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Activity Theory-based Ecosystem for Artificial Intelligence in Education (AIED)

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Abstract

The integration of Artificial Intelligence in Education (AIED) stands as a pivotal trend in education, yet comprehensive design frameworks remain a subject of ongoing exploration. While many AIED studies are still in their early stages of development and implementation, the uncertainties and challenges surrounding the ethical and responsible use of AI in education persist. Anchoring on the Activity Theory, this paper proposes a conceptual framework, aiming to construct a sustainable ecosystem for AIED design within the dynamic landscape in all levels of education. Within the constructs of Activity Theory, this framework endeavors to scrutinize the intricate relationship between individuals (learners), their learning activities, and the broader socio-cultural context wherein these activities unfold. Moreover, the paper advocates for collaborative agreements among educators, learners, and educational institutions as essential pillars in the design and implementation of AIED systems tailored for education. In essence, this conceptual paper serves as a theoretical proposition, utilizing Activity Theory as a lens to envisage an adaptive and ethically responsible AIED ecosystem specifically crafted to address the nuanced dynamics inherent in all levels of education. It urges designers to meticulously consider the interplay between learners, educators, technology, and the socio-cultural fabric when devising strategies for fostering effective, inclusive, and engaging learning experiences.

Keywords: artificial intelligence in education, activity theory, learner and task relationship, ecosystem

Activity Theory-based Ecosystem for Artificial Intelligence in Education (AIED)

1. Introduction

Artificial Intelligence in Education (AIED) is emerging as a transformative force in modern education, offering the possibility of improving students' learning outcomes and experiences (Hwang et al., 2020). However, much to the frequent misleading information, AIED has been tainted with issues of uncertainty and fears (Smith, 2024). In our current age, the integration of AI in education has emerged as one of the most important education trends of the century. The development of AIED is said to promises the transformation of the entire teaching and learning experience in a significant manner (Kuleto et al., 2021; Paek & Kim, 2021; Zawacki-Richter et al., 2019). These transformation in AIED is also said to be accelerated due to the recent COVID-19 pandemic, with AIED serving to improve the university's performance in ensuring effective management of academic and non-academic operations (AlDhaen, 2022). Overall, these have opened up various opportunities to improve the overall online teaching and learning processes (Ouyang et al., 2022).

Additionally, AI-based education technologies such as adaptive learning platforms, personalized learning, and predictive analytics are also noted to have the potential to provide students with a more personalized learning experiences specifically tailored to their individual needs (Crompton & Burke 2023; Gocen & Aydemir, 2020). For instance, AI systems can specifically fit the learning difficulties in line with the levels of the students. This tailored designed can actually lead to better student engagement and higher academic performance (Huang et al., 2023). However, the design of AIED systems no matter in what level of education remains a complex and evolving field, with various approaches and paradigms shaping its development (Bhimdiwala et al., 2022).

The design of AIED systems encompasses multi-diverse approaches, reflecting both the dynamic and multifaceted nature of education and the evolving role of AI (Ouyang & Jiao, 2021). From AI-directed learning, characterized by personalized instruction and feedback akin to a human tutor (Sinatra et al., 2019), to AI-supported collaborative learning environments, where learners engage in socially situated contexts (Järvelä et al., 2023), and finally, to AI-empowered adaptive learning systems that tailor experiences based on individual characteristics (Aleven et al., 2017). In all of these mentioned designs, each paradigm offers a kind of unique opportunities for advancing education. Moreover, the integration of augmented reality (AR) technology provides a promising avenue to enhance learning through immersive experiences (W. Yang, 2022). In spite of these paradigms, many continue to use the Technological Pedagogical Content Knowledge (TPACK) model (Mishra & Koehler, 2006) to emphasize the importance of integrating technological, pedagogical, and content knowledge for effective learning environments while ensuring a harmonious integration of these elements (Celik, 2023; Chaipidech et al., 2022). However, TPACK seems unclear in terms of its relationship to educational policy and the overall curriculum (O'Dea & O'Dea, 2023). In addition, it lacks consideration towards the social and emotional contexts of both teachers and students (Velander et al., 2023). Therefore, there is somewhat a need to develop a more over encompassing theoretical framework for AIED.

Despite the promising potential of AIED, several challenges and areas for improvement persist. One critical concern lies within the transparency of decision-making processes within AIED systems (Blikstein & Worsley, 2016). For instance, how does AIED systems actually decides the levels of learning difficulties, is there a kind of rubric or checklist or in programming terms an algorithm that makes the decisions. However, the intricate algorithms powering these systems often lack transparency, thus, raising questions about how decisions are made and potentially hindering learner understanding (Crockett et al., 2021). Additionally, while AIED systems are lauded for their personalization capabilities, there is a need for further refinement to ensure truly tailored learning experiences (Sinatra et al., 2019). Ethical considerations, including issues of data privacy, security, and fairness, must be rigorously addressed to mitigate potential biases and inequities (Adams et al., 2021). Furthermore, the integration of social and emotional factors in AIED design remains to be develop with additional opportunities to enhance the learning experience by incorporating elements such as social interactions, emotional support, and effective feedback mechanisms (Lai et al., 2023).

As the field of AIED advances, it is imperative to consider the increased impact of AIED on human values and educational practices (Renz & Vladova, 2021). The very essence of human-centered design principles should guide the development of AIED systems, ensuring alignment with the various learners' needs, learning goals, and values (Guesmi et al., 2022). Recognizing the unique qualities and abilities of human teachers, including their capacity for personal connection, emotional support, and real-time adaptability, underscores the complementary role that AI can play in education are also quite important and should not be neglected (Guilherme, 2019). By merging the strengths of human educators with the capabilities of AI, we can create powerful educational environments that empower learners and foster ethical values, ultimately promoting autonomy and responsible AI use in education (Richards & Dignum, 2019).

In light of these considerations, the paper argues that the process of designing AIED can best be described as the dynamic interactions as well as adaptive orientations of a system in which new phenomena, new properties, and new behaviors are observed (Mason, 2008). Understanding the importance of fostering a comprehensive ecosystem, this paper advocates for the development of a sustainable framework that aligns with the intricate dynamics within educational environments (Liu et al., 2021). Moreover, by proposing Activity Theory as the foundational framework for crafting this ecosystem, designers can safely navigate the multifaceted interplay between learners, activities, and socio-cultural contexts, thereby forging a path towards more effective and engaging learning experiences in the era of AI (Bakhurst, 2009; Bertelsen & Bødker, 2003; Jonassen & Rohrer-Murphy 1999). This proposed theoretical framework emphasizes not only the technological aspects but also the socio-cultural dimensions of AIED design, fostering an environment conducive to ethical, inclusive, and transformative educational practices. Additionally, it underscores the imperative of collaborative agreements among teachers, learners, and educational institutions to ensure the responsible and ethical use of AI in education.

2. Approaches to designing AIEDs

As a general rule, applications of AI can be divided into two categories: those involving humans or not, and/or those involving systems that are specific or adaptive (PWC, 2017). This also hold true for AIEDs (Office of Educational Technology, 2023). In the design of educational technology, there is always a model or an underlying concept that is used (Smaldino et al., 2019). Likewise, in the design of AIED systems, researchers and developers employ a variety of approaches. A much simpler approach is to categorized within the basic aspects and functions of teaching and learning, wherein AIED is used for preparing and transmitting learning content, helping students to apply knowledge, engaging students in learning tasks, helping students to improve through assessment and feedback, and helping students to become self-regulated learners (Seldon & Abidoye, 2018). It is important to note that these approaches may either involve humans or not, or may be either specific or adaptive.

Within a more theoretical perspective, as noted earlier, Ouyang and Jiao (2021) proposed three paradigms: AI-directed (learner as recipient), AI-supported (learner as collaborator), and AI-empowered (learner as leader). Intelligent Tutoring Systems (ITS) is an example of AI-directed learning, wherein personalized instruction and feedback are provided to learners, mimicking the role of a human tutor (Ouyang et al., 2022). These systems employ cognitive models and domain-specific knowledge in order to determine the learner's needs and to adapt the instruction accordingly (Sinatra et al., 2019). ITS typically consists of a representation of the student's current level of knowledge, a domain model to describe the content to be taught, and a pedagogical model to orientate the student towards his or her learning goals (Tuomi, 2020). These AI tutors can also be described as pedagogical agents (Johnson et al., 2000). A pedagogical agent is a virtual character or avatar that interacts with learners in an instructional setting. More advance systems are able to provide guidance, explanations, and emotional support to enhance the learning process (Kim & Baylor, 2016). As a result, they can exhibit behavior similar to that of humans, such as facial expressions, gestures, and speech (Johnson & Lester, 2016).

AI-supported learning involves the AI system serving as a support tool while the learner collaborates with the system to focus on their learning needs (Lee & Lee, 2021; Ouyang & Jiao, 2021). In other words, AI-supported learning involves the interaction with other learners within a socially situated context (Järvelä et al., 2023). These collaborative learning support systems facilitate learning by providing tools and support for learners to engage in group activities and discussions. These systems may also incorporate features such as shared workspaces, communication tools, and collaborative problem-solving environments (Linn et al., 2004). Eventually, as AI systems become more sophisticated, they are able to optimize the learner-centered experience through personalized learning, which is achieved through mutual interaction and sustained collaboration between the learner and the system (Ouyang & Jiao, 2021).

AI-empowered learning is a complex system that is capable of adapting to the learning needs of students (Ouyang & Jiao, 2021). In adaptive learning systems, the learning experience is tailored to the individual's characteristics, such as previous knowledge, learning style, and performance. By analyzing learner performance and data, these systems dynamically adjust its content, pace, and difficulty level according to learner preferences (Aleven et al., 2017). These systems are also data driven, wherein educational data are used to inform the design of AIED systems. This includes techniques such as educational data mining and learning analytics to analyze student performance, behavior, and engagement data (Ifenthaler et al., 2019). Furthermore, newer complex systems have even incorporated AR technology to enhance the overall learning experience by delivering interactive and immersive learning content (Yang et al., 2021).

Nowadays, learning can be enhanced by either using virtual or augmented reality for visualization and simulations that provide learners with visual representations and simulations of complex concepts. AR provides learners with the opportunity to interact with and manipulate virtual objects, models, and data by overlaying digital content on the real-world environment (Dunleavy et al., 2009; Radu, 2014). Aside from providing contextualized learning, AR can also be used to provide additional information, multimedia resources, or interactive exercises related to their immediate surroundings (Chen et al., 2022). Importantly, virtual and augmented reality technologies also gave rise to the popularity of using *metaverse* in education (Mystakidis, 2022). An important consideration when integrating AR into AIED systems is to ensure that the learning objectives, instructional design, and technological implementation are carefully considered.

Furthermore, when discussing educational technology design concepts, one of the most important models is the TPACK. Popularized by Mishra and Koehler (Mishra & Koehler, 2006), TPACK is a framework that highlights the intersection of three types of knowledge: Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK). It emphasizes the significance of understanding how technology, pedagogy, and content interact in educational settings. In designing AIED systems, the TPACK model should be capable of integrating technology, pedagogy, and content to ensure effective learning environments. In other words, the TPACK model emphasizes the importance of balancing and integrating these three types of knowledge (Ching & Roberts, 2020; Graham, 2011; Graham et al., 2012). In the context of AIED design, it calls for a thoughtful integration of technology, pedagogy, and content to create effective and meaningful learning experiences (Celik, 2023; Chaipidech et al., 2022). There are, however, some challenges associated with the use of TPACK as an overarching model. A common problem regarding the implementation of TPACK at the institutional level is the lack of consideration given to teachers' perspectives, beliefs, and how their views affect both the interpretation and operationalization of the course curriculum (Velander et al., 2023).

Due to the diversity of approaches and paradigms involved in the design of AIED systems, the integration of these approaches and paradigms enhances the complexity and richness of the process. As a result of this complexity, an overarching framework is required that comprehensively encapsulates the interrelationships among technology, pedagogy, content, and socio-cultural contexts. As an emerging ecosystem, *activity theory* offers a lens for understanding the complex relationships within educational settings, and provides a critical guide for designing adaptive, culturally sensitive, and effective AIEDs.

3. Current Problems in AIED designs

A review of AIED's previous roles revealed four specific responsibilities, which include reducing teacher workload, contextualizing learning, revolutionizing assessments, and developing intelligent tutoring systems (Chaudhry & Kazim, 2022). Similarly, AIED offers various opportunities in terms of improved lesson planning, implementation, and assessment (Celik et al., 2022). While AIED holds great promise, there are several challenges and areas where current design can be improved. AIED primarily focuses heavily on the technological aspects of the systems (Pellas, 2023). Studies have noted the importance of *incorporating sound pedagogical principles* into AIED design to ensure effective learning outcomes (Tuomi, 2018; Vázquez-Cano, 2021). Although current systems have already improved significantly, even incorporating a culturally-responsive approach into pedagogical design (W. Yang, 2022) and has been shown to have a positive impact on students' motivation, engagement, and attitude. There is, however, a lack of sufficient research that *objectively measures students' knowledge acquisition* as learning outcomes (Yue et al., 2022).

There is also a *lack of transparency in the decision making process* of AIED (Blikstein & Worsley, 2016). Using educational data mining and learning analytics, AIED systems often make complex decisions based on AI algorithms (Romero & Ventura, 2020), but the lack of transparency can make it challenging for learners and educators to understand how these decisions are made. This also leads to the issues of *adaptability and personalization*. Although AIED is known for its capability of personalizing instructions, however, not all systems are able to fully leverage learner data to deliver truly tailored learning experiences (Pedró et al., 2019; Sinatra et al., 2019). Thus, in the age of AI, the idea of a digital divide has once again gained traction (Carter et al., 2020; Kitsara, 2022). This can also raise issues of *ethical considerations and bias*. For instance, pedagogical appropriateness, students' rights, AI literacy, and teacher well-being are some of the issues that should be consider within AIED systems (Adams et al., 2021; Celik, 2023). AIED systems must address ethical considerations, including data privacy, security, and fairness. Bias in AI algorithms can perpetuate inequalities and marginalize certain groups of learners.

Importantly, AIED systems often overlook the integration of social and emotional factors into the learning process (Blanchard, 2015). These factors play a crucial role in effective learning and motivation. Incorporating social interactions, emotional support, and feedback mechanisms into AIED design can enhance the overall learning experience (Xie et al., 2022). For instance, Lai et al. (2023) noted the need for the development of social adaptability in AIED system. Furthermore, AIED lacks the necessary personality traits, instructional delivery style, social interaction, and affect that are quite obvious in human teachers (Edwards & Cheok, 2018). Lastly, not all students are accessible to AIED systems due to various reasons, hence, there is also a need to consider the socio-economic backgrounds of the learners (Carter et al., 2020; Kitsara, 2022; Tapalova & Zhiyenbayeva, 2022). In essence, AIED systems should be designed with a commitment to promoting equity and inclusion in education. This involves addressing potential biases in data and algorithms, ensuring equal access to technology and resources, and considering the needs of diverse learners.

4. Education and Human Factors in AIED designs

AI is always a subject of debate, particularly in terms of whether it will replace human teachers and how human ethics will be affected by it (Lameras & Arnab, 2022). When designing AIED systems, it is crucial to consider the impact on human and educational values (Richards & Dignum, 2019). Besides the previous mentioned issues of equity, inclusion, and ethical considerations, the human aspect is also quite important. This might include the design of the AIED itself. AIED systems should prioritize *human-centered design principles* to ensure that they align with learners' needs, goals, and values. This involves involving end-users (such as learners, teachers, and educational stakeholders) in the design process, conducting user research, and incorporating feedback iteratively (Guesmi et al., 2022; Renz & Vladova, 2021). More important, AIED systems should promote the development of basic human values in education, such as autonomy, critical thinking, and ethical reasoning, among others (Jamil et al., 2023; Mouta et al., 2019). The goal is to empower learners to make informed decisions, to foster ethical values and responsible use of AI, which ultimately promote the autonomy of students.

In comparison with AIED, real teachers possess a number of unique qualities and abilities that set them apart. Among the qualities that teachers possess are the ability to establish a personal connection with their students, to provide emotional support, and to empathize with their individual needs and difficulties (Guilherme, 2019). Furthermore, Darling-Hammond (2017) emphasized that teachers are able to adjust their instructional approaches in real time based on real-time observations and assessments of the progress and engagement of their students. Their teaching strategies can be modified, additional explanations can be provided, and individual misconceptions can be addressed. An ability to adapt to learners' diverse needs and adjust instruction accordingly is an essential component of meeting learners' educational needs. It is important to note that while AIED systems are capable of providing valuable support and personalized learning experiences, they lack the nuanced human qualities and expertise that teachers possess. By combining human teachers with AI technologies, powerful educational environments can be created that leverage the strengths of both. Furthermore, incorporating Activity Theory in the design and implementation of AIED is crucial, as it can help human values, learner autonomy, and meaningful engagement within educational settings.

5. Proposed Ecosystem for AIED design

The original concept of activity theory proposed by Vygotsky (1978, 1986) was that learning is both social and situational and that knowledge is constructed through activity. Moreover, the Vygotskian triangle noted that an activity (which has motives) can be considered at the top of the hierarchy above the actions (which are goal-oriented) and the underlying operations (tasks) (Leontiev, 1978, 1981). It can also be described as the integration of consciousness, behavior and activity into a carefully planned relationship (Blunden, 2023). Importantly, an activity must always be understood within its cultural and historical contexts (Kaptelinin, 2005). Hence, it is sometimes also referred to as the Cultural-Historical Theory of Activity (CHAT) (Holzman, 2006; Roth & Lee, 2007). This was later expanded into a collective activity system consisting of a subject, an object, a tool, a rule, a division of labor and a community (together with their subsequent relationships) (Engeström, 1987, 2014). Based on this model, it emphasizes the difference between the purpose or motive of an activity and its outcomes, which are not always the ones that are anticipated or desired (Engeström, 2001). In many ways, it is similar to the way activities are mediated in higher education institutions, including their rules and division of labor, goals and outcomes, contradictions, and the constant changes that occur within the process (McAvinia, 2016).

Looking into the Activity Theory and designing an ecosystem for AIED. Activity Theory has long been considered an important theoretical framework for understanding the role of technology in human activities (Kaptelinin & Nardi, 2006; Karanasios et al., 2021) and its subsequent effective usage (Blayone, 2019). It is also one of the most widely used frameworks for analyzing human-computer interaction (Clemmensen et al., 2016). Accordingly, as information technology continues to transform into a cognitive tool, Activity Theory can assist in analyzing the role of computers within a social and cultural context (Tan, 2019). With AI advancing into the micro, meso, and macro levels of the learning process (Gibson et al., 2023), Activity Theory provides an appropriate illustration of the dynamic interactions and contradictions associated with AIED (H. Yang, 2022). Therefore, by anchoring on the collective activity system of Engeström's (2000, 2007), the AIED design process can be clearly explained.

In AIED design, the six components (a subject, an object, a tool, a rule, a division of labor, and a community) of the collective activity system provides a comprehensive structure for understanding and organizing the various elements and interactions within an educational environment. Utilizing this ecosystem in the design of AIED allows for a systematic approach (see Figure 1):

- **Subject**: Refers to the participants, which are the individual or group whose activity is the focus. In the context of AIED, this component may refer to both learners (students) and educators (teachers). Designing an effective AIED system requires understanding both students' and teachers' needs, goals, and roles to support and enhance the learning and teaching experiences. Taking a university biology class as an example, undergraduate students studying genetic concepts are the individuals involved in the learning activities, whereas faculty and teaching assistants are responsible for teaching and conducting assessments.

- **Object**: Represents the target or goal of the activity. As part of the teaching and learning process, the object could be the acquisition of knowledge, the improvement of skills, the development of critical thinking, among others. For an AIED design to be effective, the systems must support and align with these learning objectives. For the biology class, some lesson objectives are the understanding of fundamental genetic principles, applying them to practical experiments, and developing critical thinking skills in the area of genetics.

- **Tool**: Refers to the AI technologies (including hardware and/or software) that serve as tools within the activity system. AIED systems can include a variety of tools such as adaptive learning platforms, intelligent tutoring systems, and educational chatbots. It is important that these tools be capable of complementing and enhancing the teaching and learning process, thus achieving the various objectives. For instance, genetics experiments can be assisted with the use of AI assisted virtual laboratories.

- **Rule**: Refers to the norms, regulations, or guidelines that govern the activity. It may include guidance regarding what is allowed, who is allowed, when, where, and how. AIED designs should generally incorporate ethical guidelines, privacy regulations, pedagogical principles, and curriculum guidelines in order to ensure responsible AI use in education.

- **Division of Labor**: Describes the distribution of tasks and responsibilities among participants. In the context of AIED, it includes the roles of teachers, AI developers, educational policymakers, and students. Clarifying these roles helps in designing systems that accommodate and support the diverse needs of each participant.

- **Community**: Encompasses the social context and networks within which the activity takes place. In AIED, it involves the educational community: teachers, students, administrators, and other stakeholders (including the parents). Creating AIED systems that foster collaboration, interaction, and knowledge sharing within this community can enhance the learning ecosystem.

In terms of their interactions, the uniqueness of the AIED ecosystem is that it seeks a balance between the various components as such interactions usually cause contractions or disturbances (disagreements between them). It is possible, for instance, that teachers and students (subjects) may perceive lessons differently depending on how AI (tool) is employed. The AIED ecosystem seeks to create balance and ensure that the different components work together in harmony. This is done through active dialogue and communication between the components (or stakeholders), as well as through the implementation of effective policies (rules). Consequently, some of these interactions may be more complex (involving two or more components), for instance. In a school setting, the division of labor (between teachers and AI developers) is usually determined by the relationship between teachers (subject) and school administrators (community), which is also very influenced by the extent of the pedagogy and curriculum (rules). Additionally, these relationships can also be shaped by resources, and expectations of the various components, such as funding and technology availability.

By leveraging Engeström's collective activity system, AI developers and educators can systematically analyze, organize, and address the complex interactions and dynamics within the educational context. It facilitates a holistic approach to AIED design that considers the needs of participants, the learning objectives, ethical considerations, and the social context, leading to more effective and learner-centered AI-integrated educational environments.

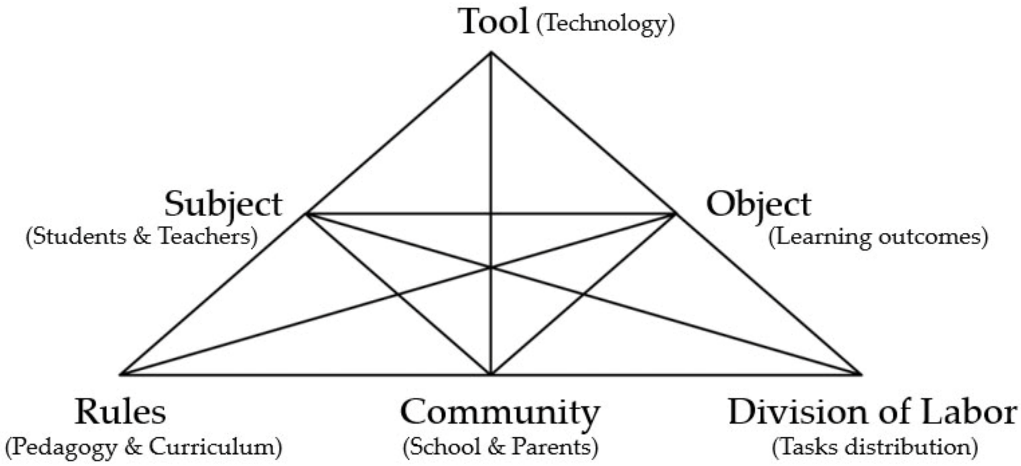

Figure 1. Proposed Ecosystem for AIED design (Adapted from Engeström's (Engeström, 2000) collective activity system, p. 962).

6. Conclusion

As the education in our current age continues to evolve into the digital era, the strategic integration of AIED stands as a pivotal force in shaping the future of learning. The emergence of AIED as a transformative force in modern learning, offers the potential to enhance educational experiences through personalized learning, adaptive instruction, and innovative pedagogical approaches. However, the design and implementation of AIED systems present multifaceted challenges and opportunities. This conceptual paper explored diverse paradigms in designing AIED, spanning AI-directed, AI-supported, and AI-empowered learning approaches. Amidst the promises of AIED, several challenges persist, such as transparency in decision-making, ethical concerns, and the need for greater inclusion of social and emotional factors within learning environments. Notably, the distinct qualities of human teachers, including their ability to establish connections, provide emotional support, and dynamically adapt instruction, remain indispensable. Moreover, the absence of a unified framework capable of seamlessly integrating technological advancements with pedagogical strategies and socio-cultural contexts further accentuates the necessity for a structured ecosystem in AIED design.

Crucially, the paper advocates for a shift towards a sustainable ecosystem in AIED design rooted in Activity Theory. Engeström's collective activity system offers a comprehensive framework that encompasses diverse components: subject, object, tool, rule, division of labor, and community: emphasizing their interactions and mutual influence within the higher education landscape. Activity Theory, with its focus on understanding social and cultural dynamics in all levels of education, providing a critical guide for creating adaptive, culturally sensitive, and effective AIED systems. By leveraging this theoretical framework, designers can navigate the complexities of human-AI interactions, fostering collaboration, and aligning systems with learners' needs, values, and goals.

In essence, the future of AIED lies in merging the strengths of AI technology with the unique qualities of human educators. By anchoring AIED design in Activity Theory, educational ecosystems can be cultivated to empower learners, promote ethical values, and ensure responsible AI integration in all levels of education. This paper contends that embracing Activity Theory as a foundational framework for AIED design can pave the way for dynamic and engaging learning experiences, ultimately shaping a more inclusive, learner-centered, and ethically responsible AI-integrated educational landscape.

7. References

Adams, C., Pente, P., Lemermeyer, G., & Rockwell , G. (2021). Artificial intelligence ethics guidelines for K-12 education: A review of the global landscape. In I. Roll, D. McNamara, S. Sosnovsky, R. Luckin, & V.

Dimitrova (Eds.), *International conference on artificial intelligence in education* (Vol. 12749, pp. 24-28). Springer. https://doi.org/10.1007/978-3-030-78270-2_4

AlDhaen, F. (2022). The use of artificial intelligence in higher education: Systematic review. In M. Alaali (Ed.), *COVID-19 challenges to university information technology governance* (pp. 269–285). Springer.

Aleven, V., Mclaughlin, E. A., Glenn, R. A., & Koedinger, K. R. (2017). Instruction based on adaptive learning technologies. In R. E. Mayer & P. A. Alexander (Eds.), *Handbook of research on learning and instruction* (2nd ed., pp. 522-560). Routledge.

Bakhurst, D. (2009). Reflections on activity theory. *Educational Review, 61*(2), 197-210. https://doi.org/10.1080/00131910902846916

Bertelsen, O. W., & Bødker, S. (2003). Activity theory. In J. M. Carroll (Ed.), *HCI models, theories, and frameworks: Toward a multidisciplinary science* (pp. 291-324). Morgan Kaufmann.

Bhimdiwala, A., Neri, R. C., & Gomez , L. M. (2022). Advancing the design and implementation of artificial intelligence in education through continuous improvement. *International Journal of Artificial Intelligence in Education 32*, 756–782. https://doi.org/10.1007/s40593-021-00278-8

Blanchard, E. G. (2015). Socio-cultural imbalances in AIED research: Investigations, implications and opportunities. *International Journal of Artificial Intelligence in Education, 25*, 204-228. https://doi.org/10.1007/s40593-014-0027-7

Blayone, T. J. B. (2019). Theorising effective uses of digital technology with activity theory. *Technology, Pedagogy and Education, 28*(4), 447-462. https://doi.org/10.1080/1475939X.2019.1645728

Blikstein, P., & Worsley, M. (2016). Multimodal learning analytics and education data mining: Using computational technologies to measure complex learning tasks. *Journal of Learning Analytics, 3*(2), 220-238. https://doi.org/10.18608/jla.2016.32.11

Blunden, A. (2023). *Activity theory: A critical review*. Brill.

Carter, L., Liu, D., & Cantrell, C. (2020). Exploring the intersection of the digital divide and artificial intelligence: A hermeneutic literature review. *AIS Transactions on Human-Computer Interaction, 12*(4), 253-275. https://doi.org/10.17705/1thci.00138

Celik, I. (2023). Towards Intelligent-TPACK: An empirical study on teachers' professional knowledge to ethically integrate artificial intelligence (AI)-based tools into education. *Computers in Human Behavior, 138*, 107468. https://doi.org/10.1016/j.chb.2022.107468

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*, 616–630. https://doi.org/10.1007/s11528-022-00715-y

Chaipidech, P., Srisawasdi, N., Kajornmanee, T., & Chaipah, K. (2022). A personalized learning system-supported professional training model for teachers' TPACK development. *Computers and Education: Artificial Intelligence, 3*, 100064. https://doi.org/10.1016/j.caeai.2022.100064

Chaudhry, M. A., & Kazim, E. (2022). Artificial Intelligence in Education (AIEd): A high-level academic and industry note 2021. *AI and Ethics, 2*, 157–165. https://doi.org/10.1007/s43681-021-00074-z

Chen, M.-P., Wang, L.-C., Zou, D., Shu-Yuan, L., Xie, H., & Tsai, C.-C. (2022). Effects of captions and English proficiency on learning effectiveness, motivation and attitude in augmented-reality-enhanced themebased contextualized EFL learning. *Computer Assisted Language Learning, 35*, 381-411. https://doi.org/10.1080/09588221.2019.1704787

Ching, G. S., & Roberts, A. (2020). Evaluating the pedagogy of technology integrated teaching and learning: An overview. *International Journal of Research Studies in Education, 9*(6), 1-9. https://doi.org/10.5861/ijrse.2020.5800

Clemmensen, T., Kaptelinin, V., & Nardi, B. A. (2016). Making HCI theory work: An analysis of the use of activity theory in HCI research. *Behaviour & Information Technology, 35*(8), 608-627. https://doi.org/10.1080/0144929X.2016.1175507

Crockett, K., Colyer, E., & Latham, A. (2021). The ethical landscape of data and artificial intelligence: Citizen perspectives. 2021 IEEE Symposium Series on Computational Intelligence, Orlando, FL.

Crompton, H., & Burke , D. (2023). Artificial intelligence in higher education: The state of the field. *International Journal of Educational Technology in Higher Education, 20*, 22. https://doi.org/10.1186/s41239-023-00392-8

Darling-Hammond, L. (2017). Teacher education around the world: What can we learn from international practice? *European Journal of Teacher Education, 40*(3), 291-309. https://doi.org/10.1080/02619768.2017.1315399

Dunleavy, M., Dede, C., & Mitchell, R. (2009). Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning. *Journal of Science Education and Technology, 18*, 7-22. https://doi.org/10.1007/s10956-008-9119-1

Edwards, B. I., & Cheok, A. D. (2018). Why not robot teachers: Artificial intelligence for addressing teacher shortage. *Applied Artificial Intelligenc, 32*(4), 345-360. https://doi.org/10.1080/08839514.2018.1464286

Engeström, Y. (1987). *Learning by expanding: An activity-theoretical approach to developmental research*. Orienta-Konsultit.

Engeström, Y. (2000). Activity theory as a framework for analyzing and redesigning work. *Ergonomics, 43*(7), 960-974. https://doi.org/10.1080/001401300409143

Engeström, Y. (2001). Expansive learning at work: Toward an activity theoretical reconceptualization. *Journal of Education and Work, 14*(1), 133-156. https://doi.org/10.1080/13639080020028747

Engeström, Y. (2007). Enriching the theory of expansive learning: lessons from journeys toward coconfiguration. *Mind, Culture, and Activity, 14*(1/2), 23-39. https://doi.org/10.1080/10749030701307689

Engeström, Y. (2014). *Learning by expanding: An activity-theoretical approach to developmental research* (2nd ed.). Cambridge University Press.

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

Gocen, A., & Aydemir, F. (2020). Artificial intelligence in education and schools. *Research on Education and Media, 12*(1), 13-21. https://doi.org/10.2478/rem-2020-0003

Graham, C. R. (2011). Theoretical considerations for understanding technological pedagogical content knowledge (TPACK). *Computers & Education, 57*(3), 1953-1960.

https://doi.org/10.1016/j.compedu.2011.04.010

Graham, C. R., Borup, J., & Smith, N. B. (2012). Using TPACK as a framework to understand teacher candidates' technology integration decisions. *Journal of Computer Assisted Learning, 28*, 6. https://doi.org/10.1111/j.1365-2729.2011.00472.x

Guesmi, M., Chatti, M. A., Tayyar, A., Ain, Q. U., & Joarder, S. (2022). Interactive visualizations of transparent user models for self-actualization: A human-centered design approach. *Multimodal Technologies and Interaction, 6*(6), 42. https://doi.org/10.3390/mti6060042

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

Holzman, L. (2006). What kind of theory is activity theory? Introduction. *Theory & Psychology, 16*(1), 5-11. https://doi.org/10.1177/0959354306060105

Huang, A. Y. Q., Lu, O. H. T., & Yang, S. J. H. (2023). Effects of artificial Intelligence–Enabled personalized recommendations on learners' learning engagement, motivation, and outcomes in a flipped classroom. *Computers & Education, 194*, 104684. https://doi.org/10.1016/j.compedu.2022.104684

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. https://doi.org/10.1016/j.caeai.2020.100001

Ifenthaler, D., Mah, D.-K., & Yau, J. Y.-K. (Eds.). (2019). *Utilizing learning analytics to support study success*. Springer.

Jamil, H., Raza, S. H., & Naqvi, S. G. (2023). Artificial intelligence and grand challenges for education. *Journal of Policy Research, 9*(1), 317-322. https://doi.org/10.5281/zenodo.7951651

Johnson, W. L., & Lester, J. C. (2016). Research-based design of pedagogical agent roles: A review, progress, and recommendations. *International Journal of Artificial Intelligence in Education, 26*, 25-36. https://doi.org/10.1007/s40593-015-0065-9

Johnson, W. L., Rickel, J. W., & Lester, J. C. (2000). Animated pedagogical agents: Face-to-face interaction in interactive learning environments. *International Journal of Artificial Intelligence in Education, 11*(1), 47-78.

Jonassen, D. H., & Rohrer-Murphy , L. (1999). Activity theory as a framework for designing constructivist learning environments. *Educational Technology Research and Development, 47*, 61-79.

Järvelä, S., Nguyen, A., & Hadwin, A. (2023). Human and artificial intelligence collaboration for socially shared regulation in learning. *British Journal of Educational Technology, 54*(5), 1057-1076. https://doi.org/10.1111/bjet.13325

Kaptelinin, V. (2005). The object of activity: Making sense of the sense-maker. *Mind, Culture, and Activity, 12*(1), 4-18. https://doi.org/10.1207/s15327884mca1201_2

Kaptelinin, V., & Nardi, B. A. (2006). *Acting with technology: Activity theory and interaction design*. MIT Press.

Karanasios, S., Nardi, B., Spinuzzi, C., & Malaurent, J. (2021). Moving forward with activity theory in a digital world. *Mind, Culture, and Activity, 28*(3), 234-253. https://doi.org/10.1080/10749039.2021.1914662

Kim, Y., & Baylor, A. L. (2016). Research-based design of pedagogical agent roles: A review, progress, and recommendations. *International Journal of Artificial Intelligence in Education, 26*, 160–169.

https://doi.org/10.1007/s40593-015-0055-y

Kitsara, I. (2022). Artificial intelligence and the digital divide: From an innovation perspective. In A. Bounfour (Ed.), *Platforms and artificial intelligence* (pp. 245–265). Springer. https://doi.org/10.1007/978-3-030-90192-9_12

Kuleto, V., Ilić, M., Dumangiu, M., Ranković, M., Martins, O. M. D., Păun, D., & Mihoreanu, L. (2021). Exploring opportunities and challenges of artificial intelligence and machine learning in higher education institutions. *Sustainability, 13*(18), 10424. https://doi.org/10.3390/su131810424

Lai, T., Xie, C., Ruan, M., Wang, Z., Lu, H., & Fu, S. (2023). Influence of artificial intelligence in education on adolescents' social adaptability: The mediatory role of social support. *PLoS One, 18*(3), e0283170. https://doi.org/10.1371/journal.pone.0283170

Lameras, P., & Arnab, S. (2022). Power to the teachers: An exploratory review on artificial intelligence in education. *Information, 13*(1), 14. https://doi.org/10.3390/info13010014

Lee, H. S., & Lee, J. (2021). Applying artificial intelligence in physical education and future perspectives. *Sustainability, 13*(1), 351. https://doi.org/10.3390/su13010351

Leontiev, A. (1978). *Activity, consciousness, and personality*. Prentice-Hall.

Leontiev, A. (1981). *Problems of the development of the mind*. Progress.

Linn, M. C., Davis, E. A., & Bell, P. (2004). *Internet environments for science education* (1st ed.). Lawrence Erlbaum Associates.

Liu, H., Kulturel-Konak, S., & Konak, A. (2021). Key elements and their roles in entrepreneurship education ecosystem: Comparative review and suggestions for sustainability. *Sustainability, 13*(19), 10648. https://doi.org/10.3390/su131910648

Mason, M. (2008). What Is complexity theory and what are its implications for educational change? *Educational Philosophy and Theory, 40*(1), 35-49. https://doi.org/10.1111/j.1469-5812.2007.00413.x

McAvinia, C. (2016). *Online learning and its users: Lessons for higher education*. Chandos Publishing.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record, 108*(6), 1017-1054. https://doi.org/10.1111/j.1467-9620.2006.00684.

Mouta, A., Sánchez, E. T., & Llorente, A. P. (2019). Blending machines, learning, and ethics. TEEM'19: Proceedings of the Seventh International Conference on Technological Ecosystems for Enhancing Multiculturality, León Spain.

Mystakidis, S. (2022). Metaverse. *Encyclopedia, 2*(1), 486-497. https://doi.org/10.3390/encyclopedia2010031

O'Dea, X., & O'Dea, M. (2023). Is artificial intelligence really the next big thing in learning and teaching in higher education? A conceptual paper. *Journal of University Teaching and Learning Practice, 20*(5). https://doi.org/10.53761/1.20.5.05

Office of Educational Technology. (2023). *Artificial intelligence and future of teaching and learning: Insights and recommendations*. U.S. Department of Education, Office of Educational Technology.

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

Ouyang, F., Zheng, L., & Jiao, P. (2022). Artificial intelligence in online higher education: A systematic review of empirical research from 2011 to 2020. *Education and Information Technologies, 27*, 7893–7925. https://doi.org/10.1007/s10639-022-10925-9

Paek, S., & Kim, N. (2021). Analysis of worldwide research trends on the impact of artificial intelligence in education. *Sustainability, 13*(14), 7941. https://doi.org/10.3390/su13147941

Pedró, F., Subosa, M., Rivas, A., & Valverde, P. (2019). *Artificial intelligence in education: Challenges and opportunities for sustainable development*. UNESCO.

Pellas, N. (2023). The influence of sociodemographic factors on students' attitudes toward AI-generated video content creation. *Smart Learning Environments, 10*, 57. https://doi.org/10.1186/s40561-023-00276-4

PWC. (2017). *Sizing the prize*. PricewaterhouseCoopers.

Radu, I. (2014). Augmented reality in education: A meta-review and cross-media analysis. *Personal and Ubiquitous Computing, 18*, 1533-1543. https://doi.org/10.1007/s00779-013-0747-y

Renz, A., & Vladova, G. (2021). Reinvigorating the discourse on human-centered artificial intelligence in educational technologies. *Technology Innovation Management Review, 11*(5), 5-16. https://doi.org/10.22215/timreview/1438

Richards, D., & Dignum, V. (2019). Supporting and challenging learners through pedagogical agents: Addressing ethical issues through designing for values. *British Journal of Educational Technology, 50*(6), 2885-2901. https://doi.org/10.1111/bjet.12863

Romero, C., & Ventura, S. (2020). Educational data mining and learning analytics: An updated survey. *Wires: Data Mining and Knowledge Discovery, 10*(3), 1355. https://doi.org/10.1002/widm.1355

Roth, W.-M., & Lee, Y.-J. (2007). Vygotsky's neglected legacy: Cultural-historical activity theory. *Review of Educational Research, 77*(2), 186-232. https://doi.org/10.3102/003465430629827

Seldon, A., & Abidoye, O. (2018). *The fourth education revolution: Will artificial intelligence liberate or infantilise humanity*. The University of Buckingham Press.

Sinatra, A. M., Graesser, A. C., Hu, X., Brawner, K., & Rus, V. (Eds.). (2019). *Design recommendations for intelligent tutoring systems: Self-improving systems* (Vol. 7). US Army Research Laboratory.

Smaldino, S. E., Lowther, D. L., Mims, C., & Russell, J. D. (2019). *Instructional technology and media for learning* (12th, Ed.). Pearson.

Smith, D. A. (2024). How fears of AI in the classroom reflect anxieties about choosing sophistry over true knowledge in the American education system. *Critical Humanities, 2*(2). https://doi.org/10.33470/2836-3140.1032

Tan, S.-C. (2019). Learning with computers: Generating insights into the development of cognitive tools using cultural historical activity theory. *Australasian Journal of Educational Technology, 35*(2), 25-38. https://doi.org/10.14742/ajet.4848

Tapalova, O., & Zhiyenbayeva, N. (2022). Artificial intelligence in education: AIEd for personalised learning pathways. *Electronic Journal of e-Learning, 20*(5), 639-653. https://doi.org/10.34190/ejel.20.5.2597

Tuomi, I. (2018). *The impact of artificial intelligence on learning, teaching, and education*. Publications Office of the European Union.

Tuomi, I. (2020). *The use of artificial intelligence (AI) in education*. Retrieved 11 November 2023 from https://research4committees.blog/2020/09/07/the-use-of-artificial-intelligence-ai-in-education/

Velander, J., Taiye, M. A., Otero, N., & Milrad, M. (2023). Artificial Intelligence in K-12 Education: Eliciting and reflecting on Swedish teachers' understanding of AI and its implications for teaching and learning. *Education and Information Technologies*. https://doi.org/10.1007/s10639-023-11990-4

Vázquez-Cano, E. (2021). Artificial intelligence and education: A pedagogical challenge for the 21st century. *Educational Process International Journal, 10*(3), 7-12. https://doi.org/10.22521/edupij.2021.103.1

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Vygotsky, L. S. (1986). *Thought and language*. MIT Press.

Xie, C., Ruan, M., Lin, P., Wang, Z., Lai, T., Xie, Y., Fu, S., & Lu, H. (2022). Influence of artificial intelligence in education on adolescents' social adaptability: A machine learning study. *International Journal of Environmental Research and Public Health, 19*(13), 7890. https://doi.org/10.3390/ijerph19137890

Yang, H. (2022). The current research trend of artificial intelligence in language learning: A systematic empirical literature review from an activity theory perspective. *Australasian Journal of Educational Technology, 38*(5), 180–210. https://doi.org/10.14742/ajet.7492

Yang, S. J. H., Ogata, H., Matsui, T., & Chen, N.-S. (2021). Human-centered artificial intelligence in education: Seeing the invisible through the visible. *Computers and Education: Artificial Intelligence, 2*, 100008. https://doi.org/10.1016/j.caeai.2021.100008

Yang, W. (2022). Artificial Intelligence education for young children: Why, what, and how in curriculum design and implementation. *Computers and Education: Artificial Intelligence, 3*, 100061. https://doi.org/10.1016/j.caeai.2022.100061

Yue, M., Jong, M. S.-Y., & Dai, Y. (2022). Pedagogical design of K-12 artificial intelligence education: A systematic review. *Sustainability, 14*(23), 15620. https://doi.org/10.3390/su142315620

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