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THE COGNITIVE SCIENCE BEHIND AI LEARNING MODELS VERSUS HUMAN LEARNING

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Abstract

Artificial Intelligence (AI) is increasingly transforming educational environments, prompting critical comparisons between machine learning models and human cognitive processes. While AI systems excel in processing vast datasets, recognizing statistical patterns, and optimizing performance through supervised, unsupervised, and reinforcement learning, they fundamentally differ from human learning mechanisms. Human cognition is shaped by memory construction, abstraction, contextual understanding, emotional engagement, and socio-cultural interaction. Learners actively construct meaning through experience, empathy, intuition, and moral reasoning—dimensions that remain beyond the scope of purely computational systems. In contrast, AI operates through algorithmic optimization without consciousness, lived experience, or intrinsic understanding. Although AI demonstrates speed, scalability, and efficiency in tasks such as grading, personalization, and analytics, it lacks creativity, common-sense reasoning, and adaptive flexibility in unfamiliar contexts. Emerging hybrid approaches—including neuro-symbolic AI, embodied systems, and human-in-the-loop models—aim to bridge these gaps by integrating computational strengths with human judgment. The future of education lies not in replacing teachers but in augmenting human capabilities through responsible, ethical, and collaborative human–AI partnerships that preserve the relational and cultural foundations of learning.

Keywords: *Artificial Intelligence in Education, Human Cognition, Machine Learning, Hybrid Intelligence, Educational Technology*

1.Introduction

In recent years, artificial intelligence (AI) has been widely used in many areas of modern life, particularly in education, where its adoption is rapidly increasing. An important question arises: does AI-integrated learning act as a rival to traditional teacher-led instruction, or can it surpass it? What implications does this have for future teaching and learning processes?

This issue is not merely theoretical. To ensure that AI supports classrooms rather than replaces them, it is essential to understand the fundamental differences between how machines and humans learn (Cukurova, 2024; Jose et al., 2025). Human teaching is

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inherently learner-centered and shaped by relationships, as well as cultural and traditional values passed down through generations. Teachers provide meaning, emotional depth, and real-life experience—qualities that cannot easily be programmed into machines (Brown University, 2025).

In contrast, AI lacks feelings, empathy, and cultural understanding. It functions through algorithms, identifying patterns in large datasets and generating outputs based purely on computational processes (Stanford News, 2024). While both human educators and AI systems can support learning, the processes through which they operate are fundamentally different.

Therefore, comparing these approaches is essential. As educational institutions worldwide increasingly adopt AI, it becomes clear that learning is not uniform. Elements such as social guidance, empathy, and moral development require human involvement, whereas tasks like large-scale grading, personalized assessment, and continuous progress monitoring can be effectively managed by AI tools (Sun et al., 2021).

By recognizing the strengths of both, we not only improve educational practices but also reflect on the true purpose of education and the values we aim to pass on to future generations.

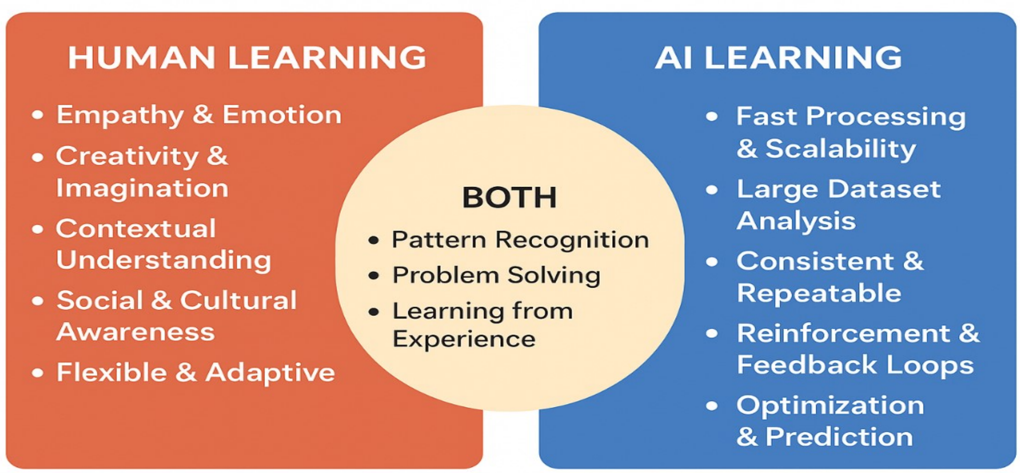

Figure 1. Human Learning vs AI Learning

2. Foundations: Human Cognition and Learning

Human learning is dynamic, complex, and shaped by cognitive, social, biological, and emotional factors. It extends beyond information acquisition, functioning as an active, interpretive process grounded in real-life contexts (Bransford, Brown, & Cocking, 2000; Sawyer, 2014). Several principles explain its adaptability and meaning.

- **Knowledge and Memory Construction**

Memory is an active system that integrates new information with prior knowledge and reshapes understanding through experience (Baddeley, 2012). Learning is influenced by emotion, context, and attention (Immordino-Yang & Damasio, 2007). Constructivist theory emphasizes that learners build knowledge by connecting new ideas to existing understanding (Piaget, 1970).

• Abstraction and Concept Formation

Humans form concepts from limited examples and apply them flexibly to new situations (Carey, 2009; Gentner, 2010). This “few-shot learning” enables efficient generalization beyond available data.

• Context and Meaning

Learning is shaped by cultural, linguistic, and experiential contexts. Sociocultural theory highlights that knowledge develops through participation in real-life settings (Vygotsky), with teachers linking content to meaningful experiences.

• Generalization and Adaptability

Humans interpret incomplete information using intuition and adapt to new situations (Kahneman, 2011). The brain continuously reorganizes itself through experience (Kolb & Gibb, 2011), supporting flexible learning.

• Social and Emotional Dimensions

Learning is inherently social and emotional, developed through interaction and collaboration (Bandura, 1986; Rogoff, 2003). Emotions enhance motivation and memory (Immordino-Yang & Damasio, 2007), while supportive relationships improve outcomes (Wentzel, 2016).

"Table 1. Key Human Cognitive Processes and Educational Implications

Cognitive Process	Description	Educational Implication
Memory	An active process of encoding, storing, and recalling information; influenced by attention, emotional states, and prior knowledge (Baddeley, 2012)	Design lessons that connect new content with prior knowledge; use repetition and retrieval practice
Abstraction	Formation of general concepts from limited examples; supports transfer of learning (Carey, 2009)	Encourage students to generalize from examples; use analogies and conceptual scaffolding
Contextual Understanding	Interpretation of information through cultural, linguistic, and situational lenses (Rogoff, 2003)	Create learning activities that are culturally relevant and context-sensitive
Generalisation	Ability to apply knowledge to novel situations	Include problem-solving tasks that

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Cognitive Process	Description	Educational Implication
& Adaptability	and reason under uncertainty (Kahneman, 2011)	require flexible thinking and creativity
Social & Emotional Learning	Learning through collaboration, imitation, motivation, empathy, and relationships (Immordino-Yang & Damasio, 2007; Bandura, 1986)	Promote group work, peer learning, and emotional engagement in lessons

3. AI Learning Models: Basics and Inspirations

Artificial intelligence does not think like humans. Although inspired by the brain, it learns by processing large datasets and identifying patterns without emotions, experience, or true understanding. Recognizing these differences clarifies both its potential and limitations in education.

• Neural Networks and Their Origins

Artificial neural networks (ANNs) were designed to mimic brain structure but function through mathematical computation rather than biological processes (LeCun et al., 2015). They lack the brain's adaptability, making terms like "learning" largely metaphorical (Marcus, 2018).

• Supervised Learning

Supervised learning uses labelled data to train models through error minimization (Goodfellow et al., 2016). Unlike humans, AI requires large datasets and does not genuinely understand concepts (Lake et al., 2017).

• Unsupervised Learning

Unsupervised learning identifies patterns in unlabelled data, but these are based on numerical similarity rather than meaning (Hinton, 2021). Humans interpret patterns through context and experience.

• Reinforcement Learning

Reinforcement learning improves performance through rewards in goal-oriented tasks (Sutton & Barto, 2018). However, it lacks curiosity, intention, and moral reasoning, which guide human learning.

• Historical and Interdisciplinary Influences

Although inspired by multiple disciplines, AI ultimately operates through computational principles, highlighting its fundamental differences from human cognition.

4. Parallels & Paradoxes: How AI Learns Like Us—and Where It Doesn't

At first glance, AI appears to learn in ways similar to humans. However, closer examination reveals clear differences in how it acquires knowledge, applies it, and what "understanding" means in each case. These similarities and differences highlight both the potential and limitations of AI in education.

• Data vs. Experience

AI requires large amounts of data—such as labelled images or text—to learn effectively. In contrast, humans often learn from minimal exposure, sometimes after only a few experiences. While AI can outperform humans in data-intensive tasks, it lacks intuition, contextual awareness, and experiential knowledge.

• Pattern Recognition vs. Understanding

AI excels at identifying patterns and predicting outcomes, particularly in language and data analysis. However, it does not truly understand meaning; it generates outputs based on statistical probabilities. Humans, by contrast, construct meaning through experience, beliefs, and reasoning, enabling deeper comprehension.

• Speed vs. Depth

AI processes vast amounts of information rapidly, identifying patterns in a fraction of the time required by humans. Human learning, though slower, involves reflection, emotional engagement, and trial-and-error processes, resulting in deeper and more lasting understanding.

• Strengths and Limitations

AI is efficient, consistent, and well-suited for repetitive or data-driven tasks such as analysis and feedback. However, it lacks creativity, empathy, and judgment, particularly in complex or unpredictable situations. Human educators remain essential for providing these qualities, making AI best suited as a supportive tool rather than a replacement.

• Creativity and Imagination

AI can generate text, images, and music by recombining learned patterns, but it lacks genuine creativity or intention. Human creativity emerges from emotions, cultural experiences, and personal insight, which AI cannot replicate.

• Flexibility and Adaptation

Humans demonstrate strong adaptability, adjusting quickly to new or unexpected situations. AI systems, however, often struggle when faced with conditions outside their training data, limiting their effectiveness in dynamic environments like classrooms.

• Common-Sense Reasoning

Human learning is supported by common sense developed through lived experience and social interaction. AI lacks this experiential grounding, making it less effective in interpreting context
or responding appropriately in nuanced situations.

• Generalisation and Few-Shot Learning

Humans can generalize knowledge and learn new concepts from very few examples. In contrast, AI typically requires extensive data and still struggles to apply knowledge beyond its training. Bridging this gap remains a major challenge in AI development.

6. Hybrid approaches & Future direction: Human-Machine Cooperation, Neuro-Symbolic, and Embodied AI

AI continues to advance rapidly, yet purely data-driven models remain limited. Increasing focus is therefore placed on hybrid approaches that incorporate contextual understanding and adaptability. The aim is not to replicate human intelligence, but to create transparent, flexible systems that effectively support education.

• Neuro-Symbolic AI

Neuro-symbolic AI integrates neural networks' pattern recognition with symbolic reasoning, enabling both learning flexibility and interpretability (d'Avila Garcez &

Lamb, 2020). It reflects dual-process cognition, combining intuitive and analytical thinking (Kahneman, 2011).

• Embodied AI

Embodied AI emphasizes learning through interaction rather than passive data processing. Grounded in embodied cognition, it enhances adaptability by enabling systems to engage with real or simulated environments (Pfeifer & Bongard, 2007).

• Human-in-the-Loop Learning

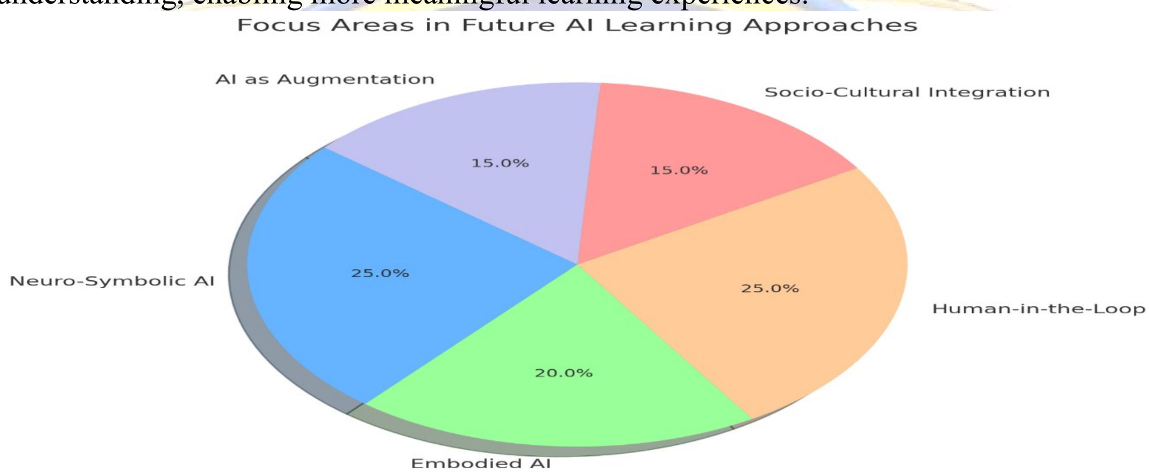
Human-in-the-loop (HITL) learning incorporates human feedback and ethical guidance into AI systems, improving reliability and reducing risks such as bias (Amershi et al., 2019).

• Socio-Cultural Integration

AI systems must align with diverse cultural and linguistic contexts, as learning is socially and culturally shaped (Rogoff, 2003). Adaptability to local contexts supports inclusive education.

• The Future: Augmentation, Not Replacement

AI's role in education is to augment, not replace, human teachers. While AI enhances efficiency and personalization, educators contribute empathy, creativity, and cultural understanding, enabling more meaningful learning experiences.



The chart represents the emphasis on neuro-symbolic AI, human-in-the-loop learning, embodied AI, socio-cultural integration, and AI as an augmentation tool rather than a replacement.

7. Implications for Education and Pedagogy

For AI to enhance education effectively, it is essential to understand how it differs from human thinking. Teachers remain central to the classroom, providing relationships, judgment, and guidance that AI cannot replicate. At the same time, AI offers valuable support by assisting with lesson design, personalized learning, and administrative tasks.

• Rethinking the Role of Teachers

The role of teachers has evolved beyond delivering content. AI can handle tasks such as information retrieval, grading, and feedback, allowing teachers to focus on mentoring, designing learning experiences, and guiding students' social and emotional development (Darling-Hammond et al., 2020). Human educators foster trust, curiosity, and critical thinking—elements that remain beyond AI's capabilities.

• AI as a Support to Human Judgment

AI is effective at processing large datasets, identifying patterns, and providing personalized recommendations. Adaptive learning tools enable students to progress at their own pace while offering teachers insights into performance (Holmes et al., 2022). However, teachers must interpret and evaluate AI outputs to ensure they align with students' needs, cultural contexts, and developmental stages. Thus, AI complements rather than replaces professional judgment.

• Curriculum Design with AI

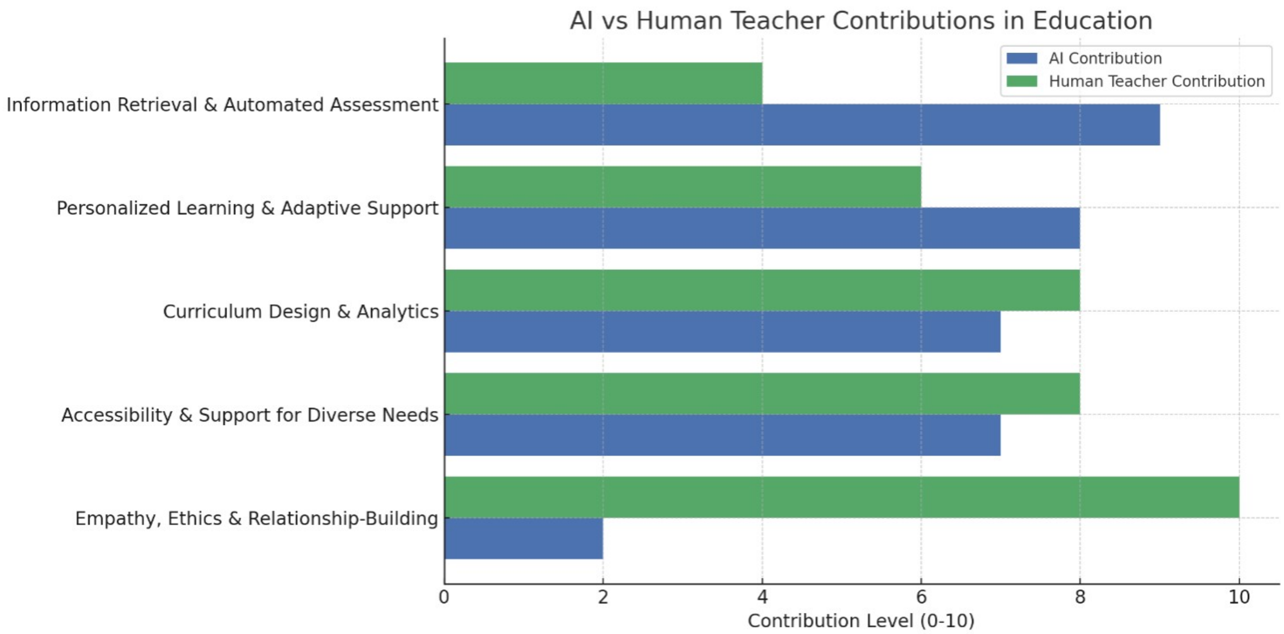
AI enables more flexible and responsive curriculum design. Real-time analytics allow teachers to identify learning gaps and provide timely support (Luckin et al., 2016). While AI enhances instructional adaptability, human educators remain responsible for fostering creativity, critical thinking, and ethical awareness, as well as ensuring data privacy and digital literacy.

• Supporting Inclusive Education

AI has significant potential to promote inclusivity by supporting multilingual learning, assisting students with disabilities, and providing personalized support (Kose & Fox, 2021). However, careful implementation is required to avoid over-reliance and potential bias in AI systems. Teachers play a key role in ensuring equitable and responsible use.

• The Continuing Importance of Teachers

Core human qualities—such as empathy, ethical judgment, creativity, and cultural understanding—cannot be replicated by AI (Williamson &Piattoeva, 2022). While AI improves efficiency and accessibility, it cannot replace the human dimension of teaching. The most effective approach is a collaborative model in which AI enhances, rather than substitutes, human educators.



8. Ethical, Cultural, and Societal Considerations

AI is increasingly integrated into classrooms, but its impact extends beyond technical functionality. Critical questions arise regarding who benefits, who may be excluded, and how AI reshapes the roles of teachers, students, and educational environments. Responsible implementation requires prioritizing human values, ensuring transparency, inclusivity, and preserving the human essence of learning.

• Bias and Fairness

AI systems rely on large datasets that may contain existing social and cultural biases. Without careful oversight, these systems can reinforce inequalities. For example, automated assessment tools may disadvantage minority students if biases remain unaddressed (Buolamwini& Gebru, 2018). Ensuring fairness requires continuous evaluation, diverse datasets, and active involvement of educators and communities.

• Explainability and Trust

Many AI systems function as "black boxes," making their decision-making processes difficult to interpret. This lack of transparency can reduce trust among users (Doshi-Velez & Kim, 2017). Explainable AI (XAI) addresses this issue by making system outputs more understandable, allowing educators and learners to evaluate and question AI-generated decisions.

• Cultural Sensitivity

Educational AI is often developed within specific cultural and institutional contexts, which may not align with diverse global learning environments (Rizvi & Lingard, 2010).

To be effective and equitable, AI systems must adapt to different cultural, linguistic, and pedagogical settings.

• Privacy and Data Security

AI-driven platforms depend heavily on student data, raising significant concerns about privacy and security. Young learners are particularly vulnerable to data misuse (Livingstone & Third, 2017). Schools must implement clear policies, ensure transparency, and prioritize robust data protection measures.

9. Conclusion and Forward Look

Although AI and human teachers share certain functional similarities, their approaches to learning and teaching remain fundamentally different. AI excels in processing data, identifying patterns, and personalizing instruction. However, it lacks essential human qualities such as empathy, creativity, and contextual judgment, which are central to meaningful education (Noddings, 2012; Selwyn, 2019).

AI is best understood as a supportive tool rather than a replacement for teachers. When used effectively, it can manage tasks such as assessment, personalization, and administrative work, enabling educators to focus on fostering relationships, critical thinking, and student engagement (Holmes et al., 2022). A collaborative model—combining human insight with AI capabilities—offers the greatest potential for enhancing learning outcomes.

At the same time, ethical challenges such as bias, privacy, transparency, and accountability must be carefully addressed (Williamson & Eynon, 2020). While AI will continue to transform education, human teachers remain central to guiding, inspiring, and shaping the learning experience in ways that technology cannot replicate.

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