

AI as a Co-Pilot: Framework for Sustainability Education in Early Childhood

Ruiqin Fan¹, Hailu Yu², Lihua Gao^{3*}

Binzhou Polytechnic, Binzhou, Shandong Province, 256600, China

*Corresponding author: Lihua Gao, 343675513@qq.com

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Abstract: Amidst the burgeoning discourse on Artificial Intelligence (AI) in education, its application within Early Childhood Education (ECE), particularly for value-laden domains such as Education for Sustainable Development (ESD), remains a subject of intense debate. While AI presents significant opportunities for resource generation, concerns persist regarding its potential to undermine the humanistic essence of early childhood pedagogy. This paper addresses a pivotal question: How can AI empower ECE teachers while safeguarding their pedagogical autonomy? Employing a theoretical-speculative methodology, we propose an “AI Co-Pilot” model that conceptualizes AI not as a replacement, but as a synergistic partner operating under the teacher’s strategic leadership. We establish a three-dimensional integrated framework—comprising “Value-Guidance, Function-Matching, and Boundary-Constraints”—to operationalize this collaborative dynamic. Specifically, we illustrate how AI’s supportive, supplementary, and adaptive functions can bridge critical teacher capability gaps in resource provision and individualized differentiation, while robust boundary constraints mitigate inherent ethical risks. This framework directly contributes to the realization of Sustainable Development Goal (SDG) 4.7 and SDG 12.8 by equipping educators with adaptive tools for value transmission. Ultimately, the study demonstrates how the “AI Co-Pilot” approach harmonizes technological efficiency (instrumental rationality) with value rationality to uphold humanistic educational objectives.

Keywords: AI Co-Pilot; Early Childhood Education (ECE); Education for Sustainable Development (ESD); Human-AI Synergy; SDG 4.7; Ethical Framework

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1. Introduction

Education for Sustainable Development (ESD) is a key enabler for all Sustainable Development Goals (SDGs), specifically targeting SDG 4.7. In the global context, ECE-ESD is critical because the foundational values of environmental stewardship and social justice are formed in early childhood. Recently, the rapid advancement of Generative AI (GenAI) has transformed educational landscapes, yet its integration into the delicate “care-education” balance of ECE remains under-explored.

Early Childhood Education (ECE) is the foundational stage for value formation. In the context of Education for Sustainable Development (ESD), teachers face the dual challenge of translating abstract concepts (e.g., conservation) into perceptible play-based activities while maintaining emotional connectivity^[3]. The integration of AI has sparked a polarized debate. While some view AI as a threat to the “teacher-child” dyad^[4], others advocate for its efficiency. However, current research

largely focuses on AI as an instructional tutor or a passive content generator, often overlooking the unique “care-education” integration required in ECE. This paper argues that existing models fail to address the specific need for empowerment without replacement in ESD^[5]. We propose the “AI Co-Pilot” framework to bridge this gap, exploring how human-AI synergy can enhance teacher efficacy while preserving pedagogical primacy.

This conceptual paper aims to bridge this gap. It contributes to ESD research by operationalizing value-based teaching, to SDG-focused education by providing a scalable model for goal implementation, and to Human-AI synergy scholarship by defining a teacher-led “Co-Pilot” interaction logic.

2.Literature Review

2.1. Research on SDG and ESD Current literature emphasizes that SDG 4.7 requires more than knowledge; it demands value internalization, which in ECE is achieved through play-based immersion.

2.2. AI in Sustainability Education Recent studies explore Generative AI as a content generator for environmental stories, yet many highlight the risk of AI-driven content lacking cultural sensitivity.

2.3. Research Gap There is a notable gap in frameworks that specifically address how AI can support teachers in the “human-centric” tasks of ECE-ESD without replacing the teacher’s emotional role. This paper justifies the need for a “Co-Pilot” model to fill this void.

3.Conceptual Deconstruction: The AI Co-Pilot and ECE-ESD

First, we clarify the concept of an AI Co-Pilot. Rather than a mere tool, a “Co-Pilot” acts as a supportive partner that provides navigational data while the teacher retains pedagogical command. The relationship between an “AI Co-Pilot” and “ECE-ESD” is not merely one of technological application, but a synergistic partnership guided by deeply held educational values.

3.1 From “Tool” to “Synergistic Partner”

The concept of “AI Co-Pilot” transcends the traditional “tool” metaphor^{[7][8]}. Drawing on the theory of “Human-AI Teaming”, we define the Co-Pilot as an auxiliary entity that operates under the teacher’s explicit leadership^[9]. Unlike autonomous tutoring systems, the Co-Pilot’s role is grounded in “augmented intelligence” —it provides navigational support (resources and data) while the teacher retains full control over the flight path (pedagogical decisions)^[6]. This distinction is crucial for ECE-ESD, where value transmission relies on human empathy—a quality AI cannot replicate^[13].

3.2 ECE-ESD: Foundational Value Transmission

The essence of ESD in early childhood is foundational value transmission, grounded in developmentally appropriate practice. As concrete thinkers—a concept central to Piagetian theory—young children cannot grasp abstract ideas like “carbon footprint.” Therefore, the goal is not to impart encyclopedic knowledge but to instill core values through daily routines, sensory experiences, and meaningful activities. A recycling game is not about memorizing categories but about internalizing the powerful idea that objects can have a second life. Planting a seed is less about botany and more about the profound experience of nurturing and caring for other living things.

This educational approach is characterized by three essential features:

Life-Based: All activities are deeply embedded in the child’s daily life. Resource conservation is taught by turning off the tap while washing hands or ensuring all the food on one’s plate is eaten^[10].

Interactive: Learning is an active, social process that occurs through play, hands-on manipulation, and rich dialogue^[2]. Children learn about reusing materials by transforming a cardboard box into a spaceship, not by listening to a lecture^[11].

Progressive: It follows the child’s natural cognitive and emotional development, moving from simple actions (picking up litter) to initial understanding (“we want our playground clean”) and, eventually, to the internalization of a value (a sense of responsibility for one’s environment)^{[1][12]}.

4.The AI Co-Pilot Framework

The effective integration of an AI Co-Pilot into the complex world of ECE-ESD hinges on a clear and principled synergistic logic. The AI’s functions must be precisely and ethically mapped to the core challenges of ECE-ESD pedagogy.

4.1 Current Teacher Roles and Challenges in ECE-ESD

Teachers currently struggle with resource scarcity and the high cognitive load of differentiating abstract SDG concepts for toddlers. While the teacher’s role as the “pilot” is a non-negotiable pedagogical imperative, maintaining this primacy is increasingly difficult due to three systemic capability gaps:

Resource Scarcity: Many ECE practitioners lack specialized training in sustainability science, making it hard to generate a continuous stream of child-friendly, scientifically accurate resources^[14].

Differentiation Demands: In high-ratio classrooms, teachers struggle to track and respond to the unique developmental pace and interests of every individual child.

Adaptive Complexity: The dynamic nature of play-based learning requires rapid, in-the-moment pedagogical adjustments that overtax a teacher’s cognitive bandwidth. Without intervention, these pressures risk eroding the humanistic, “care-education” core that defines early childhood pedagogy.

4.2 Proposing the AI Fit: The Co-Pilot Logic

To bridge these gaps, we propose the AI Co-Pilot as a supportive partner rather than a mere tool or a substitute. Under this model, the AI’s functions are precisely mapped to the challenges identified in Section 4.1:

Supportive Function: AI acts as a creative drafting service, augmenting the teacher’s ability to provide diverse ESD resources.

Supplementary Function: AI enhances observational capacity by providing anonymized data insights on child interactions, aiding in individual differentiation.

Adaptive Function: AI offers pedagogical suggestions that the teacher can evaluate and implement based on real-time classroom dynamics. This synergy creates an “augmented intelligence” environment where the AI proposes possibilities, but the human teacher retains full authority over the final instructional path. The systematic mapping of these functions to the identified teacher challenges is summarized in Table 1.

Table 1. Mapping Teacher Challenges to AI Co-Pilot Functions in ECE-ESD.

Teacher Challenges in ECE-ESD	AI Co-Pilot Functions
<p>1. Resource Scarcity Lack of specialized ESD training and child-friendly materials.</p>	<p>Supportive Function Acts as a creative drafting service to augment diverse resource generation.</p>
<p>2. Differentiation Demands High-ratio classrooms hindering tracking of individual child interests.</p>	<p>Supplementary Function Enhances observation via anonymized data insights on child interactions.</p>
<p>3. Adaptive Complexity High cognitive load for real-time pedagogical adjustments.</p>	<p>Adaptive Function Offers pedagogical suggestions for real-time classroom adjustments.</p>

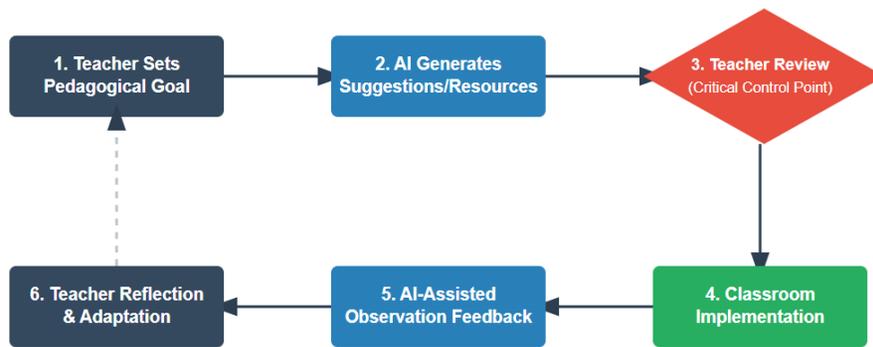
4.3 Synthesis: The Complementary Nature of Instrumental and Value Rationality

The perceived conflict between AI’s instrumental rationality (data and efficiency) and ECE’s value rationality (ethics and emotion) is a false dichotomy. Within the Co-Pilot framework, these two forms of rationality are a complementary and unified whole.

The AI provides the objective “what”: It delivers the evidence-based resources and data patterns necessary for informed teaching.

The Teacher delivers the meaningful “why”: The teacher uses AI-generated data to initiate value-laden lessons on empathy, responsibility, and moral balance. For instance, while an AI can detect a child overwatering a plant (instrumental data), only the teacher can transform that data into a profound learning experience about nurturing living things. Thus, the framework ensures that technological efficiency serves, rather than replaces, the essential task of value transmission. The operational logic of this synergy is structured as a closed-loop process, emphasizing the teacher’s role as the final decision-maker (see Figure 1).

Figure 1. The Operational Loop of Human-AI Synergy in the Co-Pilot Framework.

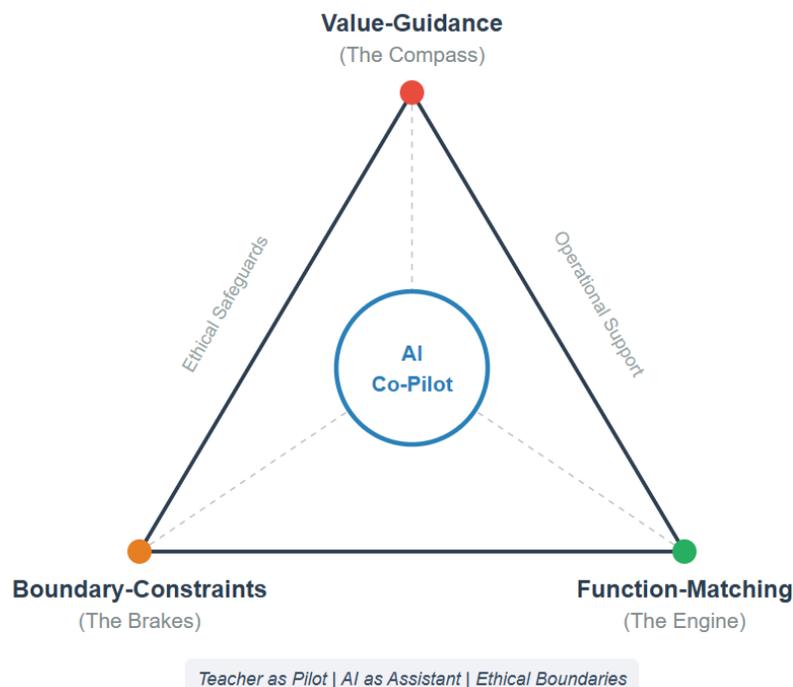


"AI Proposes, but the Human Disposes"

5.A Three-Dimensional Integrated Framework for Implementation

We propose a systemic framework comprising ‘Value-Guidance’ (The Compass), ‘Function-Matching’ (The Engine), and ‘Boundary-Constraints’ (The Brakes), the relationship of which is illustrated in Figure 2.

Figure 2. The Three-Dimensional Integrated Framework of the AI Co-Pilot in ECE-ESD.



5.1 Dimension 1: Value-Guidance

This dimension serves as the framework’s unwavering ethical compass. It dictates that all AI functions must be explicitly and transparently aligned with the core ECE-ESD goal of foundational value transmission. This principle guides the design, selection, and ongoing audit of AI tools. For instance, when an AI generates a storybook about water conservation, this principle ensures it uses simple, allegorical language that a child can connect with emotionally (e.g., “the little water drop needs to get home to its family in the river”), rather than presenting abstract scientific data. This allows the teacher to use the tool as a springboard for fostering empathy and a sense of personal responsibility. This aligns with the concept of “Value-Sensitive Design,” ensuring human values are central to the technology’s architecture^{[15][16]}.

5.2 Dimension 2: Function-Matching

To demonstrate the framework’s operationalization, we present a hypothetical classroom scenario: The “Caring for Our Water Friends” Unit.

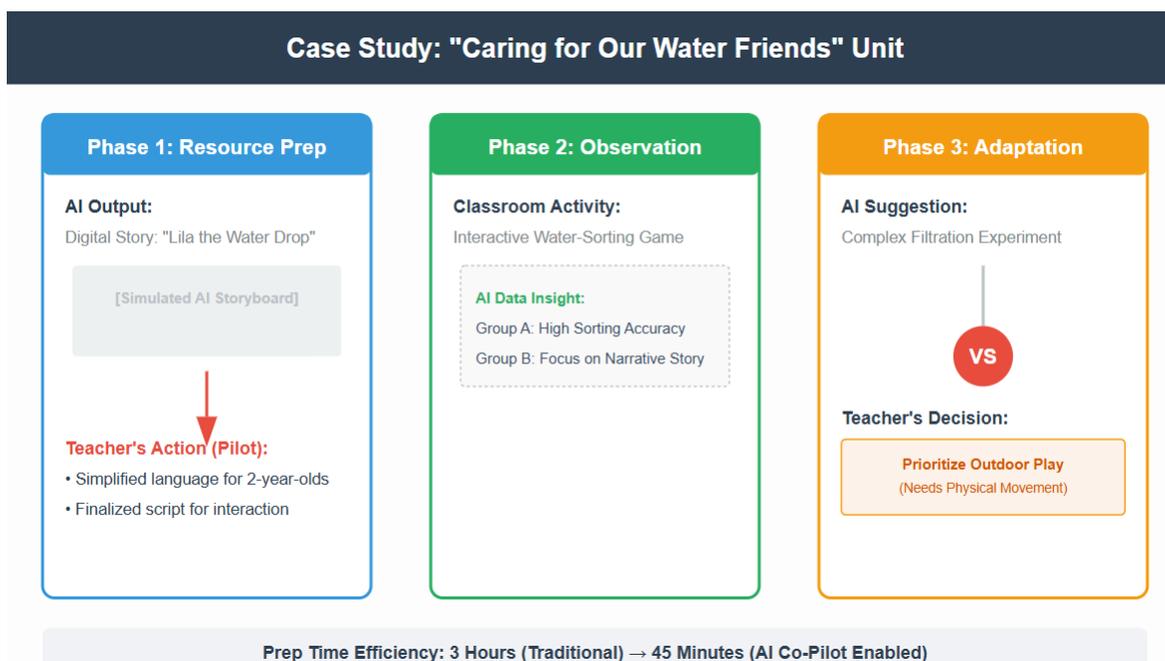
Phase 1: Supportive Function (Resource Augmentation): Teacher Wang intends to introduce water conservation. Lacking

specialized ESD resources, she queries the AI Co-Pilot. The AI generates a digital storybook, “Lila the Water Drop.” Crucially, Wang notices the language is too complex for her 2-year-olds. She utilizes her professional judgment to edit the text, using the AI merely as a creative drafting service. This illustrates the “Pilot” taking control of the “Co-Pilot’s” output.

Phase 2: Supplementary Function (Observation Support): During the activity, children engage with a water-sorting game on a tablet. The AI unobtrusively tracks interactions and provides Wang with an anonymized summary: “Group A excels at sorting; Group B focuses on narrative elements.” This data augments Wang’s observational capacity, highlighting patterns she might miss in a busy classroom.

Phase 3: Adaptive Function (Pedagogical Differentiation): Based on the data, the AI suggests: “Offer Group A a complex filtration experiment.” Wang evaluates this suggestion but decides to prioritize outdoor play instead, recognizing the group’s need for physical movement. This highlights the framework’s core logic: AI proposes, but the Human disposes. In a pedagogical reflection, Teacher Wang noted that with the AI Co-Pilot’s assistance, her total preparation time for the “Caring for Our Water Friends” unit—including generating initial drafts for the storybook, song, and images—was reduced from an estimated 3 hours to approximately 45 minutes. This efficiency gain allowed her to dedicate significantly more time and energy to observing and responding to the children’s individualized needs.

Figure 3. Visual Workflow of the “Caring for Our Water Friends” Unit: Demonstrating Human-AI Synergy.



5.3 Dimension 3: Boundary-Constraints

This dimension establishes the crucial, non-negotiable “rules of engagement” to protect the humanistic core of ECE. It clearly defines what the AI Co-Pilot must not do, acting as an ethical safeguard.

No Decision-Making Authority: The AI provides suggestions, options, and data, but the teacher makes all final pedagogical decisions. The teacher decides whether to use the storybook, which activity to implement for which group, and how to respond to a child’s individual needs. The AI’s role is to inform, not to direct^[16].

No Emotional Response: The AI is strictly restricted to instrumental and cognitive support. If a child becomes sad during the story because the little water drop gets lost, the AI system does not and cannot intervene. It is the teacher’s exclusive and essential role to provide comfort^[17], a hug, and empathetic emotional guidance.

No Evaluative Judgment: The AI can provide objective, descriptive data (e.g., “Leo completed the sorting task in 30 seconds with 90% accuracy”), but it is prohibited from making subjective or evaluative judgments (e.g., “Leo is good at this,” or “Mia is not paying attention”). Assessment, interpretation, and judgment remain the exclusive professional responsibility of the teacher.

This three-dimensional framework ensures that AI is integrated not as a disruptive or dehumanizing force, but as a carefully

calibrated, powerful, and respectful ally for the professional teacher^[18].

5.4 Potential Risks and Implementation Challenges

While the “AI Co-Pilot” model offers significant potential for enhancing pedagogical practice, its implementation must be accompanied by a rigorous assessment of potential risks to ensure a balanced integration of technology. This study identifies four core challenges that must be addressed:

Risk of Over-reliance and Automation Bias: There is a distinct danger that teachers may succumb to “automation bias,” where the pursuit of efficiency leads to the passive acceptance of AI-generated suggestions without critical scrutiny. Such passive adoption would ultimately erode the pedagogical autonomy and professional agency that this framework seeks to protect.

Data Privacy and Security Boundaries: Within the highly sensitive context of early childhood education, data privacy remains a paramount concern. As AI systems track child interactions to provide observational support, ensuring the de-identification of personal information and preventing sensitive data leaks represent significant technical and ethical hurdles for the framework’s operationalization^[19].

Algorithmic Bias and Content Homogenization: If AI Co-Pilot systems are trained on narrow or culturally limited datasets, the generated ESD resources—such as stories or illustrations—may lack cultural diversity or reinforce existing stereotypes. This poses a severe challenge to SDG-themed education, which emphasizes global citizenship and diverse values.

AI Literacy Gap and Operationalization: The framework assumes that ECE practitioners possess the necessary digital competencies to serve as “Pilots”. However, a significant gap in AI literacy and “AI-pedagogical” competence among teachers remains a barrier to effective oversight. Furthermore, collaborating with computer scientists to translate abstract ethical boundaries into executable system constraints—such as permission limits or real-time ethical prompts—is essential for future implementation.

6. Conclusion

This study refines the discourse on educational AI by shifting the focus from “automation” to “augmented empowerment” within the unique context of ECE-ESD. It provides the first systematic framework that maps AI functionalities directly to the specific capability gaps of ECE teachers (resource scarcity, differentiation, adaptation) while embedding strict humanistic boundaries.

6.1 Theoretical Contributions

This research offers three key theoretical contributions. It refines the “instrumental view” of educational AI by arguing its functions must serve the primary goal of value transmission. It enhances “human-AI synergy” theory by adapting its principles to the unique, play-based context of ECE and its specific teacher capability gaps. Finally, it fills a theoretical void by providing the first comprehensive framework to systematically address how AI can support teachers in ECE-ESD, integrating functional possibilities with ethical imperatives.

6.2 Limitations and Future Research

Limitations: The primary limitation of this study lies in the scope of the theoretical lens, which focuses on human-AI synergy but may not fully account for infrastructure disparities or digital divide issues in different geographic regions. Furthermore, the theoretical generalizability is bounded by the specific play-based nature of ECE pedagogy; the framework’s applicability to more structured primary or secondary education settings remains to be explored. While this manuscript is intentionally non-empirical to establish a conceptual foundation, these boundaries should be considered when applying the model to real-world practice.

Future Research Directions: To advance the proposed framework, future research should focus on the following four areas:

- **Empirical Validation:** Testing the AI Co-Pilot framework through classroom-based empirical studies to measure its actual impact on reducing teachers’ cognitive load and instructional design time.
- **Cultural Adaptation:** Exploring how the model can be adapted for different cultural or educational contexts, particularly in non-Western ECE-ESD settings.
- **SDG-Aligned Indicators:** Developing specific evaluation metrics to assess AI–teacher collaboration using indicators directly aligned with SDG 4.7.

·Ethics and Privacy: Operationalizing data privacy constraints and developing mechanisms to mitigate “automation bias” within real-world AI systems.

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Conflict of Interests

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