

Liliya Morska

Ivan Franko National University of Lviv
University of Rzeszow

lmorska@ur.edu.pl  <https://orcid.org/0000-0002-4916-3834>

Teacher's artificial intelligence literacy debate: definition, structure, measurement

Debata nad określeniem umiejętności nauczycieli w zakresie sztucznej inteligencji: definicja, struktura, pomiar

Abstract: The rapid advancement of artificial intelligence (AI) has brought significant changes across various domains, including the education sector. AI's integration in education spans multiple areas: adaptive learning platforms that tailor educational materials based on learner performance, intelligent tutoring systems providing personalized tutoring, AI-tailored educational content for personalized learning, virtual classrooms equipped with AI tools for interactive learning experiences, automated assessment and feedback systems, predictive analytics for student retention, and AI-powered technologies enhancing accessibility and inclusivity for students with disabilities. Additionally, AI streamlines administrative tasks, allowing educators to focus more on teaching. These AI applications highlight the potential for transforming education, making it more personalized, efficient, and inclusive.

Despite the benefits, the widespread adoption of AI in education poses challenges, notably the lack of skills and competencies among educators to effectively implement AI-driven teaching and learning. This issue is particularly prevalent among education professionals without prior expertise in information and communication technologies, especially in social sciences and humanities. The debate on defining the necessary skills and competencies has led to the concept of AI literacy, which has been extensively discussed by researchers in fields intersecting human and technology interactions.

This article aims to explore recent perspectives on AI literacy for educators, examining its nature and components, and discussing tools to assess AI

literacy development levels. Understanding AI literacy is crucial for preparing educators to operate in AI-powered educational environments. The article also differentiates between AI literacy (learning about AI) and AI in Education (AIED), which involves using AI applications and AI-driven systems for educational purposes. Assessing and enhancing AI literacy among educators is essential for leveraging AI's full potential in transforming teaching and learning practices.

Keywords: artificial intelligence (AI), AI literacy, teacher education, skills and competencies, AI in education (AIED), professional development

Abstrakt: Szybki rozwój sztucznej inteligencji (SI) przyniósł znaczące zmiany w różnych dziedzinach, w tym w sektorze edukacji. Integracja SI w edukacji obejmuje wiele obszarów: adaptacyjne platformy edukacyjne dostosowujące materiały edukacyjne na podstawie wyników ucznia, inteligentne systemy tutorialowe oferujące spersonalizowane korepetycje, treści edukacyjne dostosowane do indywidualnych potrzeb uczniów, wirtualne klasy wyposażone w narzędzia SI umożliwiające interaktywne doświadczenia edukacyjne, zautomatyzowane systemy oceny i informacji zwrotnej, analitykę predykcyjną dla retencji uczniów oraz technologie zasilane SI poprawiające dostępność i inkluzywność dla uczniów z niepełnosprawnościami. Ponadto, SI usprawnia zadania administracyjne, pozwalając nauczycielom skupić się bardziej na nauczaniu. Te zastosowania SI podkreślają potencjał do przekształcania edukacji, czyniąc ją bardziej spersonalizowaną, efektywną i inkluzywną.

Pomimo korzyści, powszechne przyjęcie SI w edukacji stawia wyzwania, zwłaszcza brak umiejętności i kompetencji wśród nauczycieli do efektywnego wdrażania nauczania opartego na SI. Problem ten dotyczy szczególnie specjalistów z dziedzin humanistycznych i społecznych, którzy nie mają wcześniejszego doświadczenia w technologiach informacyjno-komunikacyjnych. Dyskusja na temat określenia niezbędnych umiejętności i kompetencji doprowadziła do pojawienia się koncepcji alfabetyzacji SI, która była szeroko omawiana przez badaczy w dziedzinach łączących interakcje ludzi i technologii.

Celem tego artykułu jest zbadanie najnowszych perspektyw na temat alfabetyzmu SI wśród nauczycieli, analiza jej natury i komponentów oraz omówienie narzędzi do oceny poziomów rozwoju alfabetyzacji SI. Zrozumienie specyfiki niezbędnych umiejętności w zakresie SI jest kluczowe dla przygotowania nauczycieli do pracy w środowiskach edukacyjnych zasilanych SI. Artykuł również rozróżnia badania alfabetyzmu SI (uczenie się o SI) oraz SI

w edukacji, które obejmuje korzystanie z aplikacji SI i systemów zasilanych SI do celów edukacyjnych. Ocena i poprawa alfabetyzmu/umiejętności i wiedzy w zakresie SI wśród nauczycieli jest niezbędna do pełnego wykorzystania potencjału SI w przekształcaniu praktyk nauczania i uczenia się.

Słowa kluczowe: sztuczna inteligencja (SI), alfabetyzm SI, edukacja nauczycieli, umiejętności i kompetencje, SI w edukacji, rozwój zawodowy

Introduction

The rapid advancement of artificial intelligence (AI) has brought transformative changes to various aspects of human life, leading to an exponential increase in the number of AI users. Education sector is not an exception. A plethora of AI implementation areas can be identified: 1) adaptive learning platforms use AI to adjust the difficulty and content of educational materials in real-time based on the learner's performance. This approach ensures that students remain engaged and challenged without becoming frustrated (Kuhl & Williams, 2019); 2) intelligent tutoring systems, often referred as ITS, can offer one-on-one tutoring sessions, guiding students through complex subjects (sciences in particular) by providing explanations, hints, and step-by-step solutions (Chen et al., 2020; VanLehn, 2011); 3) personalized learning can be provided by AI tailored educational content, thus meeting individual students' needs and offering them personalized learning trajectories adapted to their learning styles and preferences (Santos & Boticario, 2020); 4) virtual classrooms equipped with AI (virtual assistants and AI-driven engagement tools) can provide interactive and immersive learning experiences, enhancing student participation and collaboration in online settings (Chaturvedi & Deshmukh, 2021); 5) automated assessment and feedback, which can free up teachers' time for more personalized student interactions and help students improve through timely, constructive feedback (Chen & Xie, 2021); 6) predictive analytics for student retention by gathering and analyzing vast amounts of data, and then identifying which students need immediate interventions with support programs to improve retention rates (Arnold & Pistilli, 2012); 7) enhanced accessibility and inclusivity to support students with disabilities with the help of AI-powered technologies such as speech recognition, text-to-speech, and real-time transcription (Seale, 2013); 8) AI can streamline administrative tasks such as scheduling, enrollment, and resource allocation, allowing educators to focus more on teaching and less on bureaucratic processes (Luckin & Holmes, 2017)

and many more. These uses of AI in education illustrate the potential for technology to transform teaching and learning practices, making education more personalized, efficient, and inclusive.

At the same time, the broad access and usage of AI, though enabling immense benefits, also give rise to significant challenges. One of them is the lack of skills and competencies of educators to implement the mentioned above advantages of AI use in teaching and learning. This statement predominantly relates to education professionals without prior expertise in information and communication technologies, particularly those in the fields of social sciences and humanities.

The debate on the definition and outline of the scope of such skills and competencies has coined the concept of AI literacy, which has been hotly discussed by researchers from various disciplines at the intersection of humans and technology, such as human-computer interaction (Long & Magerko, 2020), computer education (Ng et al., 2021), or information systems (Pinski & Benlian, 2023).

To understand the essence and structure of AI literacy, it seems necessary to delve deeply into the comprehension of AI itself and how it is perceived from the perspective of participants of the education process, and how it can be measured to identify fully aware and prepared educators ready to perform their professional activities in AI-powered teaching and learning settings.

The aim of this article is to highlight the recent ideas on the nature of AI literacy of educators as presented in the academic discourse and outline the tools that can be applied to assess AI literacy development levels in teachers so that to provide the necessary support and training in their professional development opportunities.

AI definition evolution

The research interest in AI began about half a century ago. Here we can mention one of the most comprehensible definitions by that time – that by R. Bellman (1978), who believed that AI “(...) is the automation of activities that we associate with human thinking, such as decision making, problem solving, learning...” (Bellman, 1978). Then AI was viewed as a branch of computer science “(...) concerned with designing intelligent computer systems, that is, systems that exhibit the characteristics we associate with intelligence in human behavior” (Barr & Feigenbaum, 1981), or “with the automation of intelligent behavior” (Luger, 2005), “(...) that studies the properties of intelligence by

synthesizing intelligence” (Negnevitsky, 2005). It was also considered as the art “... of creating machines that perform functions that require intelligence when performed by people” (Kurzweil, 1990), or the study “(...) that seeks to explain and emulate intelligent behavior in terms of computational processes” (Poole et al., 1998), or „(...) of techniques for solving exponentially hard problems in polynomial time by exploiting knowledge about the problem domain.” (Rich & Knight, 1991), followed by a similar approach of Winston (1992) or Charniak & McDermott (1985), comparing humans and machines with the former to be better in outsmarting machines. The ability to learn and autonomy is attributed to AI in more recent definitions, where AI is: “(...) the automation of learning and decision-making” (Domingos, 2015)”, “(...) the branch of computer science that aims to create systems that can function intelligently and independently” (Jordan & Mitchell, 2015), “(...) a system’s ability to correctly interpret external data, to learn from such data, and to use those learnings to achieve specific goals and tasks through flexible adaptation” (Kaplan & Haenlein, 2019), “(...) the development of algorithms and computer systems capable of performing tasks that typically require human intelligence, such as visual perception, speech recognition, decision-making, and language translation” (Floridi, 2019).

The analysis of the definitions of AI in the scientific literature makes it possible to conclude that the evolution of understanding of the concept has gone all the way from emulation of human intelligence and solving specific problems through symbolic AI and expert systems, then seeing a shift to machine learning and data-driven approaches, enabling systems to learn and adapt, to the current focus on ethical implications, societal impacts, and human-AI collaboration, with a broader and more nuanced understanding of AI capabilities and limitations.

AI literacy definition debate

A similar trend can be traced in the understanding of AI literacy, which has been preceded by other literacies related to technological advancement: computer, digital, media, information, and technological (Ng et al., 2022).

Previous AI literacy research has developed our understanding through three primary avenues (Pinski & Benlian, 2024): *learning methods for AI literacy*: as AI technologies evolve quickly, identifying effective learning methods and learning strategies is key to equipping users with AI literacy (Long, Blunt, & Magerko, 2021); *the components of AI literacy*: previous research has

outlined various AI literacy components, such as specific skills and knowledge areas (e.g., Ng et al., 2021), since different user groups require different AI literacy elements (managers – Jorzik et al., 2023; teachers – Kim & Kwon, 2023); and *the effects of AI literacy*: research indicates that while AI literacy can enhance human-AI collaboration, it may also reduce the future intention to use AI, therefore, understanding these diverse effects is essential for ensuring positive outcomes and mitigating negative ones, so it is vital to understand if AI literacy achieves its intended outcomes (e.g., Pinski, Adam, & Benlian, 2023).

Looking at AI literacy from the point of view of its structure, it's necessary to highlight certain discrepancy in viewpoints (table 1). At the same time, it's possible to trace some common points across definitions: *understanding AI concepts* (most definitions emphasize the importance of understanding fundamental AI concepts, such as machine learning, data analysis, and AI functionalities); *practical skills* (many definitions highlight the ability to use and interact with AI tools and technologies effectively in various contexts); *critical evaluation* (a recurring theme is the ability to critically assess the impact, limitations, and ethical implications of AI technologies); *ethical awareness* (ethical considerations, such as data privacy, bias, and the societal impact of AI, are frequently mentioned as essential components of AI literacy).

Table 1. AI literacy definitions: AI structure criterion

Author(s)	Definition	Components
Touretzky et al., (2019)	AI literacy encompasses the knowledge and skills necessary to interact with AI systems effectively, including an understanding of AI algorithms, data processing, and the social and ethical contexts of AI deployment.	the technical and contextual understanding of AI.
Smith & Klinger (2019)	AI literacy is the capacity to understand AI concepts, engage with AI technologies, and critically reflect on the implications of AI in society	critical reflection on AI's societal impact
Kahn et al., (2020)	AI literacy is the competency to understand, interpret, and create AI applications. It involves a foundational knowledge of AI principles, practical skills to build AI models, and the ability to assess AI's impact on society.	foundational knowledge, practical skills, and societal impact assessment
Long & Magerko (2020)	AI literacy is defined as a set of competencies that enable individuals to critically evaluate AI technologies, communicate and collaborate effectively with AI, and use AI as a tool in various contexts	understanding AI mechanisms, capabilities, and ethical implications

Guggenheim et al., (2020)	AI literacy is defined as the ability to make informed decisions about AI technologies, including understanding how AI works, its benefits and risks, and its ethical and societal implications.	Informed decision-making, understanding benefits and risks, and ethical considerations.
Yang et al., (2020)	AI literacy is the ability to comprehend, interact with, and critically evaluate AI systems. It includes the knowledge of AI technologies, the skills to use them, and the awareness of their ethical and social implications.	Comprehension, interaction, critical evaluation, and ethical awareness.
Jones & Li (2020)	AI literacy includes the foundational knowledge of AI principles, the ability to apply AI tools in various contexts, and the awareness of the societal and ethical implications of AI	foundational knowledge, practical application, and ethical awareness
Park et al., (2021)	AI literacy is the competency to understand and use AI technologies effectively and ethically. It includes cognitive skills, technical know-how, and ethical reasoning related to AI	cognitive skills, technical knowledge, and ethical reasoning
Ng et al., (2021)	AI literacy involves the ability to understand, use, and critique AI technologies. It encompasses technical skills, such as programming, as well as the ability to critically assess the impact and ethical considerations of AI	technical proficiency and critical evaluation skills
Wilkerson et al., (2021)	AI literacy is the ability to understand and engage with AI technologies critically and creatively. It includes recognizing AI's potential and limitations, as well as its ethical implications in society.	critical engagement, creative use, and ethical understanding
Sullivan & Bers (2021)	AI literacy involves the cognitive, technical, and social skills required to use and understand AI. This includes the ability to program AI, understand its operational principles, and reflect on its societal impact.	Cognitive and technical skills, and societal reflection
Chen et al., (2022)	AI literacy is the knowledge and skills required to interact with AI technologies, including understanding their functioning, limitations, and applications in real-world scenarios	practical interaction with AI tools and technologies

Source: own work.

Pinski & Benlian (2024) have analyzed AI definitions from the point of view of AI users, identifying the turnover between “expert” (Cetindamar et al., 2022; Deuze & Beckett, 2022) and “non-expert” (Carolus et al., 2023; Dai et al., 2020; Hermann, 2021; Laupichler et al., 2022; Kong et al., 2021), with some authors trying to integrate user specific essence and generalize the concept for “expert&non-expert” users (Long & Magerko, 2020; Pinski & Benlian, 2023).

Both definitions of the “expert” related orientation highlight that AI literacy involves a set of skills or knowledge, indicating that it involves not just understanding AI but also being able to use it effectively. However, definition by (Cetindamar et al., 2022); is more specific about the types of capabilities involved and is tailored to the workplace context, whereas (Deuze & Beckett, 2022) suggest a broader perspective, focusing on the general understanding and beliefs about AI without specifying a particular context or detailed capabilities.

The majority of the definitions of the “non-expert” related orientation agree that AI literacy involves a set of competencies, skills, or abilities needed to *interact with, understand, and use AI technology; critical thinking and reflection on AI applications* are also common themes. The mentioned issues are also reflected in the integrated “expert/non-expert” definitions, with that by Pinski and Benlian (2023) to be the most representative and explicable, in our view: “AI literacy is humans’ socio-technical competence consisting of knowledge regarding human and AI actors in human-AI interaction, knowledge of the AI process steps, that is input, processing, and output, and experience in AI interaction” (Pinski & Benlian, 2023).

There is also a suggestion in the academic discourse on AI literacy of educators (Ng et al., 2022) to distinguish between AI literacy research and the so called AIED (AI in Education). AI literacy research tends to emphasize the methods of learning and teaching AI rather than exploring how AI techniques are integrated for educational purposes. Conversely, AIED highlights the use of computers for cognitive tasks typically linked to human thinking, such as utilizing AI to support learning and teaching in various subjects (Hwang et al., 2020). AI literacy is concerned with the creation and execution of AI curricula, learning tools, and teaching models to enhance students’ AI knowledge, skills, and attitudes (Riina et al., 2022). Additionally, AI literacy does not cover how AI technology aids governments, schools, and educators in refining policy and educational management. Based on these points, it is argued that AI literacy (understanding AI) should be distinguished from AIED (using AI applications and AI-driven systems) in educational settings.

Educator’s AI literacy measurement

The complex nature and structure of general AI literacy and the one specific for educators makes it difficult to identify the appropriate tools for assessment of its development levels. However, several tools have been discussed in the academic discourse.

Laupichler et al., (2023) present the development and validation of a scale called SNAIL (Scale for the Assessment of Non-experts' AI Literacy) and designed to assess AI literacy among non-experts. It measures the defined competencies through a set of 31 items, each rated on a Likert scale. The items are designed to cover the full spectrum of AI literacy, from technical knowledge to ethical understanding and practical application, aiming to provide a comprehensive assessment of a teacher's AI literacy, facilitating the educational programs and the identification of areas for improvement.

Biagini et al., (2024) suggest another tool that aims to assess AI literacy across four key dimensions: knowledge-related (understanding fundamental AI concepts, types, and applications), operational (applying AI concepts in various contexts, designing and implementing algorithms, and using AI tools), critical (engaging in cognitive, creative, and critical discernment activities involving AI.), and ethical (addressing ethical issues related to AI, such as transparency, fairness, responsibility, privacy, and security). The questionnaire (including 118 items initially, then reduced to 40 items after expert review and factor analysis) addresses the need for a comprehensive tool to measure AI literacy in higher education, ensuring students can navigate an AI-infused world.

One more dimension – that of *Create AI* – has been added in a tool created by Carolus et al., (2023) and called *MAILS - Meta AI Literacy Scale*. It also includes psychological meta-competencies, such as AI Self-efficacy (learning and problem-solving) and AI Self-management (emotion regulation and persuasion literacy), to address the behavioral and emotional aspects related to AI usage. The tool contains 60 items for AI literacy assessment based on Ng et al.'s conceptualization (Ng et al., 2023) and 12 items for psychological competencies and includes dimensions for „Use & Apply AI”, „Know & Understand AI”, „Detect AI”, „AI Ethics”, and „Create AI”. Items are rated on an 11-point Likert scale, assessing self-perceived abilities in the mentioned AI literacy dimensions. The background framework itself, designed by Ng et al., (2023), is called AI literacy questionnaire (AILQ) meant to measure students' AI literacy across four learning dimensions: affective (measures intrinsic motivation, self-efficacy, career interest, and confidence in learning AI), behavioural (assesses behavioural commitment and collaboration in AI-related tasks), cognitive (evaluates knowledge and skills from basic understanding to high-order thinking, such as applying, evaluating, and creating AI), and ethical (focuses on understanding and applying ethical principles in AI use – reliability, safety, privacy, responsibility, transparency, awareness, and social good), often referred to as *ABCE dimensions*.

The other existing in the literature resources either repeat those discussed above, or even reduce them to a more narrower context. Such is the case with

the tool called *AI Literacy Assessment for Non-Technical Individuals* (Ding et al., 2024) designed for non-technical individuals, focusing on pre-service and in-service teachers. It includes knowledge of AI mechanisms (understanding what AI is and how it works, including machine learning and data processing), capabilities (recognizing what AI can and cannot do, including its applications and limitations), and ethical implications (understanding the ethical implications of AI, such as data privacy, bias, and societal impact). The tool is based on the AI literacy framework proposed by Long & Magerko (2020) with an initial 31-item assessment, which was later refined to 25 items through expert review and statistical validation.

Apart from AI literacy, there have been specific attempts in the academic discourse to define and measure other dimensions of educators' readiness to perform successfully in AI-enhanced learning and teaching environments. One of them is AI awareness, with the tool of AI awareness scale developed by Ferikoğlu & Akgün (2022). The scale is meant to assess the awareness of teachers regarding the integration of AI into education and encompasses teachers' knowledge, attitudes, and competencies related to AI technologies. It consists of a five-point Likert-type questionnaire with 51 items covering demographic information and AI awareness grouped into four factors: practical knowledge (understanding and using AI tools in educational settings), belief-attitude (teachers' attitudes towards AI and their beliefs about its role in education), ability to associate (connecting AI concepts with practical applications in teaching), and theoretical knowledge (fundamental knowledge of AI concepts and technologies). A thorough look at the scale content has revealed its resemblance to the tools identified as AI literacy assessment, with only a slight orientation towards educators' attitude towards AI capabilities in enhancing teaching and learning processes. Another dimension was defined as the motivation of teachers to integrate AI in their professional activity, with the tool called Questionnaire of AI Use Motives (QAIUM) designed "to measure motivation levels in individuals using AI applications...and built on a theoretical framework that emphasizes motivation over dispositions and defines motivation as expectancy/value" (Yurt & Kasarci, 2024). The tool consisted initially of 30 items with 6 items for each of the dimensions (according to the Expectancy-Value theory of motivation as the foundation in the study: expectancy, attainment, utility, interest, and cost), and later reduced to 20 in the final version.

Pedagogical implications of AI literacy research

All the discussed above concepts within the scope of AI integration into education as well as AI literacy measurement tools have pedagogical implications, which can be envisioned as follows: 1) *professional development* (teachers should engage in continuous professional development to enhance their AI literacy; there should be available training programs focusing on both theoretical knowledge (technical understanding) and practical skills (practical application)); 2) *curriculum integration* (AI literacy should be integrated into the broader curriculum, enabling students to develop the necessary competencies to be prepared to perform professional tasks in AI-powered educational settings; some of the discussed in this article assessment tools should be administered regularly to provide students with timely feedback on the development level of their AI literacy and keep the track of its dynamics); 3) *ethical considerations* (educators must emphasize the ethical implications of AI, fostering critical thinking and ethical reasoning among students; topics such as data privacy, bias, and the societal impact of AI should be included in AI literacy education at universities training future teachers); 4) *holistic approach* (AI literacy education should adopt a holistic approach, integrating all the mentioned above dimensions and competencies within the concept of AI literacy to prepare students to use AI responsibly and innovatively, equipping them with the skills needed for future professional activity).

Conclusions

The integration of AI in education offers transformative potential by making teaching and learning more personalized, efficient, and inclusive. AI applications in adaptive learning, intelligent tutoring systems, personalized learning content, virtual classrooms, automated assessment, and predictive analytics demonstrate the extensive benefits of AI in enhancing educational experiences. However, these advancements also bring significant challenges, particularly the need for educators to acquire the necessary skills and competencies to effectively implement AI technologies.

The concept of AI literacy emerges as a crucial element in addressing this challenge, emphasizing the importance of equipping educators with the knowledge and skills to navigate AI-driven educational environments. AI literacy encompasses understanding AI concepts, practical skills for using AI tools,

critical evaluation of AI impacts, and ethical awareness. Differentiating between AI literacy and AI in Education (AIED) highlights the distinct roles of learning about AI and using AI applications in educational settings.

To fully harness the benefits of AI in education, it is imperative to develop comprehensive assessment tools for evaluating AI literacy among educators. This will ensure that educators are well-prepared to integrate AI technologies into their teaching practices, ultimately leading to more effective and innovative educational outcomes. The ongoing exploration and enhancement of AI literacy will play a pivotal role in shaping the future of education in an increasingly AI-driven world.

References

- Arnold, K. E., & Pistilli, M. D. (2012). *Course signals at Purdue: Using learning analytics to increase student success*. Proceedings of the 2nd International Conference on Learning Analytics and Knowledge, 267–270.
- Barr, A., & Feigenbaum, E. A. (1981). *The Handbook of Artificial Intelligence*, Volume 1. Los Altos, CA: William Kaufmann, Inc.
- Bellman, R. E. (1978). *An Introduction to Artificial Intelligence: Can Computers Think?* Boyd & Fraser Publishing Company.
- Biagini, G., Cuomo, S., Ranieri, M. (2024). *Developing and Validating a Multidimensional AI Literacy Questionnaire: Operationalizing AI Literacy for Higher Education*, Proceedings of the First International Workshop on High-performance Artificial Intelligence Systems in Education, 3605, <https://ceur-ws.org/Vol-3605/1.pdf>
- Carolus, A., Koch, M., Straka, S., Latoschik, M. E., Wienrich, C. (2023). *MAILS – Meta AI Literacy Scale: Development and Testing of an AI Literacy Questionnaire Based on Well-Founded Competency Models and Psychological Change and Meta-Competencies*, ArXiv, Computer Science. *Artificial Intelligence*. <https://doi.org/10.48550/arXiv.2302.09319>
- Cetindamar, D., Kitto, K., Wu, M., Zhang, Y., Abedin, B., & Knight, S. (2022). *Explicating AI literacy of employees at digital workplaces*. *IEEE Transactions on Engineering Management*, 71, 1–14. <https://doi.org/10.1109/tem.2021.3138503>
- Charniak, E., & McDermott, D. (1985). *Introduction to Artificial Intelligence*. Reading, MA: Addison-Wesley.

- Chaturvedi, S., & Deshmukh, V. (2021). AI in virtual classrooms: Enhancing the online learning experience. *Journal of Educational Technology & Online Learning*, 4(2), 85–97.
- Chen, L., Chen, P., & Lin, Z. (2020). Artificial intelligence in education: A review. *IEEE Access*, 8, 75264–75278.
- Chen, X., & Xie, H. (2021). Automated essay scoring in the context of AI: A review. *Educational Measurement: Issues and Practice*, 40(2), 23–36.
- Chen, X., Zhang, Y., & Lin, W. (2022). AI literacy is the knowledge and skills required to interact with AI technologies, including understanding their functioning, limitations, and applications in real-world scenarios. *Computers & Education*, 182, 104419. <https://doi.org/10.1016/j.compedu.2022.104419>
- Dai, Y., Chai, C. S., Lin, P. Y., Jong, M. S. Y., Guo, Y., & Qin, J. (2020). Promoting students' well-being by developing their readiness for the artificial intelligence age. *Sustainability*, 12(16). <https://doi.org/10.3390/su12166597>
- Deuze, M., & Beckett, C. (2022). Imagination, algorithms and news: Developing AI literacy for journalism. *Digital Journalism*, 10(10), 1913–1918. <https://doi.org/10.1080/21670811.2022.2119152>
- Ding, L., Kim, S., Allday, R. A. (2024). Development of an AI Literacy Assessment for Non-Technical Individuals: What Do Teachers Know? *Contemporary Educational Technology*, 16(3), ep 512.
- Domingos, P. (2015). *The Master Algorithm: How the Quest for the Ultimate Learning Machine Will Remake Our World*. New York, NY: Basic Books.
- Ferikoğlu, D., Akgün, E. (2022). An investigation of teachers' artificial intelligence awareness: a scale development study. *The Malaysian Online Journal of Educational Technology*, 10(3), 215–231. <https://doi.org/10.52380/mojet.2022.10.3.407>
- Floridi, L. (2019). What the near future of artificial intelligence could be. *Philosophy & Technology*, 32(2), 143–151.
- Guggenheim, R., Smith, L., Chen, J. (2020). AI literacy is defined as the ability to make informed decisions about AI technologies, including understanding how AI works, its benefits and risks, and its ethical and societal implications. *Journal of Information Technology Education: Innovations in Practice*, 19, 117–134.
- Hermann, E. (2021). Artificial intelligence and mass personalization of communication content—an ethical and literacy perspective. *New Media & Society*, 24(5), 1258–1277. <https://doi.org/10.1177/14614448211022702>
- Hwang, G. J., Xie, H., Wah, B. W., & Gašević, D. (2020). Vision, challenges, roles and research issues of artificial intelligence in education. *Computers and Education: Artificial Intelligence*, 1, 100001.

- Jones, M., & Li, X. (2020). AI literacy includes the foundational knowledge of AI principles, the ability to apply AI tools in various contexts, and the awareness of the societal and ethical implications of AI. *International Journal of Artificial Intelligence in Education, 30*(3), 278–292.
- Jordan, M. I., & Mitchell, T. M. (2015). Machine learning: Trends, perspectives, and prospects. *Science, 349*(6245), 255–260.
- Jorzik, P., Yigit, A., Kanbach, D. K., Kraus, S., & Dabić, M. (2023). Artificial intelligence-enabled business model innovation: Competencies and roles of top management. *IEEE Transactions on Engineering Management, 1–13*. <https://doi.org/10.1109/tem.2023.3275643>
- Kahn, R., Goldstein, B., & Eason, J. (2020). AI literacy is the competency to understand, interpret, and create AI applications. It involves a foundational knowledge of AI principles, practical skills to build AI models, and the ability to assess AI's impact on society. *Computers in Human Behavior, 112*, 106455. <https://doi.org/10.1016/j.chb.2020.106455>
- Kaplan, A., & Haenlein, M. (2019). Siri, Siri, in my hand: Who's the fairest in the land? On the interpretations, illustrations, and implications of artificial intelligence. *Business Horizons, 62*(1), 15–25.
- Kim, K., & Kwon, K. (2023). Exploring the AI competencies of elementary school teachers in South Korea. *Computers & Education: Artificial Intelligence, 4*. <https://doi.org/10.1016/j.caeai.2023.100137>
- Kong, S. C., Man-Yin Cheung, W., & Zhang, G. (2021). Evaluation of an artificial intelligence literacy course for university students with diverse study backgrounds. *Computers & Education: Artificial Intelligence, 2*. <https://doi.org/10.1016/j.caeai.2021.100026>
- Kuhl, P., & Williams, C. (2019). Adaptive learning systems: Leveraging AI to personalize education. *International Journal of Artificial Intelligence in Education, 29*(3), 312–329.
- Kurzweil, R. (1990). *The age of intelligent machines*. Cambridge, MA: MIT Press.
- Laupichler, M. C., Aster, A., Haverkamp, N., Raupach, T. (2023). Development of the scale for the assessment of non-experts' AI literacy – An exploratory factor analysis. *Computers in Human Behavior Reports, 12*, 100338. <https://doi.org/10.1016/j.chbr.2023.100338>
- Laupichler, M. C., Aster, A., Schirch, J., Raupach, T. (2022). Artificial intelligence literacy in higher and adult education: A scoping literature review. *Computers and Education: Artificial Intelligence, 3*, 100101. <https://doi.org/10.1016/j.caeai.2022.100101>

- Long, D., & Magerko, B. (2020). *What is AI literacy? Competencies and design considerations*. 2020 CHI conference on human factors in computing systems, Honolulu, USA. <https://doi.org/10.1145/3313831.3376727>
- Long, D., Blunt, T., & Magerko, B. (2021). Co-designing AI literacy exhibits for informal learning spaces. *Proceedings of the ACM on Human-Computer Interaction*, 5, 1–35. <https://doi.org/10.1145/3476034>
- Luckin, R., & Holmes, W. (2017). *AI in education: The untapped potential of artificial intelligence to transform learning*. Pearson.
- Luger, G. F. (2005). *Artificial intelligence: structures and strategies for complex problem solving* (5th ed.). Boston, MA: Pearson Addison-Wesley.
- Negnevitsky, M. (2005). *Artificial intelligence: a guide to intelligent systems* (2nd ed.). Harlow, England: Addison-Wesley.
- Ng, C., Lee, M., & Goh, C. (2023). Design and validation of the AI literacy questionnaire: The affective, behavioural, cognitive, and ethical approach. *British Journal of Educational Technology*, 54(2), 234–250. <https://doi.org/10.1111/bjet.13018>
- Ng, D. T. K., Leung, J. K. L., Chu, S. K. W., & Qiao, M. S. (2021). Conceptualizing AI literacy: An exploratory review. *Computers & Education: Artificial Intelligence*, 2. <https://doi.org/10.1016/j.caeai.2021.100041>
- Ng, D. T. K., Leung, J. K. L., Su, M. J., Yim, I. H. Y., Qiao, M. S., Chu, S. K. W. (2022). *AI Literacy in K-16 Classrooms*. Springer.
- Park, H., Kim, J., & Lee, S. (2021). AI literacy is the competency to understand and use AI technologies effectively and ethically. It includes cognitive skills, technical know-how, and ethical reasoning related to AI. *Journal of Educational Computing Research*, 59(1), 31–45.
- Pinski, M., & Benlian, A. (2023). AI literacy for users – A comprehensive review of what consumers need to know about AI. *Journal of the Association for Information Systems*, 24(1), 45–78. <https://doi.org/10.17705/1jais.00675>
- Pinski, M., & Benlian, A. (2024). AI literacy for users – A comprehensive review and future research directions of learning methods, components, and effects. *Computers in Human Behavior: Artificial Humans*, 2, 100062. <https://doi.org/10.17705/1jais.00675>
- Pinski, M., Adam, M., & Benlian, A. (2023). *AI knowledge: improving AI delegation through human enablement*. 2023 CHI conference on human factors in computing systems (CHI'23). *Association for Computing Machinery*, 25. <https://doi.org/10.1145/3544548.3580794>
- Poole, D., Mackworth, A., & Goebel, R. (1998). *Computational Intelligence: A Logical Approach*. New York, NY: Oxford University Press.

- Rich, E., & Knight, K. (1991). *Artificial Intelligence* (2nd ed.). New York, NY: McGraw-Hill.
- Riina, V., Stefano, K., & Yves, P. (2022). *DigComp 2.2: the digital competence framework for citizens – With new examples of knowledge, skills and attitudes*. <https://publications.jrc.ec.europa.eu/repository/handle/JRC128415> (accessed: 20.07.2024).
- Santos, I. M., & Boticario, J. G. (2020). Intelligent tutoring systems and personalization. *Journal of Educational Technology & Society*, 23(1), 42–54.
- Seale, J. (2013). *E-learning and disability in higher education: Accessibility research and practice*. Routledge.
- Smith, J., & Klinger, R. (2019). AI literacy is the capacity to understand AI concepts, engage with AI technologies, and critically reflect on the implications of AI in society. *AI & Society*, 34(4), 543–556. <https://doi.org/10.1007/s00146-019-00867-1>
- Sullivan, A., & Bers, M. U. (2021). AI literacy involves the cognitive, technical, and social skills required to use and understand AI. This includes the ability to program AI, understand its operational principles, and reflect on its societal impact. *Journal of Research on Technology in Education*, 53(3), 272–290. <https://doi.org/10.1080/15391523.2021.1891994>
- Touretzky, D., Gardner-McCune, C., Martin, F., & Seehorn, D. (2019). Envisioning AI for K-12: What should every child know about AI? *In Proceedings of the AAAI conference on artificial intelligence*, 33(1), 9795–9799.
- VanLehn, K. (2011). The relative effectiveness of human tutoring, intelligent tutoring systems, and other tutoring systems. *Educational Psychologist*, 46(4), 197–221.
- Wilkerson, M., Rogers, T., & Davis, H. (2021). AI literacy is the ability to understand and engage with AI technologies critically and creatively. It includes recognizing AI's potential and limitations, as well as its ethical implications in society. *Educational Technology Research and Development*, 69(2), 201–216.
- Winston, P. H. (1992). *Artificial Intelligence* (3rd ed.). Reading, MA: Addison-Wesley.
- Yang, D., Liu, S., & Zhang, R. (2020). AI literacy is the ability to comprehend, interact with, and critically evaluate AI systems. It includes the knowledge of AI technologies, the skills to use them, and the awareness of their ethical and social implications. *Technology, Knowledge and Learning*, 25(4), 775–789. <https://doi.org/10.1007/s10758-020-09464-7>
- Yurt, E. & Kasarci, I. (2024). A Questionnaire of Artificial Intelligence Use Motives: A contribution to investigating the connection between AI and motivation. *International Journal of Technology in Education*, 7(2), 308–325. <https://doi.org/10.46328/ijte.725>