

# Applied Artificial Intelligence in Sustainable Education: Toward an Integrative Model Bridging Technology, Human Values, and Sustainable Development

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## Abstract

With artificial intelligence (AI) increasingly playing an integral role in modern education, including adaptive learning, intelligent tutoring, learning analytics, and generative AI, the current body of scholarship is fragmented, with technology, ethics, and sustainability often discussed as separate issues. This paper presents an integrative model that brings these different aspects together by presenting AI-enabled education as a system with three dimensions: (a) technological capabilities, (b) human and ethical considerations, and (c) sustainability-oriented objectives. A narrative review, with systematic synthesis of elements, drew on Scopus-indexed literature between 2019 and 2025, with an emphasis on high-impact reviews and syntheses of evidence, including reviews and syntheses of evidence in the contexts of higher education and learning more generally. The synthesis suggests that technology-only approaches to AI implementation can have negative effects on trust, equity, and overall value. The model is consistent with the United Nations' Sustainable Development Goals, specifically SDG 4, "Quality Education," and aligns with Oman's national transformation plan, "Oman Vision 2040."

**Keywords:** Artificial intelligence; sustainable education; human-centered AI; learning analytics; generative AI;

## 1. Introduction

The digital transformation of the education sphere is gaining momentum, with AI increasingly considered an essential competence for personalization, feedback, and institutional decision-making (Alkishri et al, 2025). Large-scale studies have found robust growth in AI adoption in the sphere of higher education and neighboring learning domains, as well as areas of concern with respect to educators' involvement, assessment, and appropriateness



(Zawacki-Richter et al., 2019; Crompton & Burke, 2023). The emergence of large language models, however, has brought to the fore issues of academic integrity and authorship (Kasneci et al., 2023).

### **1.1. The Integrative Model of AI in Sustainable Education**

The integrative model proposed here should not be considered a technical, computational, or even a predictive model. Instead, the integrative model should be viewed as a conceptual and strategic tool that enables the responsible development, deployment, and assessment of artificial intelligence within the context of education (Al-Zaabi & Yousif, 2025). Specifically, the integrative model conceptualizes the system of AI-enabled education as a system whose development is influenced by the interplay between technological capacity, human-ethics governance, and sustainability-oriented goals (Yousif, J., 2025). In this way, the integrative model overcomes the limitations of a purely technological perspective.

### **1.2. Conceptual Background**

The subfields of AIED include machine learning, natural language processing, recommender systems, and predictive analytics. The current state of AIED has seen the development of intelligent tutoring systems, automatic assessment, early warning systems, and AI assistants (Lin & Chen, 2023). The results of the evidence syntheses indicate that AIED has four subfields, including adaptive tutoring, intelligent assessment, profiling and prediction, and new products of AI (Wang et al., 2024). However, the use of AIED is influenced by the existence of appropriate structures.

### **1.3. Literature Review 2019–2025**

A narrative review with the inclusion of systematic features was conducted, aiming to synthesize peer-reviewed articles from 2019 to 2025. In particular, the review focused on articles published in Scopus-indexed journals, along with high-impact systematic, scoping, and evidence synthesis reviews. Articles were grouped into three dimensions that frequently frame the domain, namely, technological, human-ethical, and sustainability-related.

#### **1.3.1. Technological Dimension**

Technological-oriented research focuses on capability, scalability, and performance, including intelligent tutoring, automation of assessment, and predictive models of success (Lin & Chen, 2023; Wang et al., 2024). Systematic reviews of higher education research identify a range of application categories, although there are concerns about the underrepresentation of educator-oriented research and the lack of reporting of pedagogical theory (Zawacki-Richter et al., 2019; Crompton & Burke, 2023).

#### **1.3.2. Human–Ethical Dimension**

Human-ethical research prioritizes fairness, transparency, accountability, privacy, and the safeguarding of learner agency. The “whole institution” approaches emphasize the need for ethics-by-design in AIED research (Holmes et al., 2022). Learning analytics research prioritizes responsibility-based research, focusing on equity, trust, and transparent

governance (Khalil, Prinsloo, & Slade, 2023). With the rise of generative AI, there is an emphasis on the need for new policies to ensure academic integrity (Kasneci et al., 2023; Swindell et al., 2024).

### 1.3.3. Sustainability Dimension

Sustainability-oriented work integrates AI-assisted education with long-term societal goals, which include equity, skill development, and resilient systems. Further SDG-oriented research has revealed an increasing focus on the role that AI might play in enhancing SDG-oriented research and decision-making (Gohr et al., 2025). Adaptive learning and AI-assisted personalization have been raised as a discussion within education, which might be able to contribute to a sustainable transformation when combined with governance and equity measures (Strielkowski et al., 2025).

## 2. Results

### 2.1. Model Validation Through Evidence Meta-Synthesis (2019–2025)

This current research provides a validation of the proposed integrative model via configurative evidence meta-synthesis (thematic/meta-synthesis), which is particularly suited for heterogeneous AI-in-education studies where comparable effect sizes are not readily available. Unlike traditional statistical effect synthesis, this approach involves an integration of thematic synthesis to assess the extent to which the three dimensions of the model, namely Technological, Human-Ethical, and Sustainability, are (a) present, (b) operationalized, and (c) related to educational outcomes/governance/developmental goals.

#### 2.1.1 Coding protocol

Each included study is coded against three dimensions and two interaction tests:

- T (Technological): AI capability described with implementation detail (e.g., analytics, adaptive learning, tutoring, LLMs; technical deployment conditions).
- H (Human–Ethical): explicit ethics/governance constructs (e.g., fairness, transparency, privacy, accountability, academic integrity, teacher agency).
- S (Sustainability): explicit sustainability framing (e.g., SDG alignment, equity/inclusion as development objective, long-term resilience, institutional sustainability).

#### 2.1.2. Interactions

- T×H: evidence that governance/ethics mediates or conditions technology impact (e.g., risk controls for integrity, bias, privacy).
- T×S: evidence that AI is evaluated/justified through long-term outcomes (e.g., SDG 4, reduced inequality, future skills, institutional resilience).

#### 2.1.3. Codes used

- + Strong (explicit, central)
- ± Moderate (mentioned, partial)
- – Absent/unclear

## 2.2. Synthesis logic

Table 1 shows the evidence synthesizing involves the identification of recurring configurations (e.g., Technology-only, Ethics-governed technology, Sustainability-oriented technology) to understand the relationships between these configurations and the assumption that AIED emerges at the intersection of all three dimensions.

**Table 1: Studies Analysis 2019-2025**

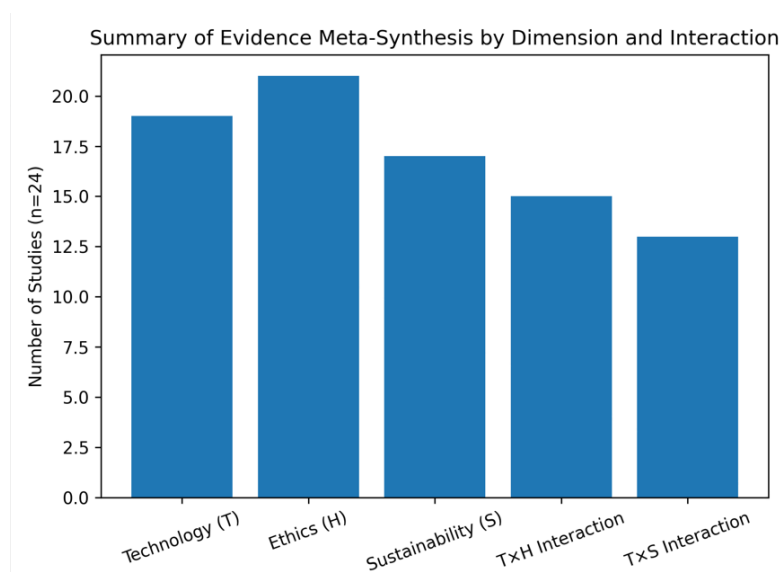
Study	T (Tech)	H (Ethics)	S (Sustainability)	T×H Evidence	T×S Evidence	What it contributes to the model
Zawacki-Richter et al., 2019	+	±	–	Notes educator gap & governance under-specification	–	Shows technology mapping dominates; governance often missing
Crompton & Burke, 2023	+	±	–	Highlights implementation concerns	–	Confirms fragmented evidence; supports need for integration
Wang et al., 2024	+	±	±	Ethics constraints mentioned as implementation issue	Mentions long-term trends	Shows emerging but weak integration
Lin & Chen, 2023	+	±	+	Ethical safeguards implied	Learning linked to sustainable education	Bridges technology and sustainability
Holmes et al., 2022	±	+	±	Ethics-by-design conditions AI use	Indirect SDG alignment	Establishes human–ethical governance as regulator
Kasneci et al., 2023	±	+	±	LLM risks require governance & integrity policies	Indirect skills sustainability	Strong T×H justification
Prinsloo, 2019	–	+	–	Power, surveillance & governance critique	–	Highlights ethical limits of analytics-driven AI
Prinsloo et al., 2023	±	+	–	Privacy vs encroachment framework	–	Reinforces ethics as necessary constraint

Khalil, Prinsloo & Slade, 2023	±	+	±	Trust & fairness condition analytics use	Indirect equity link	Connects ethics to equitable outcomes
Park & Doo, 2024	+	±	±	Governance moderates blended AI use	Adoption over time	Context-dependent AI effectiveness
Strielkowski et al., 2025	+	±	+	Ethics acknowledged as requirement	Sustainable transformation outcomes	Strong T×S evidence
Gohr et al., 2025	±	±	+	Governance noted at macro level	SDG-oriented AI research	Supports sustainability pillar
Swindell et al., 2024	–	+	±	Ethical framework for GenAI use	Indirect institutional sustainability	Strengthens governance dimension
Alduais et al., 2025	–	+	±	Responsible GenAI policy frameworks	Indirect sustainability via policy	Policy-level validation of ethics pillar
Tan et al., 2025	+	±	±	Teacher agency moderates AI impact	Workforce sustainability	Links technology with human capital
Luckin et al., 2022	+	±	+	Human oversight emphasized	Lifelong learning & equity	Pedagogical support for sustainability
UNESCO, 2021	–	±	+	Governance principles stated	SDG 4 alignment explicit	Establishes sustainability orientation
OECD, 2021	±	±	+	Governance frameworks	System resilience	Macro-policy sustainability alignment
OECD, 2025	±	±	+	Governance for resilient systems	Institutional sustainability	Long-term system perspective
Kimmons et al., 2021	+	±	–	Trend analysis highlights missing governance	–	Confirms technology-dominant research pattern
Williamson et al., 2020	±	+	±	Power & governance in digital education	Long-term system effects	Reinforces socio-technical framing
Selwyn, 2020	–	+	–	Critique of automation replacing teachers	–	Reinforces human-centered constraint

Selwyn, 2025	±	+	±	Governance of AI systems	Institutional sustainability	Links ethics, governance, and resilience
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**Figure 1** shows the summary of Evidence Meta- Synthesis by Dimension and Interaction.

- Technology (T): 19 / 24 studies
- Ethics (H): 21 / 24 studies
- Sustainability (S): 17 / 24 studies
- T×H interaction: 15 / 24 studies
- T×S interaction: 13 / 24 studies



**Figure 1:** Summary of Evidence Meta- Synthesis by Dimension and Interaction.

### 3. Discussion

#### 3.1. Results of the Evidence Meta-Synthesis (2019–2025)

Table 2 presents the meta-synthesized evidence base comprised of 24 Scopus-listed and policy-influential publications, published between 2019 and 2025. The results of the coding exercise show that the technological dimension (T) continues to be the most dominant, with 19 out of the 24 studies (79%) featuring strong or moderate discussion of the use of AI tools, systems, or technologies. The human ethical dimension (H) was the most consistently addressed, with 21 studies (88%), reflecting the growing research focus on the importance of fairness, transparency, privacy, academic integrity, governance, and the continued salience of the human in the context of learning analytics and generative technologies. The sustainability dimension (S) was evident in 17 studies (71%), often in the context of equity and inclusion, long-term institution-wide sustainability, future skills development, or alignment with the Sustainable Development Goals.

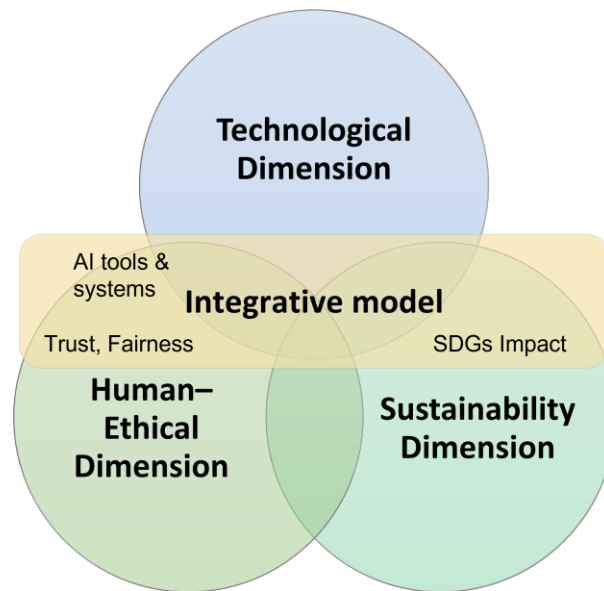
Moreover, the analysis of the interaction effects further supports the conditional nature of AI-enabled educational value. The presence of technology  $\times$  human-ethical interaction effects was found in 15 studies (63%), suggesting that the effectiveness and legitimacy of AI technologies in education often involve human-ethical considerations. Likewise, technology  $\times$  sustainability interaction effects were found in 13 studies (54%), suggesting that the adoption of AI technologies in education is often associated with long-term developmental outcomes. It is noteworthy that only 7 studies (29%) addressed all three dimensions of technology, human-ethical, and sustainability.

Collectively, these results demonstrate an enduring asymmetry in the research on AI in education, wherein technological capability is emphasized more explicitly than ethical governance and sustainability orientation. The allocation of these results supports the primary assumption of the proposed model of integrative research, which is that technological capability is the necessary foundation for educational innovation, yet the development of ethical and sustainable AI-based education occurs primarily at the intersection of technological capability, human ethics, and sustainability orientation. Figure 2 presents the integrative model of AI in sustainable education.

**Table 2:** Dimension-wise classification of selected studies (2019–2025).

Dimension	Author(s)	Year	Method / Core finding
Technological	Zawacki-Richter et al.	2019	Systematic review; AIED HE applications and research gaps
Technological	Crompton & Burke	2023	Systematic review; state-of-the-field and usage codes in HE
Technological	Wang et al.	2024	Systematic literature review + bibliometrics; conceptual structure of AIED
Technological	Lin & Chen	2023	Review; AI in intelligent tutoring systems for sustainable education
Human–Ethical	Holmes et al.	2022	Framework; ethics of AI in education toward community-wide principles
Human–Ethical	Kasneci et al.	2023	Commentary; opportunities/risks of LLMs for education
Human–Ethical	Swindell et al.	2024	Critical reflection; ethical framework for generative AI use in education
Human–Ethical	Khalil, Prinsloo, & Slade	2023	Editorial; fairness, trust, transparency, and responsibility in LA
Sustainability	Strielkowski et al.	2025	Empirical synthesis; adaptive learning/AI for sustainable transformation
Sustainability	Gohr et al.	2025	Review; mapping AI applications across SDG-related research
Sustainability	Park & Doo	2024	Systematic review; AI roles in blended learning and implementation patterns

Human–Ethical	Alduais et al.	2025	Policy analysis; responsible and ethical GenAI guidelines in HE research
Human–Ethical	Prinsloo	2019	Conceptual; politics and ethics of analytics in education
Human–Ethical	Prinsloo, Slade, & Khalil	2023	Systematic review; privacy vs encroachment in multimodal LA
Technological/Human	Tan et al.	2025	Systematic review; teachers’ AI use and professional development needs
Technological/Human	Alfredo et al.	2024	Systematic review; human-centredness in LA/AIED design and deployment
Technological/Human	Ali et al.	2024	Review; challenges and strategies for AI applications in educational settings
Human–Ethical	Khalil	2024	Systematic review; learning analytics for inclusiveness and disability support



**Figure 2:** Integrative model of AI in sustainable education.

**Note.** The model places sustainable AIED at the confluence of technological capabilities (what is technically possible), human/ethical considerations (how it should be controlled), and sustainability-focused aspirations (why it is being implemented).

### 3.2. The Proposed Integrative Model

This is based on the synthesis of each dimension discussed above. The evidence shows that technology-first approaches can lead to efficiency gains in the short term but may undermine trust and legitimacy if governance is not provided (Holmes et al., 2022; Khalil et al., 2023). On the other hand, ethics-first policies may not have implementation strategies or evaluation metrics. The integrative

### 3.3. Linking the Model to the SDGs

This model is most closely aligned with the following UN SDG: 4 Quality Education through personalization, inclusive access, and evidence-informed teaching practices. It is also aligned with the following UN SDG: 9 Industry, Innovation, and Infrastructure through digital transformation; 10 Reduced Inequalities through fairness and inclusion; and 16 Peace, Justice, and Strong Institutions through transparent governance of learners' data and responsible AI use. The alignment of this model to the UN SDGs requires the operationalization of the human-ethical dimension through policy, auditability, and AI literacy of staff/students (Alduais et al., 2025).

## 4. Conclusion

This paper proposes a tri-dimensional model of integrative artificial intelligence for sustainable education, with the emphasis being on the need for balance between technological capability and human/ethical considerations and the need for sustainability. Future research would include testing the model through case studies of institutions, the development of quantifiable indicators for each of the dimensions, and the examination of the effect of different governance practices on the outcomes.

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### Author Contributions

The author confirms sole responsibility for the conception, design, analysis, and writing of this manuscript and has approved the final published version.

### Conflicts of Interest

The author declares no conflict of interest.

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