Educational, Scientific and Cultural Organization). (2021a). *AI and education: guidance for policy-makers* (2021): Paris. <https://unesdoc.unesco.org/ark:/48223/pf0000376709>

UNESCO (United Nations Educational, Scientific and Cultural Organization). (2021b). *Reimagining our futures together: a new social contract for education*. Paris. <https://unesdoc.unesco.org/ark:/48223/pf0000379707>

UNESCO (United Nations Educational, Scientific and Cultural Organization). (2021c). *Report of the Social and Human Sciences Commission (SHS). UNESCO. General Conference, 41st, 2021 Item 8.2, the Ethics of Artificial Intelligence*, Adopted. 2411.2021. 41 C/73 Annex. Document code: 41 C/73. Paris. <https://unesdoc.unesco.org/ark:/48223/pf0000379920.page=14>

Worsley, M. (2022, submitted) Artificial Intelligence Innovations for Multimodal Learning, Interfaces, and Analytics, In H. Niemi, R. Pea, and Y. Lu (Eds.), *AI in Learning. Designing the future*. Springer Nature.

