Pedagogically aware use and adaptation of artificial intelligence in the teaching and learning practice of higher education institutions

1. Introduction

The education sector faces many challenges and trends nowadays summarized by the latest version of OECD's Trends Shaping Education: widening socio-economic inequalities, rapidly ageing population, reduction of working hours, the rise of flexible work, changing family structures, challenges of affordable housing, increasing uncertainty related to almost endless data and information, opportunities from the virtual world, changing virtual identity etc. (OECD, 2022). Many of these challenges and trends can be linked to "the rapidly unfolding processes through which digital innovation comes to fundamentally alter historically sustainable logics for value creation and capture by unbundling and recombining linkages among resources or generating new ones" (Skog et al., 2018, p. 432). Digital transformation can exacerbate existing and create new inequalities (digital divide) (Hargittai, 2021), while digital technologies are ubiquitously present in our lives (mobile phones, smart homes, wearable tech etc.) and can create additional challenges regarding the abundance and trustworthiness of information (fake news, deep fake videos etc.). The education sector just started to recover from the shock of the COVID-19-induced emergency remote teaching period and now must react to the disruptive effect of the rise of artificial intelligence solutions (Tuomi, 2022) heralded by the public release of ChatGPT by OpenAI at the end of November 2022 (Farrokhnia et al., 2023). As the Qingdao Declaration (UNESCO, 2015) affirmed the need for leveraging information and communication technology (ICT) to foster quality and inclusive education (UN's Sustainable Development Goal 4), the Beijing Consensus reaffirmed this commitment considering AI especially (UNESCO, 2019). This research was planned in alignment with these recommendations.

DEFINITIONS

Given the multidisciplinary nature of the topic, it is important to provide a comprehensive and technical review of the basic definitions that are used during the research. It is important to have a common language about how AI in education is used (Molenaar, 2022).

Artificial Intelligence: "Artificial intelligence (AI) systems are software (and possibly also hardware) systems designed by humans that, given a complex goal, act in the physical or digital dimension by perceiving their environment through data acquisition, interpreting the collected structured or unstructured data, reasoning on the knowledge, or processing the information, derived from this data and deciding the best action(s) to take to achieve the given goal. AI systems can either use symbolic rules or learn a numeric model, and they can also adapt their behaviour by analysing how the environment is affected by their previous actions." (High-Level Expert Group on Artificial Intelligence, 2019, p. 6)

Machine Learning: "Machine learning (ML) is the scientific study of computer algorithms that improve automatically through experience. ML can be considered the practical implementation of AI. ML algorithms build a model based on training data, to make predictions or decisions without being explicitly programmed to do so. ML can be divided into:

- **Supervised learning** (regression, probabilistic graphical models, artificial neural networks and deep learning, decision trees, classifiers, ensemble learning): maps input to output values based on labelled examples of input-output pairs. Supervised learning needs a considerable amount of labelled data, which is often done by humans.
- **Unsupervised learning** (clustering, dimensionality reduction, generative adversarial networks, autoencoders): helps find previously unknown patterns in datasets without pre-existing labels. The objective is to discover the underlying data structure […]. Unsupervised learning does not require labelled data but instead tries to learn by itself.
- **Semi-supervised learning**: can be considered a category between supervised and unsupervised learning, where the data contains both labelled and unlabelled data.
- **Reinforcement learning** (RL) (deep reinforcement learning, inverse reinforcement learning, q-learning): explores how agents take actions in an environment to maximize a reward. An example is when the RL agent plays Go against itself, learns the game, and acquires above human intelligence in Go." (Joint Research Centre (European Commission) et al., 2021, p. 14)

The three "laws" governing the development of information technologies (increasing processing capacity, increasing communication speed and increasing storage capacity) reached a level nowadays that allowed artificial intelligence to evolve from a rule-based system to a data- and context-driven system (Panigrahi & Joshi, 2020) which now has captured the attention of policymakers (Zhao & Liu, 2019) as it is evident from a recent comprehensive report where they found national AI strategies for 62 countries (Maslej et al., 2023). The review also includes Hungary, whose National AI Strategy includes "Education, competence development and societal preparedness" as one of the main foundation pillars (Artificial Intelligence Coalition & Digital Success Programme, 2020).

Referring to the impact of the COVID-19-induced emergency remote teaching period regarding the acceleration of digital transformation, the recent Horizon Report on teaching and learning identifies AI tools as key technologies

that significantly influence the future of education, focusing on AI for learning analytics (institutional perspective) and AI for learning tools (student perspective) (Pelletier et al., 2022). Even though the public release of ChatGPT caused a shockwave in higher education, since COVID (but pre-ChatGPT) one-quarter of educational institutions already successfully implemented some AI technologies, up by 10% between 2019 and 2022 with a further 21% and 23% planning to introduce AI in the short- and in the medium- or long-term respectively (HolonIQ Education Intelligence Unit, 2023).

Undoubtedly, AI became an important and relevant phenomenon for the education sector (Dietz, 2020), one which has the potential to disrupt existing processes and long-held beliefs. Although in the short term, we tend to overestimate the impact of a given technology (considering AI at the beginning of Gartner's hype cycle), in the long term we tend to underestimate them. Proposing the rather intimidating question in its title – "Is Education Losing the Race with Technology?" – the OECD report investigated AI capabilities with the framework of the Programme for the International Assessment of Adult Competencies (PIAAC) and found, based on expert interviews, that AI potentially can reach Level 3 proficiency in literacy (as an OECD average, 90% of adults are at or below Level 3) and Level 2 proficiency in numeracy (as an OECD average, 57% of adults are at or below Level 2) (OECD, 2023a). Furthermore, in certain tasks, OpenAI's ChatGPT 4.0 model scored above the 90th percentile (e.g. Uniform Bar Exam [Law], evidence-based reading and writing [SAT] and the verbal component of the Graduate Record Exam [GRE]), while in other tasks, there is still room for improvement (below 20th percentile in advance placement English language and literature tests and competitive programming) (Lu, 2023). A recent survey on generative AI in higher education revealed that if HEIs prohibit the use of generative AI writing tools, almost 75% of students still intend to use them. The same report shows that students are outpacing teachers and administrators in using generative AI tools (48% of students have tried these tools, while 71% of teachers and administrators never tried them and 32% reported that they never heard of them) (Ferro, 2023). Regarding education, exaggerated voices state AI could replace teachers (Guilherme, 2019) being already as effective as humans (Chaudhri et al., 2013) and solving global teacher shortage (Edwards & Cheok, 2018). More tempered opinions emphasize the potential of AI to enrich student learning and complement teacher work (Reiss, 2021) without replacing them (Kolchenko, 2018).

Even in the current state, there are many challenges associated with the educational use of AI solutions. Vazhayil and colleagues (2019) mentioned the poor belief state of teachers regarding the potential of AI in education, moreover, they emphasized challenges in policy communication, infrastructure, pedagogy and content delivery. It is clear, that one of the most significant barriers to adopting AI in educational institutions is the lack of skills to use AI (HolonIQ Education Intelligence Unit, 2023).

Regarding these pedagogical challenges, the systematic literature review of Zawacki-Richter and colleagues (2019) raises our attention to the lack of critical reflection in the literature regarding the challenges and risks of AIED (Blikstein and colleagues (2022) is a notable exception) and the weak connection to learning theories (Sperling and colleagues (2022) is a notable exception). Besides the generally mentioned privacy, security (Huang et al., 2021; Niemi, 2021; Tahiru, 2021) and ethical concerns and barriers (Holmes & Porayska-Pomsta, 2022; Shen et al., 2021), AIED research in the future needs to consider teachers in an active role besides focusing only on optimizing AI systems (Chichekian & Benteux, 2022). This is very important as currently, the greatest technical barrier to AI is the availability of appropriate training data. Meaning, that algorithms are trained on historical data which dooms systems to repeat previous mistakes and reproduce existing biases which has serious ethical considerations. Also, it could lead to scaling up bad pedagogical practices (Joint Research Centre (European Commission) et al., 2018).

By the time this research project is implemented we probably see beyond the current reformer and enabler role of AI (Jaakkola et al., 2020) and explore its complex and controversial effect on education (Vinichenko et al., 2020).

1.1. Research questions

It is clear from the introduction, that there are potential benefits and risks of using AI in education, but there is a gap between the innovation and its educational application (Zhang & Aslan, 2021), therefore, integrating an innovation theory and technology integration perspective embedded in pedagogical consideration, this research sets out to strengthen AIED research from an educational perspective, by exploring the following broader and specific research questions. The broad research question that this project contributes to is to explore in general, how educational systems adapt to the challenges of external factors, like digital transformation, or in our particular case, the rapid development of artificial intelligence solutions. Higher education is a rich field to explore the phenomena but this research will only focus on the first mission: teaching and learning (Molenaar, 2022). To get insights regarding the broader research question, three (one general and two specific) research questions are proposed:

- **RQ0 (broad): How do educational systems adapt to the challenges raised by the rapid development of artificial intelligence solutions?**
  - **RQ1: How does the higher education sector react to the rising development of AI tools?**
    - **RQ2: How do AI solutions get integrated into pedagogical practice in higher education institutions?**
    - **RQ3: How do different factors influence the successful implementation of AI tools in the teaching and learning practices of higher education institutions?**

1.2. Antecedents of the current research project

Previous research projects involving the principal investigator have direct connections to this current proposal. As one of the theoretical foundations for this research is innovation theory, it can build on the results of the Innova project (The Emergence and Diffusion of Local Innovations and their Systemic Impact in the Education Sector, **OTKA-K16 115857**) considering the unique nature of educational innovations (Halász & Horváth, 2020) and issues regarding their implementation (Horváth, 2017, 2020). A direct follow-up of the Innova project was the **DigiNOIR** project (upon the request of the Digital Pedagogy Methodology Centre) which focused on the educational technology pillar of the national educational innovation strategy expanding on the unique nature of educational technology innovations and policy implementation in the Hungarian context (Fazekas et al., 2021).

Besides the innovation perspective, the research is built on the technology integration literature, which was the main background of the principal investigator's previous **OTKA-PD20 (134206)** project focusing on the effects of digital transformation in the education sector. During this research, several models were used and tested that are also used in this current proposal. Further research gaps identified during the project also serve as a background for this current proposal, like focusing on pedagogically-aware technology use, digital competence of educators and questions of technology integration (Czirfusz et al., 2020; Horváth, 2023b; Horváth et al., 2020, 2022; Misley et al., 2021b, 2021a).

Indirectly, another OTKA-funded research project (**OTKA-K18 128738**: Investigation of Teacher Continuous Professional Development Models at the Level of the Education System, the Organisation and the Individual) can help inform the current research by exploring teacher continuous professional development and learning on the level of individual and organisation (Lénárd et al., 2022; Rapos et al., 2022).

Furthermore, the principal investigator participated in several projects that could enrich (as research experience, as a literature source, as a professional network) and help disseminate the results of the current research proposal, namely the **PROFFORMANCE+** project lead by Tempus Foundation where the principal investigator is involved as a national expert and previously was responsible for writing the final report of a benchmarking exercise focusing on higher education teachers' performance which has a digital pedagogy component as well (Horváth, 2021); and an OECD-led project focusing on the **quality assurance of digital higher education in Hungary,** where the principal investigator acted as one of the national experts, compiling the background report (OECD, 2023b).

2. Research aims

Given the fast-paced nature of the research topic, an overarching literature review is planned throughout the project. The first year will focus on **a scoping review regarding AI use in education (O1)** which will result in a paper planned to be published in an international Q1 journal. Furthermore, the existing scoping review will be expanded in every following year of the research project by the specific elements related to the research questions, incorporating new findings. In addition to the scoping review, **a systematic literature review will be carried out focusing on specifically the use of the Unified Theory of Acceptance and Use of Technology** (UTAUT – will be explained related to RQ3) **in higher education setting (O2).** The UTAUT model serves as a core research model for this project, therefore the review will inform the research with further elements to include in the model regarding the specific characteristic of AI use in education.

2.1. RQ1: How does the higher education sector react to the rising development of AI tools?

Current AIED research is dominated by two discourses. The discourse on imperative change emphasizes the inevitable change AI poses to education institutions, a change to which different actors needs to react and adapt. The discourse on altering authority focuses on the decentralization of teacher roles and authority and delegating some of the elements to other stakeholders (other staff members, machines, corporations, students), which will lead to a change in the traditional power dynamics (Bearman et al., 2022). The first research question explores the problem from the perspective of the discourse on imperative change.

Institutions are beginning to create their regulations and policies regarding the use of AI in education (and various other parts related to the work in higher education, see for example principles laid down by Nature journals (Editorial, 2023)), although currently, it is too early to have an overall view of the different national and institutional responses, by the time of realising this research project, there will be plenty of published regulations, policies to analyse. It is interesting to see, that currently, recent surveys show that around 50% of teachers and administrators who haven't used AI technologies are thinking that generative writing AI tools will harm student learning, while those, who have used these tools, have a more favourable outlook (36% of administrators and 50% of teachers thinking these tools will have a positive effect on student learning). Currently, instructors are more likely to allow students to use generative AI tools for brainstorming, editing their writing and creating outlines for an assignment than for writing some parts of an assignment (Ferro, 2023). Another example paints an eerie picture where an AI solution is used in scoring student admission documents and rating non-cognitive traits like positive attitude and performance in communication and leadership by reviewing their essays and interview recordings (Gilford, 2023). In this example, it is clear why we need to look out for bias, privacy, and ethical issues regarding AI use.

Besides these considerations, AI can bring many benefits to education in general, considering planning (information on student background, decision on learning content, activity planning), implementation (monitoring, reducing workload, immediate feedback, adapting optimal learning activity, facilitating interventions, tracking progress, increasing interaction) and assessment (better prediction of outcomes, automatic assessment, feedback on the effectiveness of teaching, assistance in decision making) (Celik et al., 2022). Institutional reactions are shaped not only by potential benefits but by challenges as well which include limited reliability of algorithms, limited technical capacity, limited infrastructure in institutions, inefficiency, lack of interest of teachers, slow processes (Celik et al., 2022), lack of relevant learning materials, negative attitudes towards AI etc. (Chiu et al., 2023). The lack of technological and pedagogical knowledge to use AI solutions in education is simultaneously mentioned by Celik and colleagues (2022), Holmes and Tuomi (2022) and Chiu and colleagues (2023).

Due to the relative infancy of AIED and the rapid changes and development it undergoes, it is hard to predict institutional reactions, **therefore one of the aims of our research project is to explore future institutional rules and regulations regarding AI use in education (O3)**. We believe that these regulations will not be independent of the given countries' approach to AI, therefore in our analysis, we include national AI strategies as well. Combining the analysis of these documents with data from the Digital Economy and Society Index (DESI) for countries, and the European Tertiary Education Register (ETER) for institutions, we can include contextual information to our analysis.

By reviewing potential benefits and challenges that can influence institutional regulations, we have identified based on Chiu and colleagues (2023) that pedagogically aware use of AI solutions in education is lagging, AI solutions are rarely connected to pedagogical considerations. As teachers usually use "off-the-shelf" solutions this can further increase educational inequalities due to either the AI tools not well designed for the given pedagogical goal, or the lack of pedagogical knowledge for using these solutions. Following Holstein and colleagues' (2019) suggestion, educational perspectives regarding AIED needs an interdisciplinary approach in addition to strengthening pedagogical frameworks and learning science approaches in future studies. Therefore, our second research question focuses on pedagogical integration.

2.2. RQ2: How do AI solutions get integrated into pedagogical practice in higher education institutions?

Referring back to the discourses that Bearman and colleagues (2022) identified, the second and third research questions will be explored from the discourse of altering authority, focusing on the potential redistribution of teachers' skills and roles due to the increasing use of AI in education.

Analysing the U.S. Occupational Information Network (O*NET) database regarding middle-school teachers' tasks, experts estimate that AI will have a high impact on the following tasks (Joint Research Centre (European Commission) et al., 2018):

- Adapt teaching methods and instructional materials to meet students' varying needs and interests
- Maintain, accurate, complete, and correct students' records as required by laws, district policies, and administrative regulations
- Prepare, administer, and grade tests and assignments to evaluate student's progress
- Assist students who need extra help, such as by tutoring, and preparing and implementing remedial programs
- Assign lessons and correct homework

AI will have a profound impact on the teaching profession. In alignment with the Beijing Consensus, we believe that teachers' roles should be dynamically reviewed and related to that, teachers' continuous professional development and learning should be supported and strengthened through initial teacher training, continuous professional development and other capacity-building activities (UNESCO, 2019). The need behind this recommendation is also supported by existing research evidence.

Currently, it is hard to imagine how AI will change teacher roles (or how AI's role in education will be changed in the future). Currently, based on the systematic literature review of Celik and colleagues (2022), we can imagine that teachers could

- Be models for AI training (as sources of data for effective teaching)
- Feed data to AI regarding their professional development (more accurate prediction of teaching quality, and performance)
- Feed AI with student information (teacher-provided information on students' characteristics could help plan better interventions)
- Train AI in assessment (checking the accuracy of grading, determining assessment criteria)
- Provide pedagogical guidance to AI (to help in the selection of materials, learning tasks etc.)

We believe that the list needs to be expanded and different elements need to be further examined, as other models suggest alternative elements as well. In their model, Xu and Ouyang (2022) developed a model considering AI as a new subject (teaching AI as a subject to students), a direct mediator (e.g. personalized feedback, assessment, adapting the learning content etc.) and a supplementary assistant (e.g. providing additional resources, facilitating communication and collaborative learning) which in turn could influence instructor-student, student-self and student-student relationships. A possible encompassing framework could be the framework proposed by Daugherty and Wilson (2018) considers human-only activities (e.g. lead, empathize etc.), machine-only activities (e.g. iterate,

predict etc.) and hybrid activities where humans complement smart machines (e.g. train, explain, sustain) or smart machines boost human capabilities (e.g. amplify, interact, embody). In our research, we will use this framework to explore AI's impact on teachers' roles.

Not only the changing role of teachers could be interesting from this point of view, but the changing role of AI in education as well. As we mentioned before, the lack of critical reflection on the challenges of AIED and the weak connection to pedagogical theories makes it imperative to explore the field of AIED from the perspective of learning theories and identify what this could mean for the further development of the field. Ouyang and Jiao (2021) identified three paradigms from this perspective. The first paradigm, AI-directed (learner-as-recipient) is underpinned by behaviourism principles, utilizing statistical reasoning techniques evident in early Intelligent Tutoring Systems (ITS). The second paradigm, AI-supported (learner-as-collaborator) is underpinned by cognitive and social constructivism learning theories, utilizing Bayesian network, natural language processing and Markov decision trees which can be seen in dialogue-based tutoring systems. Finally, the third paradigm is AI-empowered (learner-as-leader) which is based on connectivism and complex adaptive systems theories. AI techniques utilized here are brain-computer interface, machine learning and deep learning which could be seen in personalized/adaptive learning environments.

It is important to consider the problem from a learning theory perspective as previous studies on ICT integration in education highlighted that learning theories played an insignificant role in teachers' decision to adopt a certain solution (or rather, they used "folk- and pseudo theories" which are personalised mental models of teaching like "urban myths", intuitively appealing theories etc.). Although these fold-pedagogies are not necessarily to be done away with, as they could serve as a starting point of discussions, they could lead to discrepancies for example utilizing the automatization possibilities of new technologies could facilitate behaviourist approaches to teaching (e.g. the extensive and unfounded use of badges in a *l'art pour l'art* way) (Drumm, 2019). Another study, focusing on the application of learning theories in learning analytics found that self-regulated learning theory is predominant among the reviewed studies (along with cognitive load theory) while the prevalence of connectivism and constructivism waned over the years (Khalil et al., 2022). Considering that artificial intelligence and constructivism are closely linked since the middle of the 20th century (Hof, 2021), and there is growing evidence (Downes, 2020) that the assumptions of connectivism are supported by artificial neural networks (AlDahdouh, 2017) and it is influential in the field of Massive Open Online Courses (MOOCs) (Bell, 2011) it is worth to re-examine the potential connections of constructivism and connectivism in light of AI as well. These considerations are worth to consider if we want to acknowledge the value-added nature of claims regarding AIED (Selwyn, 2022).

Considering teachers' roles and assumptions regarding learning theories, it is also important to focus on teachers' knowledge and skills which could also influence the pedagogical use of AI solutions. As the literature often criticizes teachers lack of knowledge, skill, confidence and attitudes to use AI (Su et al., 2023; Su & Zhong, 2022) it is important to come up with a system describing these specific knowledge-elements, skills and attitudes (competences). Long and Magerko (2020) defined AI literacy as a "set of competencies that enables individuals to critically evaluate, communicate and collaborate effectively with AI and use it as a tool in online, at home and in the workplace." To understand how to integrate AI in teaching and learning, it must be considered from a technological, pedagogical and content knowledge framework (Ng et al., 2021; Zhai et al., 2021) like the AIED Comp model (A: designing, developing, and delivering digital content; B: acquiring data, information and data ethics' skills; C: developing skills in employing digitally and activity-led pedagogies; D: becoming proficient in AIED applications, tools and software; E: developing digital creativity skills, empathy, and a do-it-yourself culture; F: fostering student digital inclusion, social responsibility, and data compliance) developed by Lameras and Arnab (2022). These models and considerations include important pedagogical models like Bloom's taxonomy, DigCompEdu and the TPACK model which were explored in our previous research (Horváth et al., 2020, 2022)

Building on the research gap regarding the learning theory foundations of AI use in education and the related changes in teachers' roles and a need for a competency model, the research sets out as a goal, **to explore the pedagogical considerations behind teachers' decisions to use AI solutions in their teaching and learning practice (O4) and develop and test an AI literacy model (O5).** To interpret teachers' pedagogical considerations regarding AI use in education, we will use the PIC-RAT model (Kimmons et al., 2020) which considers technology's impact on teachers' work (replace – amplify – transform) and students' relation to the technology (passive – interactive – creative) in a matrix.

Finally, it is not enough to consider individual-level factors to adequately explore the domain of pedagogically aware AI integration, at the institutional level, therefore the success factors and barriers to implementation should also be considered, which is covered by our third research question.

2.3. RQ3: How do different factors influence the successful implementation of AI tools in the teaching and learning practices of higher education institutions?

Technology integration does not happen in isolation. ICT use in education is linked with other tools and participants in a learning ecosystem. Technology integration is not only the choice of a teacher or a school but is influenced by many external and internal factors as part of a wider context. Based on Engeström's model, the cultural-historical

activity theory (CHAT) is a potential framework that could help us to systematically understand the complex interrelations that influence teachers' use of educational technology (Amiel et al., 2016), in our case, AI tools.

Popular acceptance models also highlight different internal and external factors. The Unified Theory of Acceptance and Use of Technology (UTAUT) reviews the effect of performance and effort expectancy, social influence and facilitating conditions through behavioural intention to use behaviour, while also considering the moderating effects of gender, age, experience, and voluntariness of use. UTAUT proved to be the most widespread research framework to consider technology integration and many studies are complementing this model with additional elements. Venkatesh (2022), who is one of the developers of the original UTAUT model, also encourages supplementing the UTAUT model with individual, technological and environmental characteristics in relation specifically to AI. Our initial search highlighted, that the UTAUT is often complemented by the Task-Technology Fit (TTF) model that examines the match between task requirements and technology characteristics (Marikyan & Papagiannidis, 2022). This concept proves particularly useful, as it would allow the incorporation of pedagogical considerations into the UTAUT model (like whether the AI solution is aligned with the users' beliefs regarding learning theories and what pedagogical task the tool can be used for). As it is evident from the previously reviewed literature (regarding RQ2), teacher competencies could be an important factor (whether they know to what extent they can use AI solutions), therefore we plan to include the concept of usability as well from the perspective of the success of implementation. Considering (beyond functionality) the usability perspective, it would allow the incorporation of the dimension of pedagogical value into to UTAUT model by considering factors like navigation, learnability, accessibility, consistency, visual design, interactivity, content and resources etc. (Zaharias & Poylymenakou, 2009). AI use is already explored from the perspective of the UTAUT model, for example in service delivery (Gursoy et al., 2019), hospitality sector (Roy et al., 2020) and mobile banking (Abu-Taieh et al., 2022). There are also examples of using UTAUT regarding AI adoption in the field of education, for example in artificial intelligence-enabled language e-learning systems (Lin et al., 2022), humanoid robots in an academic writing course (Guggemos et al., 2020).

Considering specific elements of AI, especially its "black box" like nature, and the upheaval it causes about replacing jobs, issues of trust and anxiety could be explored. Specific scales have already been developed for teachers' AI trust (Nazaretsky et al., 2021) and AI anxiety considering learning, job replacement, sociotechnical blindness and AI configuration (Wang & Wang, 2022). Considering trust and anxiety in a wider perspective that could be integrated into the Technology Readiness Index (TRI) concept (Parasuraman & Colby, 2015), we can relate trust to positive elements of the model (openness and innovativeness) and anxiety to the negative aspects (discomfort and insecurity). Using these two dimensions we plan to **further explore cause and effect factors regarding AI use (O6)** by applying a DEMATEL (Decision Making Trial and Evaluation Laboratory) approach (Wu et al., 2013). This approach would allow us to explore the problem of AI use in education as a two-themed problem, separating elements based on their relation and prominence and creating an influential relation map.

Finally, our research **aims to explore factors that influence AI adoption and use by extending the general UTAUT model (O7).** Combining elements of the UTAUT and TTF models, we combine performance expectancy and technology characteristics as the dimension of functionality and the elements of effort expectancy, task characteristics and usability as the dimension of usability. We retain social influence and facilitating conditions as original elements of the UTAUT model under the dimension of support. We also add an expanded TRI element to the model (trust, optimism and innovativeness; anxiety, discomfort and insecurity) – this will be analysed separately using the DEMATEL approach. Furthermore, we incorporate the AI literacy scale developed under the previous research question. In addition to these measurement scales, we also plan to compute different measures of compatibility/fit based on our variables (e.g., task-technology fit). We also include a scale from our previous research (Horváth, 2023b) detailing pedagogical strategies for technology-enhanced learning to further assess pedagogy-technology fit. The listed elements, as predictor

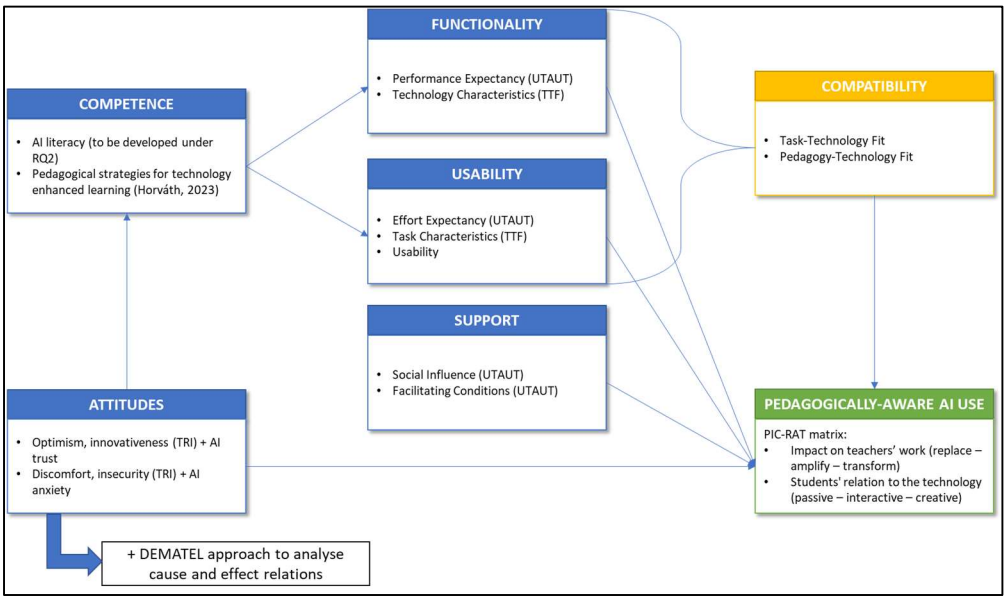

Figure 1. Elements of the proposed model to measure pedagogically-aware AI use.

variables will be incorporated into a structural equation model to explore their relation to pedagogically-aware AI use, our outcome variable which would be interpreted based on the PIC-RAT model (Kimmons et al., 2020). The elements of the proposed model are depicted in **Hiba! A hivatkozási forrás nem található.**.

3. Research methodology

Although AIED research can be traced back to the '70s, recent technological developments and capacities in connection with widespread media attention to the release of ChatGPT opened the gate for researchers to explore how stakeholders in education use AI solutions in practice. As we are at the advent of widespread AI use in education it stands to reason that the research is conducted from a pragmatist worldview which is a problem-centred and pluralistic approach focused on real-world practice and consequences of actions. This research philosophy is often associated with mixed methods research design. Considering that there is a lack of systematic empirical evidence on how educational systems adapt to the challenges raised by the rapid development of AI solutions (especially from a pedagogical perspective), an **exploratory sequential mixed methods design** was chosen (Creswell & Creswell, 2022). The following table (Table 1) details the phases of the research concerning the research questions, methodology, data source and planned outcomes (deliverables).

Table 1. Overview of research methodology.

Phase	Research Question	Objective	Method	Data source	Deliverables
PHASE 1. QUALITATIVE DATA COLLECTION AND ANALYSIS (Y1-2)	**RQ0 (broad)**	O1 – Scoping review	Literature review (scoping review)	Articles from different databases (ERIC, EBSCO, PROQUEST, WoS, SCOPUS etc.)	Publication (P1) in an international Q1 journal and international and national conference presentations (C1-2).
		O2 – Systematic literature review of UTAUT in HE	Systematic literature review (PRISMA)	Articles from different databases (ERIC, EBSCO, PROQUEST, WoS, SCOPUS etc.)	Publication (P2) in an international Q1 journal and national conference presentation (C3).
	➔ **Provide overall insights, AI-specificities and additional elements to incorporate regarding the UTAUT model for the model of O7**				
	RQ1	O3 – Institutional reactions	Document analysis	Institutional web pages and documents National AI strategy documents DESI and ETER data	Publication (P3) in an international Q1 journal and international and national conference presentations (C4-6).
	➔ **Provide insights for the "Support" dimension (Social Influence, Facilitating Conditions) for the model of O7**				
PHASE 2. IDENTIFY FEATURE OF TESTING (Y3)	**RQ2**	O4 – Pedagogical considerations	Document analysis (lesson plans, reflections, repository) Interviews	Pilot course, MOOC	Publication (P4) in a reputable Hungarian journal and international and national conference presentations (C7-9).
		O5 – AI literacy	Competence test based on course materials (analysis based on IRT Rasch-model)	Pilot course, MOOC	
	➔ **Provide insights for the outcome variable (Pedagogically aware AI use) and the "Competence" dimension (AI literacy) for the model of O7**				
PHASE 3. QUANTITATIVELY TEST THE FEATURE DESIGNED (Y4)	**RQ3**	O6 – Influential relation map	Questionnaire (DEMATEL)	Pilot course, MOOC	Publication (P5) in an international Q1 journal and international and national conference presentations (C10-12).
		➔ **Provide insights for the "Attitude" dimension (Trust, Openness, Innovativeness, Anxiety, Discomfort, Insecurity) for the model of O7**			
		O7 – Extended UTAUT	Questionnaire (merging pedagogical considerations to the UTAUT, TTF and TRI models)	Pilot course, MOOC	

The **first phase (Y1-2)** is focusing on qualitative data collection and analysis. Related to the broad research question (RQ: How educational systems adapt to the challenges raised by the rapid development of AI solutions) we conduct a scoping review (**O1**) in the first year of the project. Given the fast-paced developments in the field, the scoping review will be expanded year by year given the specific focus of the following years. Also, we conduct a systematic literature review (**O2**) based on the PRISMA protocol (Page et al., 2021) focusing on how the UTAUT model is used in higher education settings. This would allow us to explore what other models are often paired with the base UTAUT model. The literature review would provide us with qualitative insights regarding AI-specificities to include in the quantitative phase. Additionally, we conduct document analysis on national and institutional documents and regulations regarding AI use (**O3**) to answer RQ1 (How does the higher education sector react to the rising development of AI tools?). The result of this review would provide insights into the "Support" dimension of the

extended UTAUT model planned in the quantitative phase. Based on these results, the proposed model (Figure 1) will be refined into a theoretical model.

The **second phase (Y3)** is focusing on identifying elements for testing in the quantitative phase. Related to RQ2 (How do AI solutions get integrated into pedagogical practice in higher education institutions?) we plan to host a pilot course ("Artificial intelligence in Education) for students in teacher education programmes and related fields (we plan to include at least 15-30 students/semester for the pilot purposes). The course content will build upon the results of the literature review. During the course, participants will develop lesson plans (incorporating AI solutions) and reflect on their pedagogical decision from a learning theory perspective. At the end of the course, a good practice repository will be compiled based on the PIC-RAT model and a competence test will be administered to test participants' AI literacy. The artefacts produced during the pilot course (lesson plans, reflections, repository, AI literacy test) will be used to analyse pedagogical considerations (lesson plans, reflections, AI literacy test) (**O4**) influencing pedagogically aware AI use (repository) (**O5**). The coding strategy for the documents will be influenced by the results of the literature review. AI literacy test will be analysed using Item Response Theory (Rasch-model) in jamovi (The jamovi project, 2022), using the snowIRT jamovi module (Seol, 2020/2023). Products developed during the course will be thoroughly anonymised to ensure research ethics principles and GDPR compliance using the Amnesia (amnesia.openaire.eu) tool. Building upon the results of the document analysis of the pilot course artefacts, we refine our theoretical model and create a questionnaire.

The **third phase (Y4)** is focusing on quantitative testing of the theoretical model by answering RQ3 (How do different factors influence the successful implementation of AI tools in the teaching and learning practices of higher education institutions?). We develop the pilot course into a Massive Open Online Course (MOOC) as a self-paced course using the university's Canvas platform (mooc.elte.hu). Given the nature of the MOOC, the course will be open to university teachers all around Hungary and extensive marketing activities will be used to gather participants. The self-paced nature will allow flexible participation over an extended period securing enough respondents for our study (we plan to reach at least 10% of the university teacher population (according to the most recent FIR statistics for 2020/21 autumn: 21730 teachers) which is about 217 participants). As our research is not focusing on generalizing results to the university teacher population in Hungary, but exploring the connection between variables, we recruit participants through university channels and try to involve those, who are interested in using AI tools in education to allow us to explore different perspectives. The course itself would be an incentive for participants. Before implementing our questionnaire for MOOC participants, the final version will be tested with a group of experts from multiple disciplinary backgrounds (computer scientists/AI, pedagogical experts, practitioners etc.) as a face validation process (cognitive testing interview). The final instrument will be administered to MOOC participants. During the MOOC, the same tasks will be repeated as in the pilot course (lesson plan, reflection, repository, AI literacy test) and these will be analysed in connection with the survey results as well, providing additional background information for the quantitative analysis. We plan to analyse the "Attitude" part of the questionnaire in a separate study, using the DEMATEL approach to explore pedagogical decisions in detail (**O6**). DEMATEL analysis will be implemented with the "dematel" package for R (Ozdemir & Celikbilek, 2021). The theoretical model will be tested (**O7**) through structural equation modelling using jamovi software (The jamovi project, 2022) using the SEMLj module (Gallucci & Jentschke, 2021) based on the lavaan R package for structural equation modelling (Rosseel, 2012). The same research ethics standard and anonymization processes will be maintained as in the case of the pilot course. Data generated through the research will be handled according to the FAIR principles (Wilkinson et al., 2016) as detailed in the Data Management Plan (assigning metadata, unique identifiers, accessible formats, using repositories etc.).

		Y1 (2024)												Y2 (2025)											
		1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
		M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24
1. LITERATURE REVIEW (M1-M47)		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
1.1.	Main: Scoping review of AI integration in pedagogical practice and implementation of AI in HEIs (O1)	x	x	x	x	x	x	x	x	x	x	x	x												
1.2	Specific: Systematic literature review on the use of UTAUT in HE (O2)	x	x	x	x	x	x	x	x	x	x	x	x												
1.3.	Additional: National and institutional adaptation and reaction to the use of AI in HE													x	x	x	x	x	x	x	x	x	x	x	x
C1-2	International conferences (A-abstract; C-conference): scoping review			A						C															
C3	National conference (A-abstract; C-conference): UTAUT SLR					A					C														
P1	Publication: Scoping review of AI in HE (S - Submission: M11)											S													
P2	Publication: Systematic Literature Review of using the UTAUT model in HE (Submission: M11)											S													
2. ADAPTATION (M11-M20)												x	x	x	x	x	x	x	x	x	x				
2.1.	Analysing national/international policy documents related to AIED											x	x	x	x	x									
2.2.	Analysing institutional policies, regulations related to AIED																x	x	x	x	x				
P3	Publication: National and institutional reactions to AI use in HE (S - Submission: M20) (O3)																				S				
C4-5	International conferences (A-abstract; C-conference): national policies															A						C			
C6	National conference (A-abstract; C-conference): institutional policies																	A					C		
5. PROJECT MANAGEMENT (M1-M48)		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

		Y2 (2025)				Y3 (2026)												Y4 (2027)											
		9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
		M21	M22	M23	M24	M25	M26	M27	M28	M29	M30	M31	M32	M33	M34	M35	M36	M37	M38	M39	M40	M41	M42	M43	M44	M45	M46	M47	M48
1. LITERATURE REVIEW (M1-M47)		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
1.4.	Additional: AI integration in pedagogical practice in HE					x	x	x	x	x	x	x	x	x	x	x	x												
1.5.	Additional: Factors influencing AI implementation in HEIs																	x	x	x	x	x	x	x	x	x	x	x	
3. INTEGRATION (M21-M41)		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x							
3.1.	Model-development: AI integration in pedagogical practice (O4)	x	x																										
3.2.	Scale-development and operationalization (O5)			x	x																								
3.3.	Course development					x	x																						
3.4.	Piloting the questionnaire during courses						x	x	x	x				x	x	x	x		x	x	x	x								
3.5.	Summarizing the results										x	x	x																
C7-8	International conferences (A-abstract; C-conference): pilot results							A						C															
C9	National conference (A-abstract; C-conference): model									A					C														
P4	Publication (HU): Model to measure the pedagogical use of AI in HE (S - Submission: M32)												S																
4. IMPLEMENTATION (M30-M48)											x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
4.1.	Model-and scale-refinement: AI implementation in HEIs (O6)										x	x																	
4.2.	Adapting the course into a MOOC												x	x															
4.3.	Data gathering during MOOC courses													x	x	x	x	x	x	x	x	x							
4.4.	Summarizing the results, final research report																						x	x	x	x	x	x	x
C10-11	International conferences (A-abstract; C-conference): AI implementation in HEIs																			A						C			
C12	National conference (A-abstract; C-conference): AI integration in pedagogical practices																					A					C		
P5	Publication: Pedagogical use of and implementation of AI in HE (S - Submission: M47) (O7)																											S	
5. PROJECT MANAGEMENT (M1-M48)		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Figure 2. Timeline of the research (Gantt diagram).

3.1. Dissemination of research results

We have selected international and national journals as possible outlets for our publications: International Journal of Artificial Intelligence in Education (Q1 – Springer), Computers and Education (Q1 – Elsevier), International Journal of Educational Technology in Higher Education (Q1 – Springer), Computers and Education: Artificial Intelligence (Elsevier), European Journal of Teacher Education (Q1 – Routledge), Journal of Digital Learning in Teacher Education (Q1 – Taylor and Francis), Research in Learning Technology (Q1 – Association for Learning Technology), Magyar Pedagógia, Iskolakultúra. Five publications (see Table 2) are planned during the research project (P1-2: submission M11; P3: submission M20; P4 (HU): submission M32; P5: submission M47).

In addition, we have selected international and national conferences to disseminate our research results. The conferences we have selected are organised by large and reputable international scientific communities that are related to the field of our research and allow for a multidisciplinary perspective as it includes the field of higher education, AI, technology-enhanced learning and general educational sciences. Usually, registration for these conferences also includes organizational membership and most of these conferences have special interest groups (SIGs) on artificial intelligence in education that would allow for further opportunities for collaboration and dissemination. Conference participation is planned following the research phases, disseminating research results at appropriate conferences. Altogether 2 international and 1 national conference is planned per year (Table 2). The conferences are the following: Forum organized by the European Association for Institutional Research (EAIR), European Conference on Educational Research (ECER, organized by the European Educational Research Association), European Conference on Technology-Enhanced Learning (EC-TEL, organized by the European Association of Technology-Enhanced Learning), International Conference on Artificial Intelligence in Education (ICAIED, organized by the International Artificial Intelligence in Education Society), the annual conference of the Association for Learning Technology (ALT) and the Hungarian National Educational Conference (ONK).

3.2. Risk management

During the planning of the research, we identified several possible risks that could arise (Table 2). Analysing the likelihood and potential impact of these risks, we have come up with several strategies to counter them (either by avoiding the risk altogether or mitigating their effects on the project). In addition, as a general measure, a Professional Advisory Board will be recruited to follow and support the research and give feedback at certain milestones to ensure that the project is right on track and provide insights from different disciplinary perspectives.

Table 2. Identified risks and mitigation strategies.

Risk	Likelihood	Impact	Mitigation strategy
Failure to recruit an early-stage researcher as a participant at M9	Low	Medium	It is possible that there will be no suitable candidate for this role, or the candidate will fail their entrance exam. In this case, the research plan and budget will be reorganized to accommodate the entrance of the early-stage researcher at M21 without much disturbance to the schedule or the budget.
Drastic and fast-paced increase in existing empirical evidence and literature	Medium	Low	Currently, the topic of AIED shows a raising tendency. If these trends continue, it would make it harder for the literature analysis to be carried out. In this case, the task will be restructured and outsourced to BA/MA students as part of their thesis. The previous OTKA-PD project was a good example of involving students as collaborators in the research.
Unforeseen, external events	Low	High	As in the previous OTKA-PD project, unforeseen external events could steer the project in different directions (like the COVID-19-induced emergency remote teaching). Although to be able to answer the research questions,

			these events must be incorporated into the project to a certain extent, to keep the project on track, an external Professional Advisory Board will be established at the beginning of the project as detailed before.
Lack of participants in pilot/MOOC courses	Low	Medium	It is possible that we cannot recruit enough participants for the pilot and MOOC courses. The current time planning allows for additional iterations of the courses which would allow us to recruit the necessary number of participants.

4. Infrastructure and human resource capacity

As a research project in Social Sciences and Humanities, there are no significant **infrastructure requirements** for the successful realisation of the project. Although the researchers (principal investigator – PI, early-stage researcher – ESR) need to have an up-to-date laptop with appropriate computing capacity to carry out the planned multivariate statistical analysis. Also, regarding the requirements of the planned MOOC course, the laptops should have a strong graphical capacity as well to create and edit videos. Therefore, two laptops with appropriate capacity will be bought at the beginning of the project, one for the PI and one for the ESR. For other technical requirements (e.g. green box for recording videos for the MOOC) infrastructure provided by ELTE will be used (green room with technical assistants and appropriate recording equipment).

The main requirements of this research are **human resource capacities**. On the technical and administrative side, a colleague from the Finance Office will be commissioned to help with the project's financial and administrative tasks. Additionally, an ESR will be employed from M9 (aligned with the schedule of the entrance exams of the Doctoral School of Education) under the supervision of the PI forming a research group. The ESR's PhD thesis will be aligned with the current research, so the ESR can be involved in all project activities (0.3 FTE). Finally, another part of the work and scientific responsibility will be handled by the PI (0.3 FTE) along with project management tasks. To provide additional human resources, in alignment with the learning outcomes of the study programmes at the Faculty of Education and Psychology, BA/MA students will be involved during courses, thesis work and workshops to provide research assistance and aid in small research tasks related to the research. The PI has experience in coordinating such outsourcing to BA/MA students from the previous OTKA-PD research.

5. Expected results and impact

Given the opportunity and timeliness of exploring how educational institutions react to the challenges raised by the rapid development of AI tools this basic research project aims to address the research gap regarding the lack of pedagogical consideration and weak connections of AIED research in learning theories. During the research, a scoping review of the issue of AIED will be conducted (O1) based on the initial review of the topic (Horváth, 2023a) and a specific systematic literature review (O2) will be carried out also to explore the possible extensions of the base UTAUT model. The theoretical review will contribute to a better understanding of AIED and the embeddedness of the issues in the educational sciences discourse. The empirical part of the project aims to explore how nations and institutions reacted to the emergence of AI tools by analysing national AI policies and institutional regulations (O3). This outcome of this part will provide an international overview of practices that could inform policymakers and institutional management to rethink or develop their own AI strategies. The next phase of the research will explore pedagogical considerations in using AI tools (O4) and the development of an AI literacy scale (O5) with the help of a pilot course through analysing artefacts generated by participants. The results will inform the model developed in the next phase and provide a theoretical model based on the extension of the UTAUT model that can be used in further research. Finally, the study concludes in a large-scale validation of an extended UTAUT instrument that on the one hand will provide an opportunity to analyse case and effect relations of pedagogical use in detail using the DEMATEL approach (O6), and on the other hand a comprehensive overview testing the extended UTAUT model for pedagogically aware AI use (O7) fusing considerations from innovation theory, technology integration and educational sciences as a clear added value addressing the identified research gap.

Finally, the project has a clear **societal impact and innovation potential**. Results could be used to inform policymakers, the management of HEIs and teachers (especially in teacher education) on how to support and sustain pedagogical innovations regarding the pedagogically aware use of AI tools on the level of national policies and institutional regulations. The findings can also inform the development of AI tools to include pedagogical considerations and better serve the needs of teachers and students. Also, it could inform pedagogical practices on how to integrate AI tools transparently and ethically. Overall, the research contributes to a better understanding of AI use and potentially contributes to developing a more AI-literate teacher workforce and through teachers, a more open and conscious workforce that can use AI tools in their work in a responsible way.

6. References

Abu-Taieh, E. M., AlHadid, I., Abu-Tayeh, S., Masa'deh, R., Alkhawaldeh, R. S., Khwaldeh, S., & Alrowwad, A. (2022). Continued Intention to Use of M-Banking in Jordan by Integrating UTAUT, TPB, TAM and Service Quality with ML. *Journal of Open Innovation: Technology, Market, and Complexity*, *8*(3), 120. https://doi.org/10.3390/joitmc8030120

AlDahdouh, A. (2017). Does Artificial Neural Network Support Connectivism's Assumptions? *International Journal of Instructional Technology and Distance Learning*, *13*(3), 3–26.

Amiel, T., Kubota, L. C., & Wives, W. W. (2016). A systemic model for differentiating school technology integration. *Research in Learning Technology*, *24*. https://doi.org/10.3402/rlt.v24.31856

Artificial Intelligence Coalition & Digital Success Programme. (2020). *Hungary's Artificial Intelligence Strategy 2020-2030*. Ministry for Innovation and Technology. https://ai-hungary.com/files/e8/dd/e8dd79bd380a40c9890dd2fb01dd771b.pdf

Bearman, M., Ryan, J., & Ajjawi, R. (2022). Discourses of artificial intelligence in higher education: A critical literature review. *Higher Education*. https://doi.org/10.1007/s10734-022-00937-2

Bell, F. (2011). Connectivism: Its place in theory-informed research and innovation in technology-enabled learning. *The International Review of Research in Open and Distributed Learning*, *12*(3), 98–118. https://doi.org/10.19173/irrodl.v12i3.902

Blikstein, P., Zheng, Y., & Zhou, K. Z. (2022). Ceci n'est pas une école: Discourses of artificial intelligence in education through the lens of semiotic analytics. *European Journal of Education*, *57*(4), 571–583. https://doi.org/10.1111/ejed.12528

Celik, I., Dindar, M., Muukkonen, H., & Järvelä, S. (2022). The Promises and Challenges of Artificial Intelligence for Teachers: A Systematic Review of Research. *TechTrends*, *66*(4), 616–630. https://doi.org/10.1007/s11528-022-00715-y

Chaudhri, V. K., Lane, H. C., Gunning, D., & Roschelle, J. (2013). Intelligent Learning Technologies: Applications of Artificial Intelligence to Contemporary and Emerging Educational Challenges. *AI Magazine*, *34*(3), Article 3. https://doi.org/10.1609/aimag.v34i3.2482

Chichekian, T., & Benteux, B. (2022). The potential of learning with (and not from) artificial intelligence in education. *Frontiers in Artificial Intelligence*, *5*. https://www.frontiersin.org/articles/10.3389/frai.2022.903051

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

Creswell, J. W., & Creswell, J. D. (2022). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (Sixth edition). SAGE Publications, Inc.

Czirfusz, D., Misley, H., & Horváth, L. (2020). A digitális munkarend tapasztalatai a magyar közoktatásban. *Opus et Educatio*, *7*(3), Article 3. https://doi.org/10.3311/ope.394

Daugherty, P. R., & Wilson, H. J. (2018). *Human + Machine: Reimagining Work in the Age of AI*. Harvard Business Review Press.

Dietz F. (2020). A mesterséges intelligencia az oktatásban: Kihívások és lehetőségek. *Scientia et Securitas*, *1*(1), 54–63. https://doi.org/10.1556/112.2020.00009

Downes, S. (2020). Recent Work in Connectivism. *European Journal of Open, Distance and E-Learning*, *22*(2), 113–132. https://doi.org/10.2478/eurodl-2019-0014

Drumm, L. (2019). Folk pedagogies and pseudo-theories: How lecturers rationalise their digital teaching. *Research in Learning Technology*, *27*. https://doi.org/10.25304/rlt.v27.2094

Editorial. (2023). Tools such as ChatGPT threaten transparent science; here are our ground rules for their use. *Nature*, *613*(7945), 612–612. https://doi.org/10.1038/d41586-023-00191-1

Edwards, B. I., & Cheok, A. D. (2018). Why Not Robot Teachers: Artificial Intelligence for Addressing Teacher Shortage. *Applied Artificial Intelligence*, *32*(4), 345–360. https://doi.org/10.1080/08839514.2018.1464286

Farrokhnia, M., Banihashem, S. K., Noroozi, O., & Wals, A. (2023). A SWOT analysis of ChatGPT: Implications for educational practice and research. *Innovations in Education and Teaching International*, *0*(0), 1–15. https://doi.org/10.1080/14703297.2023.2195846

Fazekas, Á., Fischer, M., Horváth, L., Kovács, I. V., & Pálvölgyi, L. (2021). Első rész: A DigiNOIR stratégiajavaslat. Az oktatási ágazat innovációs stratégiája (NOIR stratégia) oktatástechnológiai pillérének kibontása. In G. Halász, I. V. Kovács, & L. Pálvölgyi (Eds.), *Oktatás, technológia, innováció. Helyzetkép és stratégia*. Akadémiai Kiadó. https://mersz.hu/?xmlazonosito=m863oti_3

Ferro, B. (2023, April 25). Generative AI in Higher Education: From Fear to Experimentation, Embracing AI's Potential. *Tyton Partners*. https://tytonpartners.com/generative-ai-in-higher-education-from-fear-to-experimentation-embracing-ais-potential/

Gallucci, M., & Jentschke, S. (2021). *SEMLj: Jamovi SEM Analysis. [Jamovi module]*. https://github.com/semlj/semlj

Gilford, A. (2023, April 25). *University Admissions Use AI to Gauge Applicant Skills, Traits*. GovTech. https://www.govtech.com/education/higher-ed/university-admissions-use-ai-to-gauge-applicant-skills-traits

Guggemos, J., Seufert, S., & Sonderegger, S. (2020). Humanoid robots in higher education: Evaluating the acceptance of Pepper in the context of an academic writing course using the UTAUT. *British Journal of Educational Technology*, *51*(5), 1864–1883. https://doi.org/10.1111/bjet.13006

Guilherme, A. (2019). AI and education: The importance of teacher and student relations. *AI & SOCIETY*, *34*(1), 47–54. https://doi.org/10.1007/s00146-017-0693-8

Gursoy, D., Chi, O. H., Lu, L., & Nunkoo, R. (2019). Consumers acceptance of artificially intelligent (AI) device use in service delivery. *International Journal of Information Management*, *49*, 157–169. https://doi.org/10.1016/j.ijinfomgt.2019.03.008

Halász, G., & Horváth, L. (2020). Innováció az oktatásban. In G. Halász, Á. Fazekas, & T. Lukács (Eds.), *Az innovációs folyamatok dinamikája az oktatási ágazatban*. Akadémiai Kiadó. https://mersz.hu/hivatkozas/m732azifd_2

Hargittai, E. (2021). *Handbook of Digital Inequality*. Edward Elgar Publishing.

High-Level Expert Group on Artificial Intelligence. (2019). *A definition of AI: Main capabilities and scientific disciplines*. European Commission. https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=56341

Hof, B. (2021). The Turtle and the Mouse: How Constructivist Learning Theory Shaped Artificial Intelligence and Educational Technology in the 1960s. *History of Education*, *50*(1), 93–111. https://doi.org/10.1080/0046760X.2020.1826053

Holmes, W., & Porayska-Pomsta, K. (Eds.). (2022). *The Ethics of Artificial Intelligence in Education* (1st edition). Routledge.

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

HolonIQ Education Intelligence Unit. (2023, 27). *Artificial Intelligence in Education. 2023 Survey Insights*. https://www.holoniq.com/notes/artificial-intelligence-in-education-2023-survey-insights

Holstein, K., McLaren, B. M., & Aleven, V. (2019). Co-Designing a Real-Time Classroom Orchestration Tool to Support Teacher–AI Complementarity. *Journal of Learning Analytics*, *6*(2), Article 2. https://doi.org/10.18608/jla.2019.62.3

Horváth L. (2017). A szervezeti tanulás és az innováció összefüggései a magyar oktatási rendszer alrendszereiben. *Neveléstudomány*, *20*(4), 44–66. https://doi.org/10.21549/NTNY.20.2017.4.3

Horváth, L. (2020). Az oktatási intézmények innovációs aktivitását befolyásoló környezeti és szervezeti tényezők feltárása. In G. Halász, Á. Fazekas, & T. Lukács (Eds.), *Az innovációs folyamatok dinamikája az oktatási ágazatban*. Akadémiai Kiadó. https://mersz.hu/hivatkozas/m732azifd_122

Horváth, L. (2021). *The landscape of higher education teachers' performance—Final report on the results of the benchmarking exercise*. Tempus Public Foundation; MTMT. https://m2.mtmt.hu/api/publication/32463505

Horváth, L. (2023a). *A mesterséges intelligencia lehetőségei és kihívásai az oktatásban—Reflexió neveléstudományi perspektívából*. Open forum of the Digital Pedagogy Subcommittee of the Hungarian Academy of Sciences' Committee on Pedagogy. Unpublished. https://rgdoi.net/10.13140/RG.2.2.33022.66888

Horváth, L. (2023b). Adaptive pedagogical strategies responding to emergency remote teaching – immediate responses of Hungarian primary school teachers. *Research in Learning Technology*, *31*. https://doi.org/10.25304/rlt.v31.2978

Horváth L., Baksa L., Csipke Á., Gutai L., & Szilágyi D. (2022). A 21. századi kompetenciák digitális technológiával támogatott fejlesztésének képessége: - Pilot kutatás a TPACK21 skála adaptálásáról. *Iskolakultúra*, *32*(6), Article 6. https://doi.org/10.14232/ISKKULT.2022.6.56

Horváth, L., Misley, H., Hülber, L., Papp-Danka, A., M. Pintér, T., & Dringó-Horváth, I. (2020). Tanárképzők digitális kompetenciájának mérése – a DigCompEdu adaptálása a hazai felsőoktatási környezetre. [Measuring the digital competence of teacher educators – adapting the DigCompEdu in Hungarian higher education]. *Neveléstudomány*, *2020*(2), 5-25. https://doi.org/10.21549/NTNY.29.2020.2.1

Huang, J., Saleh, S., & Liu, Y. (2021). A Review on Artificial Intelligence in Education. *Academic Journal of Interdisciplinary Studies*, *10*(3), 206–217. https://doi.org/10.36941/ajis-2021-0077

Jaakkola, H., Henno, J., Lahti, A., Järvinen, J.-P., & Mäkelä, J. (2020). Artificial Intelligence and Education. *2020 43rd International Convention on Information, Communication and Electronic Technology (MIPRO)*, 548–555. https://doi.org/10.23919/MIPRO48935.2020.9245329

Joint Research Centre (European Commission), Samoili, S., López Cobo, M., Delipetrev, B., Martínez-Plumed, F., Gómez, E., & De Prato, G. (2021). *AI watch, defining artificial intelligence 2.0: Towards an operational definition and taxonomy for the AI landscape*. Publications Office of the European Union. https://data.europa.eu/doi/10.2760/019901

Joint Research Centre (European Commission), Tuomi, I., Punie, Y., Vuorikari, R., & Cabrera, M. (2018). *The impact of Artificial Intelligence on learning, teaching, and education*. Publications Office of the European Union. https://data.europa.eu/doi/10.2760/12297

Khalil, M., Prinsloo, P., & Slade, S. (2022). The use and application of learning theory in learning analytics: A scoping review. *Journal of Computing in Higher Education*. https://doi.org/10.1007/s12528-022-09340-3

Kimmons, R., Graham, C. R., & West, R. E. (2020). The PICRAT model for technology integration in teacher preparation. *Contemporary Issues in Technology and Teacher Education*, *20*(1). https://citejournal.org/volume-20/issue-1-20/general/the-picrat-model-for-technology-integration-in-teacher-preparation

Kolchenko, V. (2018). Can Modern AI replace teachers? Not so fast! Artificial Intelligence and Adaptive Learning: Personalized Education in the AI age. *HAPS Educator*, *22*(3), 249–252. https://doi.org/10.21692/haps.2018.032

Lameras, P., & Arnab, S. (2022). Power to the Teachers: An Exploratory Review on Artificial Intelligence in Education. *Information*, *13*(1), Article 1. https://doi.org/10.3390/info13010014

Lénárd S., Szivák J., Tóth-Pjeczka K., Urbán K., & Horváth L. (2022). Tanulószervezeti jellemzők és a pedagógusok tanulása a hazai köznevelési rendszerben. *Neveléstudomány*, *1*, 37–52. https://doi.org/10.21549/NTNY.36.2022.1.2

Lin, H.-C., Ho, C.-F., & Yang, H. (2022). Understanding adoption of artificial intelligence-enabled language e-learning system: An empirical study of UTAUT model. *International Journal of Mobile Learning and Organisation*, *16*(1), 74–94. https://doi.org/10.1504/IJMLO.2022.119966

Long, D., & Magerko, B. (2020). What is AI Literacy? Competencies and Design Considerations. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (pp. 1–16). Association for Computing Machinery. https://doi.org/10.1145/3313831.3376727

Lu, M. (2023, April 26). *How Smart is ChatGPT?* Visual Capitalist. https://www.visualcapitalist.com/how-smart-is-chatgpt/

Marikyan, D., & Papagiannidis, S. (2022). Task-Technology Fit. In S. Papagiannidis, *TheoryHub Book*. University of Newcastle. https://open.ncl.ac.uk/theory-library/task-technology-fit.pdf

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

Misley, H., Káplár-Kodácsy, K., & Horváth, L. (2021a). *Digitális módszertani kézikönyv képzők számára*. Evangélikus Pedagógiai-szakmai Szolgáltató és Továbbképző Intézet; MTMT. https://m2.mtmt.hu/api/publication/32164177

Misley, H., Káplár-Kodácsy, K., & Horváth, L. (2021b). Digitális transzformáció a közoktatásban: A technológiai integráció lehetőségei és kihívásai. In G. Molnár & E. Tóth (Eds.), *A neveléstudomány válaszai a jövő kihívásaira: XXI. Országos Neveléstudományi Konferencia Szeged, 2021. November 18-20.* (p. 504). SZTE BTK Neveléstudományi Intézet; MTMT. https://m2.mtmt.hu/api/publication/32501700

Molenaar, I. (2022). Towards hybrid human-AI learning technologies. *European Journal of Education*, *57*(4), 632–645. https://doi.org/10.1111/ejed.12527

Nazaretsky, T., Cukurova, M., & Alexandron, G. (2021). *An Instrument for Measuring Teachers' Trust in AI-Based Educational Technology*. EdArXiv. https://doi.org/10.35542/osf.io/bcjme

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: Artificial Intelligence*, *2*, 100041. https://doi.org/10.1016/j.caeai.2021.100041

Niemi, H. (2021). AI in learning: Preparing grounds for future learning. *Journal of Pacific Rim Psychology*, *15*, 18344909211038104. https://doi.org/10.1177/18344909211038105

OECD. (2022). *Trends Shaping Education 2022*. Organisation for Economic Co-operation and Development. https://www.oecd-ilibrary.org/education/trends-shaping-education-2022_6ae8771a-en

OECD. (2023a). *Is Education Losing the Race with Technology?: AI's Progress in Maths and Reading*. Organisation for Economic Co-operation and Development. https://www.oecd-ilibrary.org/education/is-education-losing-the-race-with-technology_73105f99-en

OECD. (2023b). *Ensuring Quality Digital Higher Education in Hungary*. OECD. https://doi.org/10.1787/5f44fd6f-en

Ouyang, F., & Jiao, P. (2021). Artificial intelligence in education: The three paradigms. *Computers and Education: Artificial Intelligence*, *2*, 100020. https://doi.org/10.1016/j.caeai.2021.100020

Ozdemir, M., & Celikbilek, Y. (2021). *dematel: Decision Making Trial and Evaluation Laboratory Technique in R* (0.1.0). https://cran.rstudio.com/web/packages/dematel/index.html

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M.,

Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, *372*, n71. https://doi.org/10.1136/bmj.n71

Panigrahi, A., & Joshi, V. (2020). Use of Artificial Intelligence in Education. *The Management Accountant Journal*, *55*(5), Article 5. https://doi.org/10.33516/maj.v55i5.64-67p

Parasuraman, A., & Colby, C. L. (2015). An Updated and Streamlined Technology Readiness Index: TRI 2.0. *Journal of Service Research*, *18*(1), 59–74. https://doi.org/10.1177/1094670514539730

Pelletier, K., McCormack, M., Reeves, J., Robert, J., & Arbino, N. (2022). *2022 EDUCAUSE Horizon Report, Teaching and Learning Edition*.

Rapos N., Tókos K., Nagy K., Eszes F., & Horváth L. (2022). A pedagógusok folyamatos szakmai fejlődésének és tanulásának komplexitása. *Neveléstudomány*, *1*, 7–36. https://doi.org/10.21549/NTNY.36.2022.1.1

Reiss, M. J. (2021). The use of AI in education: Practicalities and ethical considerations. *London Review of Education*, *19*. https://doi.org/10.14324/LRE.19.1.05

Rosseel, Y. (2012). lavaan: An R Package for Structural Equation Modeling. *Journal of Statistical Software*, *48*, 1–36. https://doi.org/10.18637/jss.v048.i02

Roy, P., Ramaprasad, B. S., Chakraborty, M., Prabhu, N., & Rao, S. (2020). Customer Acceptance of Use of Artificial Intelligence in Hospitality Services: An Indian Hospitality Sector Perspective. *Global Business Review*, 097215092093975. https://doi.org/10.1177/0972150920939753

Selwyn, N. (2022). The future of AI and education: Some cautionary notes. *European Journal of Education*, *57*(4), 620–631. https://doi.org/10.1111/ejed.12532

Seol, H. (2023). *SnowIRT* [R]. https://github.com/hyunsooseol/snowIRT (Original work published 2020)

Shen, L., Chen, I., Grey, A., & Su, A. (2021). Teaching and Learning With Artificial Intelligence. In S. Verma & P. Tomar (Eds.), *Impact of AI Technologies on Teaching, Learning, and Research in Higher Education* (teaching-and-learning-with-artificial-intelligence; pp. 73–98). IGI Global. https://www.igi-global.com/gateway/chapter/www.igi-global.com/gateway/chapter/261496

Skog, D. A., Wimelius, H., & Sandberg, J. (2018). Digital Disruption. *Business & Information Systems Engineering*, *60*(5), 431–437. https://doi.org/10.1007/s12599-018-0550-4

Sperling, K., Stenliden, L., Nissen, J., & Heintz, F. (2022). Still w(AI)ting for the automation of teaching: An exploration of machine learning in Swedish primary education using Actor-Network Theory. *European Journal of Education*, *57*(4), 584–600. https://doi.org/10.1111/ejed.12526

Su, J., Ng, D. T. K., & Chu, S. K. W. (2023). Artificial Intelligence (AI) Literacy in Early Childhood Education: The Challenges and Opportunities. *Computers and Education: Artificial Intelligence*, *4*, 100124. https://doi.org/10.1016/j.caeai.2023.100124

Su, J., & Zhong, Y. (2022). Artificial Intelligence (AI) in early childhood education: Curriculum design and future directions. *Computers and Education: Artificial Intelligence*, *3*, 100072. https://doi.org/10.1016/j.caeai.2022.100072

Tahiru, F. (2021). AI in Education: A Systematic Literature Review. *Journal of Cases on Information Technology*, *23*(1), 1–20. https://doi.org/10.4018/JCIT.2021010101

The jamovi project. (2022). *Jamovi* (2.3). https://www.jamovi.org.

Tuomi, I. (2022). Artificial intelligence, 21st century competences, and socio-emotional learning in education: More than high-risk? *European Journal of Education*, *57*(4), 601–619. https://doi.org/10.1111/ejed.12531

UNESCO. (2015). *Qingdao Declaration*. UNESCO. https://en.unesco.org/icted/sites/default/files/2019-04/37_qingdao_declaration.pdf

UNESCO. (2019). *Beijing Consensus on Artificial Intelligence and Education. Outcome document of the International Conference on Artificial Intelligence and Education 'Planning education in the AI era: Lead the leap'*. UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000368303

Vazhayil, A., Shetty, R., Bhavani, R. R., & Akshay, N. (2019). Focusing on Teacher Education to Introduce AI in Schools: Perspectives and Illustrative Findings. *2019 IEEE Tenth International Conference on Technology for Education (T4E)*, 71–77. https://doi.org/10.1109/T4E.2019.00021

Venkatesh, V. (2022). Adoption and use of AI tools: A research agenda grounded in UTAUT. *Annals of Operations Research*, *308*(1), 641–652. https://doi.org/10.1007/s10479-020-03918-9

Vinichenko, M. V., Rybakova, M. V., Vinogradova, M. V., Malyshev, M. A., & Maksimov, A. A. (2020). The Effect of Digital Economy and Artificial Intelligence on The Participants of The School Educational Process. *Propósitos y Representaciones*, e694–e694. https://doi.org/10.20511/pyr2020.v8nSPE2.694

Wang, Y.-Y., & Wang, Y.-S. (2022). Development and validation of an artificial intelligence anxiety scale: An initial application in predicting motivated learning behavior. *Interactive Learning Environments*, *30*(4), 619–634. https://doi.org/10.1080/10494820.2019.1674887

Wilkinson, M. D., Dumontier, M., Aalbersberg, Ij. J., Appleton, G., Axton, M., Baak, A., Blomberg, N., Boiten, J.-W., da Silva Santos, L. B., Bourne, P. E., Bouwman, J., Brookes, A. J., Clark, T., Crosas, M., Dillo, I., Dumon, O., Edmunds, S., Evelo, C. T., Finkers, R., … Mons, B. (2016). The FAIR Guiding Principles for

scientific data management and stewardship. *Scientific Data*, *3*(1), Article 1. https://doi.org/10.1038/sdata.2016.18

Wu, W., Lan, L. W., & Lee, Y. (2013). Factors hindering acceptance of using cloud services in university: A case study. *The Electronic Library*, *31*(1), 84–98. https://doi.org/10.1108/02640471311299155

Xu, W., & Ouyang, F. (2022). A systematic review of AI role in the educational system based on a proposed conceptual framework. *Education and Information Technologies*, *27*(3), 4195–4223. https://doi.org/10.1007/s10639-021-10774-y

Zaharias, P., & Poylymenakou, A. (2009). Developing a Usability Evaluation Method for e-Learning Applications: Beyond Functional Usability. *International Journal of Human–Computer Interaction*, *25*(1), 75–98. https://doi.org/10.1080/10447310802546716

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), 39. https://doi.org/10.1186/s41239-019-0171-0

Zhai, X., Chu, X., Chai, C. S., Jong, M. S. Y., Istenic, A., Spector, M., Liu, J.-B., Yuan, J., & Li, Y. (2021). A Review of Artificial Intelligence (AI) in Education from 2010 to 2020. *Complexity*, *2021*, e8812542. https://doi.org/10.1155/2021/8812542

Zhang, K., & Aslan, A. B. (2021). AI technologies for education: Recent research & future directions. *Computers and Education: Artificial Intelligence*, *2*, 100025. https://doi.org/10.1016/j.caeai.2021.100025

Zhao, Y., & Liu, G. (2019). How Do Teachers Face Educational Changes in Artificial Intelligence Era. *Proceedings of the 2018 International Workshop on Education Reform and Social Sciences (ERSS 2018)*, 47–50. https://doi.org/10.2991/erss-18.2019.9