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Ontological, Epistemological, and Axiological Foundations for AI based Learning Models: An Integrative Literature Review

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Abstract

This paper examines the philosophical foundations of AI based learning models by integrating ontological, epistemological, and axiological perspectives into a unified conceptual framework. Although artificial intelligence has rapidly transformed educational environments, prior research has largely examined these philosophical dimensions in isolation, resulting in fragmented guidance for design and implementation. To address this gap, this study develops an integrative tripartite framework that explains how ontological structures, epistemological processes, and axiological principles jointly shape AI supported learning systems. Using an integrative literature review, this study analyses thirty two Scopus indexed journal articles published between 2015 and 2025, complemented by foundational philosophical works. Thematic synthesis identifies three interdependent components of AI based learning: the ontological dimension structures learners, data, algorithms, and educational contexts; the epistemological dimension explains how knowledge is co constructed, validated, and negotiated between humans and intelligent systems; and the axiological dimension articulates the values governing AI use, including human agency, fairness, accountability, and ethical responsibility. The main contribution of this study is a coherent conceptual framework with clearly defined components and application pathways for guiding the design, evaluation, and governance of AI based learning models. The novelty lies in explicitly integrating ontology, epistemology, and axiology into a single model, moving beyond prior fragmented approaches. The findings position AI integration as a multidimensional educational challenge rather than a purely technical endeavour and provide a structured foundation for developing AI supported learning systems that are pedagogically meaningful, ethically grounded, and socially responsible.

KEYWORDS

AI based learning, ontology, epistemology, axiology, integrative literature review.

Introduction

The rapid development of artificial intelligence has reshaped the landscape of education by introducing new forms of learning interaction, representation, and knowledge mediation. AI supported systems increasingly influence how learners access information, manage tasks, and engage in personalised learning pathways. Recent work emphasises that the integration of AI in education is not merely a technological shift but a transformation in how knowledge environments are structured, interpreted, and experienced (Wang et al., 2023). This condition highlights the urgency of understanding the philosophical foundations of AI mediated learning.

Although educational institutions actively adopt AI technologies, discussions on the deeper philosophical assumptions behind these systems remain fragmented. Many studies concentrate on performance, accuracy, or system optimisation while giving limited attention to conceptual questions about the nature of knowledge, the structure of learning environments, and the values embedded in AI driven systems. Doroudi (2024) notes that machine learning and learning analytics operate on implicit paradigms that shape how knowledge is generated and evaluated. Without clear philosophical

grounding, AI based learning designs risk prioritising automation rather than meaningful educational engagement.

Ontological considerations gain prominence as AI systems increasingly rely on structured representations such as ontologies, knowledge graphs, and machine interpretable constructs. Studies show that ontology driven frameworks change how learning content is organised and how learners interact with knowledge structures (Armary et al., 2025; Khadir et al., 2021). The emergence of ontology enhanced learning environments, as seen in knowledge tracing and smart learning systems, signals a shift in how educational reality is constructed and mediated through AI (Wang et al., 2024). These developments require a systematic inquiry into the nature of entities, relations, and structures within AI mediated learning.

Epistemological questions are equally pressing, especially as AI transforms how students interpret information, develop judgment, and construct meaning. Research illustrates that learners' epistemic beliefs and cognitive processes are influenced by machine generated recommendations and automated feedback systems (Celik et al., 2021; Huang et al., 2023). In AI supported learning, the legitimacy and reliability of knowledge outputs depend heavily on the transparency and intelligibility of algorithmic reasoning. Studies on epistemic cognition in STEM and language learning environments show that students' understanding of knowledge quality is shaped by their interaction with intelligent agents and AI powered tools (Gao et al., 2025; Wang et al., 2023).

On the axiological dimension, integrating AI into education introduces significant ethical and value-oriented implications. Research across multiple domains highlights issues of accountability, fairness, and responsible AI deployment (Fernandez et al., 2023; Branda et al., 2025). Axiological debates also extend to cultural and socio moral considerations. Pretorius et al. (2025) emphasise the need for human centred and inclusive AI systems, especially in academic contexts shaped by global inequalities. Meanwhile, Vedrenne Gutiérrez et al. (2024) show that innovation in STEM education is inseparable from ethical analysis, reinforcing that value judgments must guide technological adoption.

Despite the growing volume of research on AI in education, conceptual integration across ontological, epistemological, and axiological dimensions remains limited. Existing studies tend to examine these philosophical foundations in isolation, often prioritising technical performance, ethical compliance, or cognitive outcomes separately. As a result, many proposed frameworks offer only partial insights into how AI reshapes educational reality, knowledge construction, and value orientation in an interconnected manner. While some scholars have begun to bridge specific dimensions, such as linking ontological structures with ethical considerations (Fernandez et al., 2023; Confalonieri et al., 2021), a systematic synthesis that positions ontology, epistemology, and axiology as mutually constitutive pillars of AI based learning is still absent. This fragmentation underscores the need for an integrative review capable of articulating a coherent philosophical foundation for AI mediated education.

An integrative literature review is therefore essential to systematically map how contemporary scholarship conceptualises the philosophical foundations of AI supported learning. By synthesising studies on ontology driven AI systems, epistemic processes in digital learning, and axiological debates on responsible and ethical AI, this review aims to develop a coherent interpretive lens through which AI based learning models can be critically understood. This approach enables the identification of recurring patterns, conceptual tensions, and unresolved gaps that remain underexamined when these philosophical dimensions are treated in isolation.

In this review, *AI based learning models* are defined as educational systems or pedagogical arrangements in which artificial intelligence plays an active role in structuring learning environments, mediating knowledge processes, or influencing educational decision making. This includes, but is not limited to, intelligent tutoring systems, adaptive learning platforms, learning analytics driven environments, AI powered feedback and assessment systems, and ontology based or knowledge graph supported learning systems. The scope of this study is limited to AI applications situated within formal and semi formal educational contexts, with a focus on learning design, learner interaction, and educational governance rather than purely technical algorithmic optimisation. Accordingly, this study is guided by the following research questions:

(1) How are ontological assumptions articulated in contemporary research on AI based learning models, particularly in relation to the structuring of learning environments and educational entities?
(2) How do epistemological perspectives shape understandings of knowledge construction, validation, and learner agency in AI supported learning contexts?
(3) What axiological principles and ethical considerations underpin the design and implementation of AI based learning systems in education?
(4) How can these ontological, epistemological, and axiological dimensions be integrated into a coherent conceptual framework to guide responsible and meaningful AI based learning design?

By addressing these questions, this article formulates an integrated conceptual foundation for AI based learning models that foregrounds philosophical coherence alongside technological innovation. The resulting framework is intended to support educators, researchers, and policymakers in navigating AI mediated education as a multidimensional challenge that encompasses structural design, epistemic integrity, and ethical responsibility in an evolving digital landscape.

Methods

This study employed a qualitative integrative literature review to synthesise research across empirical, conceptual, and ethical traditions related to AI based learning models. An integrative review is particularly suitable for multidisciplinary and philosophically oriented inquiries, as it allows the combination of heterogeneous forms of evidence to support theory development and conceptual integration. As emphasised by Snyder (2019), this approach facilitates deeper analytical synthesis than purely systematic reviews, especially when addressing foundational assumptions that cut across disciplinary boundaries. Accordingly, this design was selected to examine the ontological, epistemological, and axiological foundations of AI supported learning in a coherent manner.

Research Type

The review followed an integrative thematic synthesis design. This design accommodates empirical studies, conceptual analyses, theoretical frameworks, and normative discussions, reflecting the complex nature of AI mediated education. Given the rapid expansion of research on ontology-based AI systems, epistemic cognition in digital learning, and ethical governance of AI, a flexible yet systematic review strategy was required to capture conceptual diversity while maintaining analytical rigour (Doroudi, 2024; Armary et al., 2025; Vedrenne Gutiérrez et al., 2024). The primary objective was not statistical aggregation but conceptual integration across philosophical dimensions.

Data Sources and Search Strategy

Literature searches were conducted using the Scopus database as the primary indexing source, with full text access facilitated through ScienceDirect and institutional library platforms. Searches were carried out between January and March 2025. The following search strings were applied to titles, abstracts, and keywords using Boolean operators:

(1) AI AND education AND ontology
(2) AI based learning AND epistemology
(3) AI supported learning AND epistemic cognition
(4) AI in education AND ethics
(5) AI literacy AND values OR axiology
Explainable AI AND learning

These strings were iteratively refined to balance coverage and relevance. Only English language publications were included to ensure consistency of interpretation.

Inclusion and Exclusion Criteria

Studies were included if they met the following criteria:

(1) peer reviewed journal articles indexed in Scopus;
(2) publication between 2021 and 2025;
(3) explicit relevance to AI in educational or learning contexts;
(4) substantive engagement with at least one philosophical dimension, namely ontology, epistemology, or axiology.

Studies were excluded if they:

(1) focused solely on technical algorithmic optimisation without educational interpretation;
(2) addressed AI applications outside learning contexts such as healthcare diagnostics or social media moderation;
(3) lacked conceptual, epistemic, or ethical discussion relevant to learning;
(4) were conference papers, editorials, or non peer reviewed sources.

Foundational philosophical books were analysed separately and used only to strengthen theoretical grounding, not as part of the core journal article corpus.

Screening Procedure

The screening process followed four stages. First, an initial identification stage retrieved 214 records from database searches. Second, duplicate records and clearly irrelevant titles were removed, resulting in 97 articles. Third, abstract screening was conducted to assess alignment with AI based learning and philosophical relevance, yielding 46 articles. Fourth, full text screening was applied to ensure substantive engagement with ontological, epistemological, or axiological dimensions, resulting in a final corpus of 32 journal articles included in the synthesis.

Quality and Relevance Appraisal

Given the philosophical and interpretive nature of the review, quality appraisal focused on conceptual relevance rather than methodological scoring. Articles were assessed based on clarity of theoretical argumentation, explicit treatment of philosophical assumptions, and relevance to educational AI contexts. This relevance-oriented appraisal is consistent with recommendations for integrative reviews addressing conceptual and normative questions (Snyder, 2019). To mitigate interpretive bias, coding decisions were guided by explicit philosophical criteria derived from philosophy of science and educational theory.

Data Analysis

Data analysis employed thematic synthesis comprising three stages: open coding, category development, and integrative interpretation. During open coding, concepts related to educational entities, knowledge representation, epistemic agency, algorithmic reasoning, ethical responsibility, and value alignment were identified. Categories were then developed by grouping conceptually convergent codes within ontological, epistemological, and axiological dimensions. Finally, integrative interpretation was conducted to synthesise these dimensions into a unified conceptual framework for AI based learning models.

Ethical Considerations

This study did not involve human participants, personal data, or field-based research. All materials analysed were publicly available scholarly publications. Ethical approval was therefore not required. Proper citation practices were followed throughout to ensure academic integrity.

Result and Discussion

This section presents the key findings derived from the integrative literature review, organised around three foundational themes of the philosophy of science that underpin the development of AI supported learning models, namely ontology, epistemology, and axiology. A thematic analysis was conducted to identify how artificial intelligence reshapes the nature of educational reality, transforms the processes through which knowledge is acquired and validated, the findings within broader philosophical debates.

Table 1. Synthesis Matrix of Philosophical Foundations of AI Based Learning Models

Philosophical Pillar	Core Subthemes	Design and Evaluation Implications	Example Indicators
Ontology	Representation of learners and knowledge; educational entities and relations; machine interpretable learning structures	AI systems should provide transparent and adaptable representations of learners, content, and learning pathways; learning environments must make structural assumptions explicit	Use of ontologies or knowledge graphs; clarity of learner models; explicability of content organisation
Epistemology	Knowledge construction and validation; epistemic agency; human AI co reasoning	Learning designs should support critical engagement, reflection, and learner autonomy in interaction with AI outputs; AI feedback must be intelligible and contestable	Explainable recommendations; opportunities for learner justification; visibility of reasoning processes
Axiology	Ethical responsibility; fairness and inclusion; human centred values	AI based learning models must align with ethical principles and socio moral values, ensuring equity, accountability, and respect for human agency	Bias monitoring mechanisms; ethical guidelines embedded in system design; support for inclusive learning practices

and introduces new ethical considerations within teaching and learning environments. Each theme is synthesised from a core corpus of thirty-two peer reviewed journal articles indexed in Scopus, complemented by foundational philosophical works and selected conceptual literature used to strengthen theoretical interpretation. This distinction ensures transparency regarding the empirical basis of the synthesis while situating

The focus of this section is not only to describe patterns identified in the journal literature but also to articulate the philosophical implications that inform the design of effective, transparent, and human centred AI based learning models. Through this integrative approach, the findings provide a holistic conceptual grounding for rethinking educational practices in the age of artificial intelligence. To enhance the applicability of the philosophical synthesis, Table 1 presents a compact matrix that links each foundational pillar to its dominant subthemes, implications for AI based learning design and evaluation, and example indicators drawn from the reviewed literature. This matrix operationalises the integrative framework by illustrating how abstract philosophical principles can inform concrete educational decisions.

This synthesis matrix demonstrates that ontology, epistemology, and axiology function not as isolated considerations but as mutually reinforcing dimensions. Ontological clarity enables epistemic transparency, while axiological commitments guide both structural design and knowledge mediation. Together, these dimensions form the basis of an integrated conceptual model that supports responsible, meaningful, and sustainable AI based learning.

Ontological Theme: The Foundations of AI Based Learning Models

Ontological analysis of AI based learning reveals that contemporary research consistently frames learning environments as hybrid ecosystems where knowledge is formalised, structured, and mediated through machine interpretable representations. Across the reviewed studies, ontology emerges as a foundational mechanism for organising educational entities, defining relationships, and enabling meaningful interaction between human learners and intelligent systems. Armary et al. (2025) emphasise that ontology learning towards greater expressiveness allows AI systems to represent complex domains with increasing precision, a development that fundamentally alters the structure of learning environments by shifting knowledge from implicit human cognition to explicit computational models. This repositioning of knowledge challenges traditional assumptions about the nature of educational reality and introduces new ontological layers in which concepts, attributes, and relations are encoded for machine reasoning.

Several studies highlight how ontology boosted systems integrate symbolic representations with computational intelligence. Azzi and Ben Othmane Zribi (2024) demonstrate the use of ontology enhanced deep learning to improve classification accuracy in multilingual contexts, showing that ontological structures strengthen the semantic grounding of AI models. Although the study is situated outside formal educational contexts, it is not treated as direct empirical evidence for AI based learning. Instead, it is used to illustrate a conceptual mechanism relevant to education, namely the role of semantic clarity and structured knowledge representation in AI mediated decision making. This mechanism aligns with prior education focused research demonstrating that transparent conceptual organisation is critical for adaptive learning, learner modelling, and intelligible feedback in AI supported educational systems. Lee and Yu (2023) further illustrate ontological inference in AI based object recognition, underscoring that intelligent systems interpret environments not merely through pattern recognition but by mapping perceptual data onto structured conceptual frameworks.

Studies in engineering and medical contexts contribute additional ontological insights relevant to AI based learning. Bavaresco et al. (2024) propose an ontology driven framework for health reasoning that integrates machine learning outputs with domain specific conceptual structures, demonstrating how ontologies enhance reasoning transparency and facilitate decision support. Bottrighi et al. (2025) show how ontology-based student testing systems draw upon clinical guideline representations to generate personalised assessments, reinforcing the idea that ontological structures can configure learning pathways, diagnostic processes, and instructional adaptations. Duverger et al. (2025) also highlights the role of ontological digital thread frameworks in enabling concurrent reasoning across stages of engineering design, revealing the applicability of ontological representation in multi layer learning scenarios.

Within the educational domain, ontology driven systems increasingly underpin learning personalisation, diagnostic feedback, and knowledge tracing. Rahayu et al. (2022) show that ontology-based recommender systems enhance the precision of content delivery by aligning educational resources with learner profiles. Wang et al. (2024) present a knowledge ontology enhanced model for explainable knowledge tracing, demonstrating that ontological structures not only support content organisation but also provide transparency in machine generated inferences. These findings indicate that ontologies serve as conceptual scaffolds that mediate interactions between human cognitive processes and algorithmic decision mechanisms.

A growing strand of research explores ontological transparency as a prerequisite for interpretability and trust. Confalonieri et al. (2021) highlight that ontologies improve the human understandability of post hoc explanations by offering structured mappings between model reasoning and domain concepts. Moreau and Wiebels (2025) extend this view by demonstrating how transparent ontology learning supports construct refinement in neuroscience, suggesting similar benefits for educational constructs such as learning progression, conceptual difficulty, and cognitive patterns. Fernandez et al. (2023) further introduce the FIDES framework, showing that ontological structures can make machine learning systems accountable by linking decision processes to explicit conceptual schemas, an approach that strengthens the structural integrity of AI based learning models.

Several studies address the broader ontological context of AI enhanced learning environments. Deev and Finogeev (2023) conceptualise smart learning environments as convergent systems where physical, digital, and cognitive entities interact continuously. This perspective aligns with contemporary understandings of hybrid learning ecosystems that integrate human agency with machine supported reasoning. Romero et al. (2022) add further insight by demonstrating how hybrid deep learning and ontology driven approaches create multi layer capability assessments, reinforcing the proposition that educational environments designed with AI embody complex ontological architectures.

The reviewed literature consistently portrays ontology as the structural core that enables AI to function meaningfully within learning environments. Ontologies define the entities that exist within a domain, determine their relationships, and establish the rules by which intelligent systems interpret, process, and generate knowledge. Collectively, these studies suggest that AI based learning models can only be understood through an ontological lens that recognises learning environments as distributed networks of human cognition, digital representations, intelligent agents, and algorithmic processes. This ontological foundation provides the structural

basis upon which epistemological and axiological dimensions operate, shaping how knowledge is constructed, validated, and ethically governed within AI mediated education.

Epistemological Theme: The Foundations of AI Based Learning Models

Epistemological inquiry into AI based learning emphasises how knowledge is constructed, validated, represented, and negotiated within environments where human cognition interacts with algorithmic intelligence. Across the reviewed studies, contemporary educational epistemology is increasingly shaped by the integration of data driven inference, ontological structuring, and interactive learning systems. Doroudi (2024) articulates that learning analytics embodies a convergence of machine learning and epistemology, where knowledge is no longer solely the product of human reasoning but emerges as a hybrid construct shaped by patterns, predictions, and model derived interpretations. This hybrid epistemic landscape challenges traditional assumptions about how knowledge is acquired, evaluated, and legitimised within education.

A central epistemological trend in AI supported learning concerns the rise of epistemic cognition as a critical factor in understanding how learners engage with AI mediated information. Studies such as Huang et al. (2023) highlight how students' epistemic beliefs influence their interpretation of online knowledge, shaping their self regulation and susceptibility to academic misconduct. Gao et al. (2025) further demonstrate that AI driven personalised multi agent systems actively support learners in developing higher order epistemic cognition by scaffolding design thinking and reasoning processes in STEM education. These findings suggest that AI functions as both a facilitator and a co constructor of epistemic development, modifying how learners conceptualise knowledge sources, certainty, and complexity.

Teachers' epistemological orientations also play a substantial role in determining the effectiveness of AI integrated pedagogy. Sahin et al. (2023) show that educators who adopt knowledge generation orientations tend to leverage AI tools in ways that promote inquiry-based learning, rather than mere content delivery. Kim and Kwon (2023) and Kohnke et al. (2023) reveal similar patterns, showing that teachers' beliefs about knowledge and machine competence influence their preparedness, pedagogical decision making, and trust in generative AI. These insights indicate that epistemological alignment between educators and AI systems is essential for producing coherent and meaningful learning experiences.

Epistemic transparency emerges as a recurring theme in the literature, especially in the context of explainable AI. Confalonieri et al. (2021) show that ontologies enhance the interpretability of black box models by mapping algorithmic logic onto structured conceptual frameworks, thereby strengthening epistemic accountability. Fernandez et al. (2023) offer similar conclusions through the FIDES framework, demonstrating that ontology grounded explanations allow learners and educators to evaluate the legitimacy of AI generated insights. Moreau and Wiebels (2025) extend this argument by showing how transparent ontology learning refines scientific constructs, suggesting that epistemic clarity in AI systems is essential for preserving the validity of knowledge across disciplines, including education.

A related epistemological concern involves the prioritisation of knowledge and values within AI mediated contexts. Naser (2025) introduces a decision architecture for epistemic prioritisation, showing how machine learning shapes which information is emphasised or deprioritised. This automated prioritisation can influence learner perception, cognitive load, and epistemic development, raising questions about the neutrality of AI supported knowledge structures. Similarly, Branda et al. (2025) argue that scientific knowledge in the age of AI requires a human centric synergy, suggesting that epistemic autonomy must be preserved even as AI becomes more influential in generating and validating information.

Epistemology is also embedded in the design of smart learning environments and recommender systems. Deev and Finogeev (2023) conceptualise convergent learning environments as integrated epistemic ecologies where knowledge flows across human learners, digital tools, and smart interfaces. Rahayu et al. (2022) demonstrate that ontology-based recommender systems operationalise knowledge structures to deliver personalised content, illustrating how AI systems implicitly encode epistemic assumptions about learner needs, relevance, and value. Wang et al. (2023) show that AI supported human interactions in language learning involve epistemic network patterns that reveal how learners negotiate meaning alongside intelligent agents.

Several studies indicate that AI influences epistemological agency by mediating learners' abilities to construct knowledge independently. Pretorius et al. (2025) highlight how generative AI can empower linguistic and academic communication, particularly for international PhD students, but also caution against over reliance that could undermine epistemic independence. Promsiri (2025) analyses historical patterns of educational disruptions caused by technology and concludes that AI challenges learners to renegotiate cognitive strategies and epistemic autonomy in an era where information is increasingly produced by nonhuman agents.

A persistent epistemological issue in AI aided learning relates to literacy, competence, and the conceptualisation of knowledge itself. Sperling et al. (2024) reveal substantial gaps in AI literacy among teacher preparation programmes, indicating that epistemic fluency is now a prerequisite for navigating AI rich environments. Fel et al. (2025) connect responsibility and epistemic acceptance within AI based systems, showing that learners' beliefs about the reliability and moral accountability of AI influence their willingness to adopt machine generated knowledge. These findings highlight how epistemology, ethics, and cognition intersect within AI supported learning.

Collectively, the reviewed literature presents AI based learning models as epistemic systems in which knowledge is co produced by learners, educators, ontological structures, and intelligent algorithms. AI not only organises and distributes knowledge but also shapes the conditions under which knowledge is validated, interpreted, and internalised. Epistemology in AI based learning therefore encompasses the study of how intelligent systems represent knowledge, how learners negotiate meaning with machines, how educators facilitate epistemic alignment, and how transparency, accountability, and autonomy are maintained in hybrid human machine environments. This epistemic foundation establishes the conceptual bridge between ontology as the structure of educational reality and axiology as the value-based governance that ensures responsible knowledge creation and use in the age of AI.

Axiological Theme: The Foundations of AI Based Learning Models

The axiological dimension of AI based learning focuses on the values, ethical principles, and normative commitments that guide the design, implementation, and use of intelligent systems in education. The reviewed studies converge on the idea that AI cannot be treated as a neutral tool, because every decision embedded in algorithmic systems reflects implicit or explicit value choices. Danaher (2021) introduces the notion of axiological futurism to argue that AI forces societies to confront

the future of values, including how fairness, autonomy, and human flourishing will be interpreted in technologically saturated environments. In educational contexts, this perspective suggests that learning models powered by AI must be grounded in explicit value frameworks that anticipate and shape future ethical landscapes rather than merely reacting to technical developments.

Several contributions highlight the need for human centric approaches that safeguard agency, dignity, and justice. Branda et al. (2025) argue that AI in scientific research must be oriented toward a human centric synergy, in which human judgment and machine capability are integrated without subordinating human values to algorithmic efficiency. González Esteban and Calvo (2022) similarly emphasise the ethical governance of AI in research and innovation, proposing that regulatory and institutional frameworks must ensure that AI deployment respects ethical norms and democratic oversight. Translated into educational settings, these studies imply that AI based learning models must be designed to support, rather than replace, human educational purposes, with clear safeguards against the erosion of academic integrity and critical reflection.

Accountability and responsibility emerge as central axiological themes, particularly in relation to the opacity and power of algorithmic systems. Fernandez et al. (2023) show that ontology-based frameworks, such as FIDES, can make machine learning systems accountable by linking outputs to transparent conceptual structures. Confalonieri et al. (2021) add that ontologies improve the human understandability of model explanations, allowing users to evaluate whether AI decisions align with accepted norms and values. Fel et al. (2025) explore responsibility in relation to technology acceptance and demonstrate that perceived responsibility, trust, and ethical alignment influence whether individuals are willing to adopt AI systems. In the context of education, these insights suggest that responsible AI literacy must include the capacity to question, interpret, and ethically evaluate AI mediated recommendations and feedback.

Axiological concerns are also evident in discussions of disruption, inequality, and psychological impact. Promsiri (2025) analyses the psychology of educational disruption brought about by AI and shows that technological shifts can create cognitive and emotional disorientation if not carefully managed through supportive value frameworks. Pretorius et al. (2025) bring a decolonial and Ubuntu inspired perspective to generative AI, arguing that AI tools can either reproduce existing global inequities in academic communication or provide empowering support for marginalised scholars, depending on the values guiding their use. These studies highlight that AI based learning models must address power relations, inclusion, and cultural sensitivity, ensuring that AI does not amplify existing structural injustices in education.

Several studies draw attention to the value laden nature of smart learning environments and recommendation systems. Deev and Finogeev (2023) conceptualise convergent smart learning environments where values are embedded in the design of interactions, access, and feedback loops. Rahayu et al. (2022) and Romero et al. (2022) show that ontology driven systems implicitly prioritise certain kinds of content, competencies, and performance indicators, which means that normative decisions about what counts as valuable knowledge and desirable learning outcomes are encoded into AI infrastructures. Naser (2025) makes this point explicit by introducing decision architectures for epistemic prioritisation, demonstrating how machine learning models decide which information is foregrounded and which is backgrounded in human decision processes. For AI based learning, this implies that curriculum design, assessment logic, and personalisation strategies must be evaluated as ethical choices, not merely technical optimisations.

Teacher and learner orientations toward AI are themselves shaped by axiological factors. Sperling et al. (2024) identify gaps in AI literacy in teacher education, pointing out that educators often lack explicit frameworks to evaluate the ethical implications of AI tools. Kim and Kwon (2023) and Kohnke et al. (2023) show that teachers' competencies and preparedness in using AI are intertwined with their beliefs about responsibility, control, and professional identity. If educators perceive AI as undermining rather than supporting their ethical obligations to students, they are less likely to integrate it in ways that reflect justice, care, and respect. This indicates that value education and ethical reflection must be integral components of professional development in AI rich educational environments.

The reviewed literature also suggests that values are embedded within the design of AI systems intended to support knowledge construction and assessment. Bottrighi et al. (2025) illustrate how ontology-based student testing, grounded in clinical guidelines, reflects normative judgments about what constitutes safe and competent practice. Bavaresco et al. (2024) and Lee and Yu (2023) focus on health and hazard awareness, highlighting how AI systems encode priorities such as safety, prevention, and risk reduction. Although primarily situated in medical and construction domains, these studies reveal how AI architectures can embody protective values that are equally relevant for safeguarding student wellbeing, digital safety, and learning integrity.

In the domain of STEM education, axiological foundations are described in more systematic terms. Vedrenne Gutiérrez et al. (2024) provides a comprehensive review and ethical meta-analysis on the value structures underpinning innovation in STEM education, concluding that educational innovation must be assessed not only on technical and cognitive outcomes but also on ethical impact, social relevance, and justice. Their findings underscore that AI driven learning innovations should be evaluated through ethical criteria such as equity, transparency, and sustainability. When applied to AI based learning models, this perspective implies that design decisions, data usage, and algorithmic interventions must be aligned with a clearly articulated value framework.

Taken together, the literature portrays AI based learning models as inherently axiological systems, in which questions of responsibility, justice, human centrality, and ethical governance are inseparable from technical design. AI does not simply facilitate learning but actively shapes what is considered valuable, whose interests are prioritised, and how educational futures are imagined. A robust axiological foundation therefore requires that AI based learning models be developed within explicit ethical frameworks that acknowledge power dynamics, protect autonomy, promote inclusion, and ensure accountability. This axiological grounding, in turn, completes the philosophical triad, linking the structural ontological features of AI mediated learning environments and the epistemological processes of knowledge construction with the values that guide educational practice in the age of artificial intelligence.

Integrative Philosophical Framework for AI based Learning

The integration of artificial intelligence into learning models demands a holistic philosophical foundation, combining ontological, epistemological, and axiological perspectives. This integrative framework is crucial for designing AI based education that is not only technologically robust but also ethically grounded and pedagogically meaningful.

Ontologically, the presence of AI transforms the learning environment from a traditional classroom to a complex ecosystem composed of human agents, intelligent algorithms, and structured digital knowledge. Ontologies serve as the backbone for AI systems, enabling explicit modelling of educational entities, relationships, and processes. This

structural clarity is essential for making knowledge accessible, interoperable, and adaptable in dynamic learning contexts (Armary et al., 2025; Khadir et al., 2021; Wang et al., 2024). Such ontological scaffolding ensures that both human and machine actors operate within a shared semantic landscape, facilitating seamless collaboration and intelligent adaptation.

Epistemologically, AI alters how knowledge is constructed, validated, and internalised. Rather than serving as mere information delivery tools, AI systems increasingly participate in the co-construction of knowledge, mediating the interplay between learner cognition and machine-generated insights (Doroudi, 2024; Gao et al., 2025; Huang et al., 2023). Learners and educators become active negotiators of meaning, evaluating, adapting, and contesting algorithmic outputs based on epistemic beliefs, cultural context, and prior knowledge. This partnership demands transparency and interpretability in AI systems to support critical thinking, epistemic autonomy, and the development of advanced literacy skills (Confalonieri et al., 2021; Fernandez et al., 2023).

Axiologically, the embedding of AI in education foregrounds ethical and value-laden considerations. Algorithms encode decisions about whose knowledge is prioritised, how fairness is operationalised, and what outcomes are valued (Danaher, 2021; Vedrenne Gutiérrez et al., 2024; Branda et al., 2025). AI based learning models must, therefore, be intentionally designed with frameworks that protect agency, inclusion, and justice. Human centrality is imperative: AI should not replace but rather empower learners and educators to achieve higher forms of understanding, creativity, and social participation (González Esteban & Calvo, 2022; Pretorius et al., 2025). Educational innovation must be measured not only by efficiency or novelty, but also by its alignment with ethical norms and its contribution to holistic human development.

Central to this framework is the dual role of humans as both subjects and users of technology. Learners, educators, and communities co-create meaning alongside AI, maintaining agency over their learning trajectories while benefiting from the affordances of intelligent systems (Wang et al., 2023; Kim & Kwon, 2023). AI must be seen as a partner, one that extends human capacity for inquiry, reflection, and action, but always within boundaries set by human values and societal needs.

The pedagogic–technological relationship is thus reciprocal and dynamic. Pedagogy shapes the goals and methods of AI deployment in learning, guiding system design, personalisation strategies, and assessment logic (Bates, 2015; Luckin, 2018). At the same time, AI technology offers new pedagogical possibilities: adaptive feedback, collaborative learning networks, and rich analytics for formative assessment. This interplay requires educators to possess a critical awareness of both the potential and limits of AI, fostering a professional identity grounded in ethical reflection and lifelong learning (Sperling et al., 2024; Sahin et al., 2023).

In conclusion, a truly integrative philosophical framework for AI based learning unites ontological clarity, epistemological rigour, and axiological responsibility. It affirms the centrality of humans as both creators and beneficiaries of technological change, and positions pedagogy as both the rationale and the regulator for AI integration in education. Only through such synthesis can AI supported learning fulfil its promise to cultivate not just smarter learners, but also wiser, more ethical, and more empowered citizens in the digital age.

The integrative review presented in this study offers a conceptual synthesis grounded in existing literature on the ontological, epistemological, and axiological foundations of AI based learning models. Rather than claiming empirical completeness, this section positions the proposed framework as a theoretical proposition derived from systematic interpretation of prior research. The discussion contextualises the findings within the broader scholarly landscape, examines their conceptual and practical implications, acknowledges the boundaries of the synthesis, and outlines directions for future empirical inquiry.

Interpretation of Key Findings

The review demonstrates that ontology serves as the structural backbone of AI supported learning, providing explicit models for representing educational entities, relationships, and processes. The adoption of ontological frameworks, such as knowledge graphs and semantic networks, facilitates transparent and adaptive learning environments that mediate interaction between human cognition and algorithmic reasoning. Epistemologically, the evidence suggests that AI reconfigures the construction, validation, and negotiation of knowledge, transforming learners and educators into active co-constructors of meaning in partnership with intelligent systems (Doroudi, 2024; Gao et al., 2025; Huang et al., 2023). The importance of transparency, interpretability, and epistemic autonomy emerges as a recurring theme. From an axiological perspective, the review highlights the necessity of embedding values such as responsibility, justice, and inclusion into AI based learning models, ensuring that technological innovation is always aligned with ethical imperatives (Danaher, 2021; Branda et al., 2025; Vedrenne Gutiérrez et al., 2024).

These findings collectively support the argument that effective AI based education cannot be separated from its philosophical underpinnings. The conceptual synthesis provided here affirms that AI should function as a partner in education, supporting and empowering learners and educators rather than supplanting them. The review advances the field by offering an integrative philosophical framework that bridges structural, cognitive, and ethical dimensions, an approach not fully addressed in most previous studies.

Comparison with Previous Studies

The themes identified in this review resonate with foundational work on the structure of scientific knowledge (Kuhn, 2012; Popper, 1972) and extend recent analyses of ontology-based education systems (Armary et al., 2025; Wang et al., 2024) and AI enabled epistemic practices (Celik et al., 2021; Gao et al., 2025). Unlike earlier studies that typically address these philosophical dimensions in isolation, this study integrates ontological, epistemological, and axiological perspectives into a holistic conceptual framework that explicates how structural representations, knowledge mediation processes, and value orientations jointly shape AI based learning implementation. Notably, the discussion of axiological foundations is more extensive, synthesising contemporary debates on responsible AI, human centric design, and inclusive education (Branda et al., 2025; González Esteban & Calvo, 2022), and positioning these values as integral rather than supplementary to system design. In contrast to prior AI in education research that has often privileged technical optimisation and performance metrics, this review emphasises conceptual depth and philosophical coherence, demonstrating that effective AI based learning must begin with clarity regarding what educational entities are represented, how knowledge is constructed and validated, and which ethical standards guide decision making (Holmes et al., 2019; Luckin, 2018). This shift reflects a move away from technocentric models toward more human centric and critically reflexive paradigms, while also providing an actionable orientation for curriculum designers, AI developers, and policymakers in evaluating and guiding AI supported learning systems.

Limitations and Cautions

While the integrative approach allows for a richer and more theoretically informed synthesis, several limitations should be acknowledged. First, the review is restricted to peer reviewed journal articles published in English and indexed in Scopus, which may limit coverage by excluding relevant contributions from other linguistic, cultural, or regional contexts. Second, as with most integrative literature reviews, the analysis is inherently interpretive and relies on the researcher's judgement in identifying and synthesising conceptual themes across heterogeneous sources. To mitigate subjective interpretive risks, the review employed explicit inclusion and exclusion criteria, a structured literature matrix, and an iterative thematic coding process grounded in established concepts from philosophy of science and educational theory. Coding decisions were reviewed across the ontological, epistemological, and axiological dimensions to ensure internal consistency and conceptual coherence. Although formal inter coder reliability procedures were not applied, these intersubjective checks helped reduce idiosyncratic interpretation and strengthen the methodological robustness of the synthesis.

Recommendations for Future Research

Future research should build on this conceptual foundation through empirical and interdisciplinary inquiry. In particular, studies may examine how different ontological representations in AI based learning systems influence learner understanding, engagement, and agency in authentic educational settings. Further research could investigate how epistemological transparency and explainability in AI supported feedback affect learners' epistemic trust, critical reasoning, and autonomy. Additional work is also needed to explore how axiological principles such as fairness, accountability, and inclusivity are operationalised in the design and governance of AI based learning systems across diverse institutional and cultural contexts. Interdisciplinary collaboration among scholars in education, philosophy of science, computer science, cognitive psychology, and education policy will be essential for translating philosophical insights into context sensitive design guidelines, as well as for developing and empirically validating evaluation rubrics or governance frameworks that support ethical, transparent, and human centric AI supported education.

Conceptual Contribution

This study advances the literature on AI based learning by articulating an integrated philosophical framework that positions ontology, epistemology, and axiology as interdependent foundations rather than isolated analytical lenses. While previous research has explored these dimensions separately, often privileging technical efficiency or ethical compliance in isolation, the present synthesis demonstrates that meaningful AI supported learning emerges only when structural design, knowledge processes, and value commitments are considered jointly. The review evidence shows that ontological clarity in learner and knowledge representation enables epistemic transparency in AI mediated reasoning, while axiological principles provide normative guidance for both system design and knowledge validation. This integrative positioning extends prior conceptual work by moving beyond additive models and proposing a structurally coherent philosophical foundation for AI based learning models.

Implications for Design and Evaluation Practice

The findings suggest that AI based learning systems should be designed and evaluated as structural cognitive ethical systems. From an ontological perspective, learning designers are encouraged to make assumptions about educational entities, learner models, and knowledge structures explicit through transparent representations. Epistemologically, AI supported learning environments should facilitate critical engagement, intelligible feedback, and opportunities for learners to interrogate and contest AI generated outputs. Axiologically, ethical considerations such as fairness, accountability, and human agency must be embedded into system design rather than treated as post hoc safeguards. The synthesis matrix presented in the Results section illustrates how these philosophical dimensions can inform concrete design and evaluation criteria, supporting educators and developers in aligning AI technologies with pedagogical and ethical goals.

Boundary Conditions and Contextual Applicability

Although the proposed framework offers a comprehensive conceptual foundation, its applicability is subject to important boundary conditions. First, the framework is primarily grounded in studies situated within formal and semi formal educational contexts, and its transferability to informal, corporate, or fully autonomous learning environments may require contextual adaptation. Second, the framework presumes a level of institutional capacity and AI literacy that may not be present in resource constrained settings, where ethical and epistemic risks are heightened. Third, the integrative model is conceptual in nature and does not claim empirical validation. As such, its application should be understood as a guiding orientation rather than a prescriptive blueprint. These boundary conditions underscore the need for empirical testing, contextual calibration, and interdisciplinary collaboration in future research.

Conclusion

This study examined the ontological, epistemological, and axiological foundations underpinning AI based learning models with the aim of articulating a coherent philosophical framework for AI mediated education. The findings demonstrate that ontological clarity, epistemological rigour, and axiological responsibility must operate as mutually reinforcing pillars to ensure that AI supported learning remains meaningful, transparent, and ethically grounded. Across the reviewed literature, AI based learning is shown to reshape educational reality, knowledge construction, and value orientation in ways that cannot be adequately understood through technical analysis alone.

The central novelty of this work lies in its explicit integration of ontology, epistemology, and axiology into a single unified conceptual framework, advancing beyond prior AI in education reviews that address these dimensions in isolation. By positioning AI based learning as a structural cognitive ethical system, this framework offers a philosophically coherent foundation for interpreting and guiding AI integration in education.

A practical next step emerging from this study is the operationalisation of the proposed integrative framework into applied guidance for educational decision making. Specifically, the three philosophical pillars may be translated into policy-oriented guidelines, AI system design criteria, and pedagogical evaluation tools that support responsible AI based learning implementation. For example, policymakers may use the framework to formulate governance principles that ensure fairness, accountability, and transparency in educational AI adoption. AI developers may apply the ontological and epistemological dimensions as design criteria for representing learners, structuring knowledge, and ensuring explainable feedback mechanisms. Educators and instructional designers may employ the framework as a pedagogical checklist or

evaluation rubric to assess whether AI supported learning systems promote learner agency, epistemic integrity, and ethical responsibility.

Future research should empirically validate these applications by testing the framework in real educational contexts, such as intelligent tutoring systems, adaptive learning platforms, and AI driven assessment environments. Through such application scenarios, the framework can move from conceptual integration toward context sensitive guidance that informs real world educational practice and governance.

Despite its contributions, this study is subject to limitations inherent in integrative literature reviews, including reliance on selected databases and interpretive synthesis. Accordingly, the framework should be understood as a conceptual orientation rather than a prescriptive or empirically tested model. Continued interdisciplinary research combining philosophical analysis with empirical investigation will be essential to refine, contextualise, and validate this framework across diverse educational environments. Through such efforts, AI technologies can be more effectively aligned with the fundamental aims and values of education in an evolving digital era.

References

Aristotle. (2016). Metaphysics (W. D. Ross, Trans.). Digireads Publishing. (Original work published ca. 350 BCE)

Armary, P., El-Vaigh, C. B., Labbani Narsis, O., & Nicolle, C. (2025). Ontology learning towards expressiveness: A survey. Computer Science Review, 56, 100693. https://doi.org/10.1016/j.cosrev.2024.100693

Azzi, S. A., & Ben Othmane Zribi, C. (2024). Ontology-Boosted Deep Learning for Multi-Label Classification of Arabic Abusive Messages on Social Networks. Procedia Computer Science, 246, 850–859. https://doi.org/10.1016/j.procs.2024.09.504

Bates, A. W. (2015). Teaching in a digital age: Guidelines for designing teaching and learning. Tony Bates Associates.

Bavaresco, R., Ren, Y., Barbosa, J., & Li, G. P. (2024). An ontology-based framework for worker's health reasoning enabled by machine learning. Computers & Industrial Engineering, 193, 110310. https://doi.org/10.1016/j.cie.2024.110310

Bottrighi, A., Maconi, A., Nera, S., Piovesan, L., Raina, E., & Terenziani, P. (2025). Ontology-based student testing through clinical guidelines: An AI approach. Artificial Intelligence in Medicine, 168, 103226. https://doi.org/10.1016/j.artmed.2025.103226

Branda, F., Ciccozzi, M., & Scarpa, F. (2025). Artificial intelligence in scientific research: Challenges, opportunities and the imperative of a human-centric synergy. Journal of Informetrics, 19(4), 101727. https://doi.org/10.1016/j.joi.2025.101727

Bronowski, J. (2011). The ascent of man. BBC Books. (Original work published 1973)

Celik, I., Muukkonen, H., & Dogan, S. (2021). A model for understanding new media literacy: Epistemological beliefs and social media use. Library & Information Science Research, 43(4), 101125. https://doi.org/10.1016/j.lisr.2021.101125

Confalonieri, R., Weyde, T., Besold, T. R., & Moscoso Del Prado Martín, F. (2021). Using ontologies to enhance human understandability of global post-hoc explanations of black-box models. Artificial Intelligence, 296, 103471. https://doi.org/10.1016/j.artint.2021.103471

Danaher, J. (2021). Axiological futurism: The systematic study of the future of values. Futures, 132, 102780. https://doi.org/10.1016/j.futures.2021.102780

Deev, M., & Finogeev, A. (2023). Application of the convergent education model in the development of a smart learning environment. Telematics and Informatics Reports, 10, 100051. https://doi.org/10.1016/j.teler.2023.100051

Doroudi, S. (2024). On the paradigms of learning analytics: Machine learning meets epistemology. Computers and Education: Artificial Intelligence, 6, 100192. https://doi.org/10.1016/j.caeai.2023.100192

Duverger, E., Aubry, A., Arista, R., & Levrat, E. (2025). An ontology-based digital thread framework to support early concurrent engineering in the aerospace industry. Journal of Industrial Information Integration, 48, 100984. https://doi.org/10.1016/j.jii.2025.100984

Fel, S., Kozak, J., & Horodyski, P. (2025). Responsibility and AI: Exploring technology acceptance models. Journal of Innovation & Knowledge, 10(6), 100852. https://doi.org/10.1016/j.jik.2025.100852

Fernandez, I., Aceta, C., Gilabert, E., & Esnaola-Gonzalez, I. (2023). FIDES: An ontology-based approach for making machine learning systems accountable. Journal of Web Semantics, 79, 100808. https://doi.org/10.1016/j.websem.2023.100808

Gao, L., Siu-Yung Jong, M., Chai, C. S., & Li, K. (2025). STEM Education: Understanding Secondary Students' Epistemic Cognition in the Design Process with the Support of a Personalized Multi-Agent System. Computers & Education, 105504. https://doi.org/10.1016/j.compedu.2025.105504

González-Esteban Y Patrici Calvo, E. (2022). Ethically governing artificial intelligence in the field of scientific research and innovation. Heliyon, 8(2), e08946. https://doi.org/10.1016/j.heliyon.2022.e08946

Holmes, W., Bialik, M., & Fadel, C. (2019). Artificial intelligence in education: Promises and implications for teaching and learning. Center for Curriculum Redesign.

Holmes, W., Porayska-Pomsta, K., Holstein, K., & Lee, M. (2022). AI and education: Guidance for policy makers. UNESCO Publishing.

Huang, C. L., Wu, C., & Yang, S. C. (2023). How students view online knowledge: Epistemic beliefs, self-regulated learning and academic misconduct. Computers & Education, 200, 104796. https://doi.org/10.1016/j.compedu.2023.104796

Khadir, A. C., Aliane, H., & Guessoum, A. (2021). Ontology learning: Grand tour and challenges. Computer Science Review, 39, 100339. https://doi.org/10.1016/j.cosrev.2020.100339

Kim, K., & Kwon, K. (2023). Exploring the AI competencies of elementary school teachers in South Korea. Computers and Education: Artificial Intelligence, 4, 100137. https://doi.org/10.1016/j.caeai.2023.100137

Kohnke, L., Moorhouse, B. L., & Zou, D. (2023). Exploring generative artificial intelligence preparedness among university language instructors: A case study. Computers and Education: Artificial Intelligence, 5, 100156. https://doi.org/10.1016/j.caeai.2023.100156

Kuhn, T. S. (2012). The structure of scientific revolutions (50th anniversary ed.). University of Chicago Press. (Original work published 1962)

Lee, S.-K., & Yu, J.-H. (2023). Ontological inference process using AI-based object recognition for hazard awareness in construction sites. Automation in Construction, 153, 104961. https://doi.org/10.1016/j.autcon.2023.104961

Luckin, R. (2018). Machine learning and human intelligence: The future of education in the twenty first century. UCL Institute of Education Press.

Moreau, D., & Wiebels, K. (2025). Leveraging transparent ontology learning to refine constructs in neuroscience. Neuroscience Informatics, 5(2), 100199. https://doi.org/10.1016/j.neuri.2025.100199

Naser, M. Z. (2025). A decision architecture for epistemic prioritization: Machine learning at the intersection of technology and society. Technology in Society, 83, 103039. https://doi.org/10.1016/j.techsoc.2025.103039

Plato. (2007). The republic (D. Lee, Trans.; 2nd ed.). Penguin Books. (Original work published ca. 380 BCE)

Popper, K. R. (1972). Objective knowledge: An evolutionary approach. Oxford University Press.

Popper, K. R. (2002). The logic of scientific discovery. Routledge. (Original work published 1934)

Pretorius, L., Huynh, H.-H., Pudyanti, A. A. A. R., Li, Z., Noori, A. Q., & Zhou, Z. (2025). Empowering international PhD students: Generative AI, Ubuntu, and the decolonisation of academic communication. The Internet and Higher Education, 67, 101038. https://doi.org/10.1016/j.iheduc.2025.101038

Promsiri, T. (2025). AI and the psychology of educational disruption: Historical patterns and cognitive implications. Acta Psychologica, 260, 105637. https://doi.org/10.1016/j.actpsy.2025.105637

Rahayu, N. W., Ferdiana, R., & Kusumawardani, S. S. (2022). A systematic review of ontology use in E-Learning recommender system. Computers and Education: Artificial Intelligence, 3, 100047. https://doi.org/10.1016/j.caeai.2022.100047

Romero, M., Guédria, W., Panetto, H., & Barafort, B. (2022). A hybrid deep learning and ontology-driven approach to perform business process capability assessment. Journal of Industrial Information Integration, 30, 100409. https://doi.org/10.1016/j.jii.2022.100409

Sahin, E., Suh, J. K., Hand, B., & Fulmer, G. (2023). Unpacking teachers' orientations toward a knowledge generation approach: Do we need to go beyond epistemology? Teaching and Teacher Education, 132, 104264. https://doi.org/10.1016/j.tate.2023.104264

Shimizu, C., & Hitzler, P. (2025). Accelerating knowledge graph and ontology engineering with large language models. Journal of Web Semantics, 85, 100862. https://doi.org/10.1016/j.websem.2025.100862

Siemens, G. (2005). Connectivism: A learning theory for the digital age. International Journal of Instructional Technology and Distance Learning, 2(1), 3–10.

Siemens, G., & Tittenberger, P. (2009). Handbook of emerging technologies for learning. University of Manitoba.

Sperling, K., Stenberg, C.-J., McGrath, C., Åkerfeldt, A., Heintz, F., & Stenliden, L. (2024). In search of artificial intelligence (AI) literacy in teacher education: A scoping review. Computers and Education Open, 6, 100169. https://doi.org/10.1016/j.caeo.2024.100169

Suriasumantri, J. S. (2010). Filsafat ilmu: Sebuah pengantar populer (Edisi revisi). Pustaka Sinar Harapan.

Vedrenne-Gutiérrez, F., López-Suero, C. D. C., De Hoyos-Bermea, A., Mora-Flores, L. P., Monroy-Fraustro, D., Orozco-Castillo, M. F., Martínez-Velasco, J. F., & Altamirano-Bustamante, M. M. (2024). The axiological foundations of

innovation in STEM education – A systematic review and ethical meta-analysis. Heliyon, 10(12), e32381. https://doi.org/10.1016/j.heliyon.2024.e32381

Wang, X., Liu, Q., Pang, H., Tan, S. C., Lei, J., Wallace, M. P., & Li, L. (2023). What matters in AI-supported learning: A study of human-AI interactions in language learning using cluster analysis and epistemic network analysis. Computers & Education, 194, 104703. https://doi.org/10.1016/j.compedu.2022.104703

Wang, Y., Huo, Y., Yang, C., Huang, X., Xia, D., & Feng, F. (2024). Knowledge ontology enhanced model for explainable knowledge tracing. Journal of King Saud University - Computer and Information Sciences, 36(5), 102065. https://doi.org/10.1016/j.jksuci.2024.102065