



Human-AI Collaboration in AI-Augmented Educational Metaverse Ecosystems: Toward a Co-Agency Perspective in Teacher Education

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ABSTRACT

The integration of generative artificial intelligence (AI), immersive technology and educational metaverse environments is transforming teacher education while establishing new forms of educational engagement. Current research has offered critical insights into AI adoption, AI literacy, immersive learning and educational outcomes. However, existing research provides limited conceptual explanation of how educators and intelligent systems collaboratively enact educational activity within AI-Augmented Educational Metaverse Ecosystems. This conceptual research intends to solve this gap by offering an agency-centered paradigm to explain Human-AI collaboration in AI-Augmented Educational Metaverse Ecosystems. In this paradigm, Human Agency and AI Agency are considered as basic skills for instructional action. It is argued that Human-AI Co-Agency is a relational mechanism that aligns and collaboratively performs these contributions inside shared educational processes. This manner, the study shifts the emphasis from technology adoption to collaborative educational engagement as the primary unit of analysis. The framework advances the conceptual understanding of Human-AI collaboration and lays the foundation for Human-AI Co-Agency as a platform for future learning and professional practice in teacher education.



Introduction

Generative artificial intelligence (AI), immersive technology and intelligent educational systems are increasingly changing the way learning is organized, experienced and evaluated during a time of tremendous change in the field of teacher education. Recent advances in generative AI have taken educational systems beyond automation to content production, intelligent evaluation, adaptive aid and tailored learning experiences (DeLuca et al., 2026; Ogunleye et al., 2024). In addition, the educational metaverse settings have become more persistent and immersive venues, which incorporate virtual presence, interaction and experience learning via more advanced technologies (Garcia, 2026; Lim et al., 2026). These are not individual technical advancements but rather trends converging into AI-Augmented Educational Metaverse Ecosystems where instructors, learners, intelligent systems and digital objects collaborate in educational activities. This is not just a radical shift in the method learning takes place, but also in the way educational activity is organized and conducted.

These advancements have driven fast growth in a number of study areas. Research in AI in education has explored intelligent tutoring, evaluation, academic integrity, adaptive learning, and educational policy (Adamakis & Rachiotis, 2025; Strielkowski et al., 2025; UNESCO, 2024). Studies on the educational metaverse have mostly focused on immersion, virtual presence, collaborative encounters and experiential learning in digitally-mediated contexts (Beck et al., 2023; Garcia, 2026; Yeganeh et al., 2025). Similarly,

research in teacher education has increasingly focused on issues of AI literacy, digital competence, ethical awareness, and professional readiness for new technologies (Chiu et al., 2023; Cong-Lem, 2024; UNESCO, 2024). Taken together, these results suggest that educators will increasingly find themselves in educational settings in which intelligent systems are active participants in teaching and learning, rather than just supplemental instructional resources.

However, this growing collection of evidence still leaves a significant conceptual lacuna. While AI in education, educational metaverse research and teacher education have made significant progress, these three areas have mostly developed separately. Existing literature describes the technology adoption, AI literacy, immersive learning, digital competence and educational outcomes (Crompton & Burke, 2023; UNESCO, 2024; Wang & Huang, 2025), yet offers very little insight into how educators and intelligent systems jointly execute instructional activities in AI-Augmented educational metaverse Ecosystems. As intelligent systems progressively contribute to the production of instructional materials, the personalization of learning experiences, the facilitation of assessment, and the engagement in pedagogical decision-making, the partnership between human teachers and AI systems emerges as a key feature of educational practice in the future. However, the processes via which such collaboration arises is poorly conceptualized, limiting our knowledge of collaborative educational activity in intelligent and immersive learning environments.

This conceptual limitation is aggravated by an inconsistent nomenclature. Today in the literature terms like AI help, AI support, Human-AI interaction, Human-AI collaboration and AI partnership are often used synonymously, yet they refer to fundamentally different educational interactions (Edwards et al., 2025; Li & Tian, 2026). Thus, Human-AI collaboration is generally seen as a description of the outcome of the usage of technology rather than a phenomenon that requires theoretical explanation. The latest research has been progressively focusing on the importance of interaction between teachers and intelligent systems (Ali et al., 2025; Richter et al., 2025). It presents a partial account of the relational mechanisms via which human judgement and AI capabilities are enacted together in educational practice. The notion of Human-AI Co-Agency has not yet been developed into a unified conceptual framework to explain the emergence of meaningful collaboration in AI-Augmented Educational Metaverse Ecosystems.

Such a framework is particularly important for teacher education. Future educators will increasingly employ AI-enhanced lesson planning, assessment, feedback, immersive simulations and professional development environments where intelligent systems actively alter educational activities (Cardona et al., 2023; Kim et al., 2025). Educating teacher for such environments is more than merely about proficiency in technology or AI literacy. This involves understanding how educators exercise professional judgement, ethical responsibility and pedagogical decision-making alongside more sophisticated AI systems. Such a necessity is particularly relevant in developing contexts like Pakistan, where AI-based educational innovation and immersive technologies are gaining swift traction, while teacher education emphasizes primarily integration of technology and digital competence, offering relatively little conceptual guidance for preparing educators to work effectively with intelligent systems. It is important to confront this dilemma to ensure that technological advancement is used to improve, not hinder, professional educational activity.

In this regard, this study advocates for a change from technology-centered approaches towards an agency-centered perspective in understanding Human-AI collaboration in AI-Augmented Educational Metaverse Ecosystems. The study conceptualizes collaborative educational activity as coming from the dynamic interaction of Human Agency, AI Agency and Human-AI Co-Agency, rather than the use of AI as an instructional instrument and educators as technology consumers. In particular, this study provides five contributions. First, it conceptualizes AI-Augmented Educational Metaverse Ecosystems as intelligent, immersive and pedagogically structured settings for teacher education. Second, it re-theorizes Human-AI collaboration as a pedagogical relational construct rather than a technical function. Third, it acknowledges Human Agency and AI Agency as complementing powers supporting instructional action. Fourth, it frames Human-AI Co-Agency as the relational process through which these capabilities are collaboratively exercised in educational activity. Finally, it proposes an integrated conceptual agenda that redirects future research from technology adoption towards agency, co-agency and collaborative educational activity in teacher education.

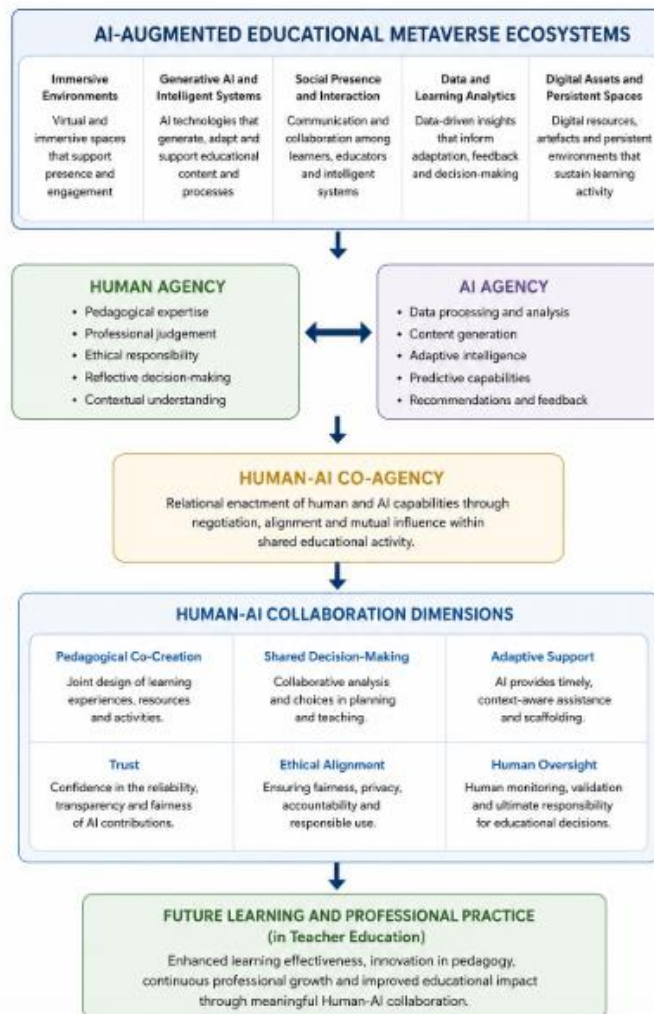


Figure 1. Conceptual Framework of Human-AI Collaboration in AI-Augmented Educational Metaverse Ecosystems

Figure 1 illustrates the proposed conceptual framework developed in this study and how Human Agency and AI Agency work together through Human-AI Co-Agency in AI-Augmented Educational Metaverse Ecosystems impacting Human-AI collaboration and future learning and professional practice in teacher education. The basic capabilities that constitute educational activity are Human Agency and AI Agency in this sense. Together they interact dynamically to provide Human-AI Co-Agency, the primary relational mechanism of the system.

The characteristics of collaboration that characterize Human-AI Co-Agency are: Pedagogical Co-Creation, Shared Decision-Making, Adaptive Support, Trust, Ethical Alignment, and Human Oversight. The variables interact to affect Future Learning and Professional Practice and achieve targeted Teacher Education Outcomes. This paradigm moves the attention from technology adoption to the co-performance of educational activity by human actors and intelligent systems in intelligent and immersive educational environments.

AI-Augmented Educational Metaverse Ecosystems in Teacher Education

Understanding Human-AI collaboration first requires paying attention to the environments where such collaboration takes place. This perspective becomes particularly important in teacher education. Preservice teachers increasingly learn, practice and make pedagogical decisions within technology-rich environments that actively shape educational activity (Abhishek et al., 2026; UNESCO, 2024). Thus, we need a conceptualization of the educational environments in which this Human-AI collaboration occurs to understand this collaboration.

One of the most influential concepts associated with this metamorphosis is the educational metaverse. However, much of this literature remains centered on technological affordances, user experiences and learning outcomes. Consequently, educational metaverse environments are often conceptualized as technologically enhanced spaces rather than as educational systems composed of multiple interacting actors,

resources and practices (Illi & Elhassouny, 2025; Lucas et al., 2025). Such perspectives explain what these environments enable, but they provide limited insight into how educational activity is collectively enacted within them. This limitation becomes all the more acute when AI capabilities are embedded in immersive educational environments.

The ecosystem perspective provides a useful answer to this problem. This perspective is particularly relevant because professional learning in teacher education depends on the relationships between prospective teachers, teacher educators, pedagogical tasks, digital resources and increasingly intelligent technological systems. An ecosystem lens thus offers a better foundation for understanding Human-AI collaboration than approaches that privilege technology over relationships.

Contemporary educational environments increasingly incorporate AI systems capable of generating content, analyzing learner data, providing recommendations, supporting assessment and adapting learning experiences in real time (Kasneci et al., 2023; Ogunleye et al., 2024). An educational metaverse ecosystem emphasizes immersion, interaction and participation in digitally mediated environments. In an AI-augmented educational metaverse ecosystem, these characteristics are extended with intelligent systems that can generate, adapt, recommend and respond in ways that shape educational activity (Illi & Elhassouny, 2025). AI augmentation fundamentally changes educational environments by introducing intelligent responsiveness that reshapes relationships among human actors, educational resources and pedagogical processes. Thus, the partnership of human and AI is more and more ingrained in the regular activities of education.

Building on the preceding discussion, this study defines an AI-Augmented Educational Metaverse Ecosystem as an immersive, intelligent and socially organized educational environment where human actors, AI systems, digital artifacts, and pedagogical processes interact to facilitate learning and professional practice. Such a conception moves the focus away from isolated technology to the interwoven connections through which educational activity is performed. It also emphasizes that AI is rapidly becoming an active part of educational ecosystems, and not just a supporting tool.

But this model does not answer how collaboration itself is developed or contributes to learning and professional practice. This constraint highlights the need for further exploration of the development of collaborative interactions between human actors and AI systems. The following part therefore reconceptualizes Human-AI collaboration as the phenomena of theoretical interest.

Reframing Human-AI Collaboration in Teacher Education

In the previous part, AI-Augmented Educational Metaverse Ecosystems were envisioned as the places where Human-AI collaboration increasingly happens. However, the identification of the environment does not elucidate the very nature of the relationships obtained between human agents and intelligent systems. Therefore, understanding how teachers and AI systems work together becomes a major problem for teacher education. To tackle this difficulty, the Human-AI partnership itself has to be studied in more detail.

As intelligent systems increasingly take on active roles in knowledge development, decision support, assessment and learning design, the potential for human-AI collaboration has received increasing interest in education and related sectors (Khalil & Ishaq, 2024; Dang et al., 2025). Yet, despite the increasing interest, Human-AI collaboration remains conceptually underdeveloped.

This conceptual gap largely stems from how collaboration is defined. Collaboration has often been used as a synonym for participation, help, support or use of technology in the past (Shneiderman, 2022; Wang et al., 2023). Such definitions ignore the specificity of teacher education where interpretation, pedagogical judgment, ethical responsibility and contextual decision-making are beyond task performance. In this way conceptualizations that are mostly oriented on technology functioning are challenged to explain how collaboration occurs in educational activity.

This limitation is particularly obvious in teacher education. Prospective teachers are increasingly being exposed to AI systems that create lesson plans, recommend teaching methods, support evaluation and encourage professional development (Cardona et al., 2023). However, just knowing that humans and AI systems engage in the same activity does not mean that they collaborate. A future teacher that takes AI-generated information at face value is not the same as a future teacher that interrogates, modifies and situates it to serve particular pedagogical purposes and the requirements of learners. Both are working with AI, but they are different kinds of educational work. Equating them obfuscates the complexity of collaboration and impedes theoretical understanding. This constraint is even more clear when Human-AI collaboration is considered along with comparable notions utilized in the literature.

This conceptual ambiguity is further explained by comparing Human-AI collaboration with similar entities. Human-AI Interaction is about how humans and intelligent systems communicate and engage with one other. It speaks of communication and engagement but not usually of shared educational activity (Lindgren, 2025; Puerta-Beldarrain et al., 2025). Human-AI teaming (HAIT) investigates human and AI

collaboration to accomplish tasks, often in well-defined contexts (Berretta et al., 2023; Lou et al., 2025). Collaborative intelligence is all about working together with humans and AI systems to get results that neither could do alone (Ali et al., 2025; Gupta et al., 2025). Shared agency is the activity of actors working together to achieve similar goals (Al-Bashrawi et al., 2026). Each perspective provides useful insights, but none sufficiently accounts for the co-enactment of educational action in continually shaping each other human and AI contributions inside AI-Augmented Educational Metaverse Ecosystems. This raises theoretical and practical problems, in turn, as there is no clear conceptual demarcation.

Different definitions limit the advancement of cumulative knowledge, make it harder to operationalize constructs, and confound comparisons of results across research (Cukurova et al., 2023; Darvishi et al., 2024; Järvelä et al., 2023). Therefore, understanding collaboration requires attention not only to what participants do but also to how they contribute to educational activity. This observation points to a more fundamental issue. Meaningful collaboration presupposes contribution to shared educational activity.

This study conceptualizes Human-AI collaboration as an educational phenomenon requiring theoretical explanation rather than a descriptive label for technology-supported activity. Explaining collaboration requires moving beyond observable interaction to the forms of agency through which human actors and AI systems contribute to educational activity. The next section therefore examines Human Agency and AI Agency as the capacities that make meaningful Human-AI collaboration possible.

Human Agency and AI Agency as Foundations of Human-AI Collaboration

The preceding section argued that Human-AI collaboration cannot be adequately explained through interaction, assistance or technology use alone. Meaningful collaboration requires participants to contribute to shared educational activity. Accordingly, understanding Human-AI collaboration in AI-Augmented Educational Metaverse Ecosystems requires examining the capacities through which human actors and intelligent systems shape educational processes.

In teacher education, Human Agency extends beyond participation in educational activity. Prospective teachers interpret complex educational situations, make pedagogical judgements, respond to learner needs and assume responsibility for educational outcomes (Cong-Lem, 2024; Solórzano-García, 2025). Human Agency refers to the capacity of educators to exercise intentional action and professional judgement in shaping educational activity. It is expressed not only through intentional action but also through critical appraisal, contextual adaptation, ethical review and professional responsibility.

Recent developments in AI call into question the premise that educational activity is only shaped by human involvement. At present, AI systems are increasingly involved in generating educational material, analyzing learner data, suggesting activities, adjusting learning experiences and responding dynamically to educational inputs (Cardona et al., 2023; Ogunleye et al., 2024). These characteristics enable AI systems to alter the course of educational activities.

The notion of AI Agency is still up for debate. Critics say agency should be reserved for beings that have purpose, conscience and moral responsibility – characteristics that AI systems do not have (Floridi, 2025; Soltanzadeh, 2024; Symons & Abumusab, 2024). These issues are especially salient since educators are ultimately still accountable for educational choices. To simply disregard AI Agency however, is to ignore the expanding significance of intelligent systems in changing the processes of education.

For this reason, this study assumes a functional, rather than a human-equivalent view of AI Agency. Human actors provide distinctive capabilities of intentionality, ethical reasoning, contextual awareness, and professional responsibility. AI systems don't have these features. Nevertheless, the impact of AI systems on educational activities is becoming more important due to their ability to produce, suggest, forecast, adapt, and reply. AI Agency is regarded here as the functional potential of intelligent systems to impact educational processes and results in a given educational context. (Darvishi et al., 2024; Floridi, 2025). This framing acknowledges that AI's educational effects are increasing but does not assign human intentionality or moral agency.

This difference is particularly significant for the education of teachers. Take an exercise of AI-assisted class preparation. An AI system might offer instructional advice, find curricular materials, and suggest assessment procedures. However, the prospective teacher must assess if such suggestions are consistent with learner requirements, pedagogical goals, ethical concerns and contextual realities. This example shows that the educational activity is a consequence of complementing contributions of humans and AI, not autonomous actions of either.

Neither a purely human-centered nor a purely technology-centered perspective adequately explains Human-AI collaboration because they separate kinds of agency that occur within relational educational contexts. Educational activity emerges through the continuous interaction between human judgement and algorithmic capability.

Human Agency explains educators' judgement, responsibility and intentional action, whereas AI Agency explains the adaptive and generative capacities through which intelligent systems influence educational activity. Together, they explain who contributes to educational activity but not how those contributions become aligned, negotiated and enacted within collaborative educational processes.

This limitation leads directly to the next stage of the argument. Collaboration is relational by nature. It relies not only on the presence of individual capacities, but on mechanisms through which those capacities become connected in shared educational action. Understanding Human-AI collaboration therefore requires a perspective that moves beyond individual forms of agency to their joint enactment in educational activity. The next section develops this argument through the concept of Human-AI Co-Agency.

Human-AI Co-Agency: Toward a Relational Understanding of Collaboration

The preceding section argued that Human Agency and AI Agency explain how human actors and intelligent systems contribute to educational activity. Human Agency captures educators' intentionality, professional judgement and responsibility, whereas AI Agency explains how intelligent systems influence educational processes through adaptive and generative capabilities. Together, these concepts explain who contributes to educational activity, but not how those contributions become integrated into collaborative educational activity. Understanding Human-AI collaboration within AI-Augmented Educational Metaverse Ecosystems therefore requires a relational perspective that explains how these forms of agency operate together.

This limitation reflects a broader gap in contemporary scholarship. Although research increasingly recognizes collaboration between humans and AI systems in educational settings, explanations typically privilege either human decision-making or technological capability (Crompton & Burke, 2023). Human-centered perspectives emphasize professional judgement and pedagogical expertise, whereas technology-centered perspectives focus on automation and AI performance. Neither adequately explains how educational activity is jointly enacted through the continuous interaction of human and AI contributions.

This challenge is particularly evident in teacher education. Consider an AI-supported lesson-planning activity. The resulting lesson does not emerge solely from human expertise or AI-generated recommendations. Rather, it develops through an ongoing process in which prospective teachers interpret, evaluate and contextualize AI-generated suggestions while AI systems provide adaptive support and alternative instructional possibilities. Similar dynamics characterize AI-supported assessment, intelligent tutoring, immersive simulations and professional learning environments (Dang et al., 2025; UNESCO, 2024). Educational outcomes therefore emerge through reciprocal human-AI contributions rather than through either participant independently.

To overcome this limitation, this study introduces Human-AI Co-Agency as a conceptual lens for understanding collaborative educational activity. Human-AI Co-Agency describes the joint performance of educational activity through the dynamic interaction of Human Agency and AI Agency in shared educational processes. It does not assume equal contributions nor attribute human qualities to AI systems such as intentionality or moral responsibility. Instead, it provides an account of the relational mechanisms through which human judgement and AI capacities are brought together to influence educational activity. Human-AI Co-Agency therefore shifts analytical attention from individual actors to the collaborative processes through which educational outcomes emerge.

To clarify its theoretical contribution, Human-AI Co-Agency must be distinguished from related perspectives on human-technology collaboration and collective action. Existing approaches offer useful insights, but differ in their assumptions, analytical focus and explanatory scope. Table 1 compares these perspectives and highlights the distinctive contribution of Human-AI Co-Agency for understanding collaborative educational activity within AI-Augmented Educational Metaverse Ecosystems.

Table 1.
Distinguishing Human-AI Co-Agency from Related Conceptual Perspectives

Conceptual Perspective	Primary Focus	Main Contribution	Limitation for Explaining Human-AI Collaboration in Teacher Education
Human-AI Interaction	Exchanges between humans and AI systems	Explains communication and engagement processes	Does not explain how educational activity is jointly enacted
Human-AI Teaming	Coordination between humans and AI for task completion	Explains collaborative task performance	Primarily task-oriented and less focused on educational processes
Collaborative Intelligence	Complementary strengths of humans and AI	Explains how humans and AI enhance outcomes together	Focuses on outcomes rather than collaborative educational enactment
Shared Agency	Collective action toward common goals	Explains coordination among actors	Traditionally developed for human actors rather than human-AI relationships
Distributed Agency	Distribution of action across multiple actors and systems	Recognizes contributions of human and non-human actors	Does not explicitly explain collaboration within AI-supported educational activity
Sociomaterial Perspectives	Entanglement of social and material elements	Explains how technologies shape human action	Emphasizes interdependence rather than collaborative educational processes
Human-AI Co-Agency	Joint enactment of educational activity through the interaction of Human Agency and AI Agency	Explains how human judgement and AI-generated contributions become aligned, negotiated and enacted within educational activity	Provides a relational explanation of collaboration within AI-Augmented Educational Metaverse Ecosystems

Table 1 illustrates, Human-AI Co-Agency does not replace existing viewpoints, but rather builds on their insights and fills a conceptual gap inadequately defined in present literature. Interaction focuses on exchange, teaming on coordination, collaborative intelligence on complementarity, and shared agency on collective action, whereas Human-AI Co-Agency is concerned with the relational processes through which human and AI contributions are jointly enacted in educational activity. This difference makes Human-AI Co-Agency the core theoretical mechanism for understanding meaningful Human-AI collaboration in teacher education and AI-Augmented Educational Metaverse Ecosystems.

Human-AI Co-Agency builds upon distributed, relational and sociomaterial perspectives of agency while extending them to educational contexts characterized by increasingly autonomous AI participation (Due, 2024; Godwin-Jones, 2024; Loehr, 2022). Although these perspectives provide valuable foundations for understanding collaborative action, they were not developed specifically to explain how educators and intelligent systems jointly enact educational activity within AI-Augmented Educational Metaverse Ecosystems. Human-AI Co-Agency therefore advances a relational perspective that explicitly focuses on how human judgement and AI capabilities become integrated within shared educational processes.

Unlike Human-AI interaction, which emphasizes communication, or Human-AI teaming, which focuses on task coordination, Human-AI Co-Agency explains how educational activity emerges through the continuous alignment of human and AI contributions. It also differs from collaborative intelligence and shared agency by recognizing the asymmetrical yet complementary roles of educators and intelligent systems without attributing human intentionality or moral responsibility to AI. Human-AI Co-Agency therefore serves as an explanatory rather than merely descriptive construct for collaborative educational activity.

Human-AI Co-Agency in AI-Augmented Educational Metaverse Ecosystems offers a conceptual lens to understand how intelligent systems and educators co-shape learning, assessment, feedback and professional practice whilst maintaining the central role of human judgement and educational responsibility. It consequently switches from the technology adoption paradigm to a collaborative educational activity paradigm and provides a basis for examining dimensions such as trust, shared decision-making, adaptive support, ethical alignment and human supervision. Human-AI Co-Agency describes how human and AI contributions are co-enacted. This discussion establishes the conceptual groundwork for the discussion and future research goals in the next section.

Discussion: Advancing Human-AI Collaboration Research in Teacher Education

This study addressed an essential conceptual gap at the junction of AI in education, educational metaverse research, and teacher education by exploring Human-AI collaboration from an agency-centered approach. The existing literature has made significant progress in understanding AI adoption, AI literacy, immersive learning and the integration of educational technologies. (UNESCO, 2024; Wang & Huang, 2025; DeLuca et al., 2026). However, these perspectives provide a partial account of how educators and intelligent systems co-construct instructional activities in AI-Augmented educational metaverse Ecosystems. In this work, collaboration is conceptualized not as a result of technology usage, but as a relational educational phenomenon that emerges via the dynamic interaction of Human Agency, AI Agency and Human-AI Co-Agency. Thus, the study's analytical emphasis moves from technology adoption to collaborative educational action.

The primary theoretical contribution of this work is the conceptualization of Human-AI Co-Agency as the relational mechanism that links Human Agency and AI Agency in joint educational action. Previous studies have mostly addressed Human-AI connections in terms of technology adoption, interaction, coordination or automation, with very little focus on the mechanisms via which human judgment and AI skills get collaboratively enacted in educational activity (Dang et al., 2025; Richter et al., 2025; Kim et al., 2025). The approach suggested here broadens these perspectives, claiming that effective Human-AI collaboration cannot be characterized just in terms of the skills of educators or intelligent systems taken individually. Collaborative educational activity arises instead from the continuous aligning, negotiating and integrating of complementing human and AI inputs. This viewpoint gives a conceptual description of collaboration beyond descriptive accounts of technology usage, providing a better theoretical framework for future research on Human-AI collaboration in teacher education. It also addresses a growing need to reconceptualize collaborative educational activity inside intelligent and immersive learning settings (Edwards et al., 2025; Garcia, 2026). The proposed framework gives rise to four conceptual propositions.

P1. Human-AI Co-Agency is the emergent product of the ongoing interplay of Human Agency and AI Agency in joint educational activity.

P2. Higher levels of Human-AI Co-Agency strengthen collaborative educational activity within AI-Augmented Educational Metaverse Ecosystems.

P3. Trust, human supervision, ethical alignment and adaptive support underpin the growth of Human-AI Co-Agency in collaborative educational activity.

P4. Human-AI Co-Agency increases educators' capacity to work with intelligent technologies while retaining professional judgment, ethical accountability and pedagogical purpose.

These propositions establish an integrated agenda for future research. Future investigations should move beyond examining educators' willingness to adopt AI towards understanding how Human-AI Co-Agency develops across diverse educational contexts. First, empirical studies should examine the relationships between Human Agency, AI Agency and Human-AI Co-Agency using qualitative, quantitative and mixed-methods approaches across different teacher education settings (Samuel, 2026; Solórzano-García, 2025). Second, future research should identify, operationalize and validate the dimensions of Human-AI Co-Agency, including trust, human oversight, ethical alignment, adaptive support and shared pedagogical decision-making, thereby enabling the development of reliable measurement instruments (George, 2026; Katsenou et al., 2025). Third, design-based and cross-cultural research should investigate how collaborative educational activity unfolds across different AI-Augmented Educational Metaverse Ecosystems, educational levels and cultural contexts (Garcia, 2026; Lim et al., 2026). Collectively, these directions provide a coherent pathway for transforming Human-AI Co-Agency from a conceptual proposition into an empirically validated theoretical framework.

The proposed framework also has important implications for teacher education. In current talks, AI literacy, digital competency and technological proficiency are still being highlighted as vital skills for future instructors (Samuel, 2026; Cong-Lem, 2024; UNESCO, 2024). While these competencies will continue to be relevant, they are unlikely to be adequate in educational situations where intelligent technologies are increasingly involved in lesson preparation, evaluation, feedback, simulation and professional development. (Cardona et al., 2023; Katsenou et al., 2025). Preparing future educators requires more than learning how to use AI technologies. This involves the ability to critically analyze AI produced outputs, apply pedagogical judgment, negotiate human-AI decision-making and retain ethical responsibility while working with intelligent systems. In this sense, Human-AI Co-Agency is a professional education competency and not only a technical skill. This view is in line with rising expectations that teachers should be collaborative partners with intelligent systems rather than consumers of technology. (Richter et al., 2025).

The framework also helps to develop AI-Augmented Educational Metaverse Ecosystems. Educational innovation should not just be about automation but also about establishing intelligent environments that support productive sorts of Human-AI Co-Agency. Design of such ecosystems has to address explainability, transparency, human oversight, pedagogical alignment and ethical obligation for intelligent systems to support rather than replace professional educational judgement (Floridi et al., 2025; UNESCO, 2024; Garcia, 2026; Lim et al., 2026). This relational perspective of educational ecosystems provides a more adequate conceptual basis for future research on intelligent learning environments and responsible AI infusion. This position is in line with the current research on the educational metaverse that increasingly conceptualizes intelligent learning environments as interconnected educational ecosystems rather than as distinct technological platforms (Garcia, 2026; Lucas et al., 2025). Therefore, future educational ecosystems need to be developed in such a way that they not only include intelligent technology but also foster meaningful Human-AI Co-Agency so that teaching, learning and professional practice may be enhanced.

This study is conceptual in nature, and consequently, the suggested framework is not experimentally validated. Human-AI Co-Agency remains a theoretical notion to be explored in many educational settings, technologies and cultures, including teacher education systems with distinct technical, institutional and cultural contexts (Samuel, 2026; George, 2026). Future qualitative, quantitative, mixed-methods and design-based research should, therefore, examine its dimensions, processes and boundary conditions and extend and validate the framework suggested in this study.

Conclusion

The accelerated adoption of generative AI and immersive technology into educational contexts is changing the circumstances in which future educators learn, teach and acquire professional competence. Research into AI in education, educational metaverse settings and teacher education has grown substantially, yet conceptual understanding of Human-AI collaboration is fractured. Much of the extant research is still oriented around concerns of adoption, acceptability, preparedness and technical functioning. While these views give valuable insights, they provide no explanation as to how educators and intelligent systems collaborate to contribute to instructional activities in more sophisticated and immersive educational environments.

In this work, we advocate for a paradigm change in the understanding of Human-AI collaboration, from a technology-centered approach to an agency-centered one. The study did not frame AI as a technical tool and educators as its consumers. Rather, it saw collaboration as a relational educational phenomenon that had to be explained in itself. To support this shift, the study conceptualized AI-Augmented Educational Metaverse Ecosystems as the environments in which collaboration occurs more and more, identified Human-AI collaboration as the central phenomenon that needs to be explained, and looked at Human Agency and AI Agency as the basic capacities through which human actors and intelligent systems contribute to educational activity.

The main contribution of this study is the proposal of Human-AI Co-Agency as a relational mechanism that links Human Agency and AI Agency in shared educational processes. In the literature today, human contribution and technology capability are often separated apart. In Human-AI Co-Agency we adopt a different viewpoint and concentrate on how these contributions are linked, negotiated and cooperatively performed in instructional action. This approach moves the unit of study in the framework from technology usage to collaborative educational action, and offers a conceptual basis for understanding how educators and intelligent systems collaborate inside AI-Augmented Educational Metaverse Ecosystems.

The framework developed in this study suggests that future learning and professional practice unfolds through a progression that starts with the capacities of human and AI actors, evolves through their relational enactment in Human-AI Co-Agency and is made visible through collaborative educational activity. This understanding offers a basis for future conceptual development, empirical research and instructional design in intelligent and immersive educational environments.

The future of teacher education may eventually be less about the existence of intelligent technology and more about the ways of Human-AI Co-Agency in which educators and intelligent systems engage in meaningful educational action together. As intelligent and immersive educational environments continue to emerge, understanding and nurturing these collaborative partnerships will therefore become more vital. Ultimately, the future of teacher education may be determined not by how intelligently technologies perform educational tasks, but by how effectively educators and intelligent systems develop forms of Human-AI Co-Agency that support meaningful learning, professional judgement and responsible educational activity.

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