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Bridging Knowledge and Action: An AI-Enabled Communication Model for Ecological Education

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Abstract

Students often understand ecological issues but fail to translate knowledge into action. Existing studies mainly position artificial intelligence (AI) as a content-delivery tool rather than a communication infrastructure linking message design to behavioral outcomes. This study proposes a six-layer AI-Enabled Communication Model for Ecological Education based on instructional communication theory and the Knowledge-Attitude-Behavior framework. Using a systematic literature review (SLR) and thematic synthesis, 20 studies published between 2016 and 2026 were analyzed. Findings show that AI supports ecological learning through personalized messaging, interactive simulations, conversational agents, and continuous feedback. However, lasting behavioral change requires supportive school culture, teacher-guided value formation, and ecological projects. The proposed model integrates message design, AI-supported communication, feedback, action reinforcement, value habituation, and ethical governance to promote sustainable ecological behavior.

Keywords: AI; ecological awareness; educational communication; instructional communication; environmental education

Abstrak

Siswa sering memahami isu-isu ekologi tetapi gagal menerjemahkan pengetahuan tersebut ke dalam tindakan. Studi yang ada sebagian besar menempatkan kecerdasan buatan (AI) sebagai alat penyampaian konten daripada infrastruktur komunikasi yang menghubungkan desain pesan dengan hasil perilaku. Studi ini mengusulkan Model Komunikasi Berbasis AI enam lapis untuk Pendidikan Ekologi berdasarkan teori komunikasi instruksional dan kerangka Pengetahuan-Sikap-Perilaku. Dengan menggunakan tinjauan literatur sistematis (SLR) dan sintesis tematik, 20 studi yang diterbitkan antara tahun 2016 dan 2026 dianalisis. Temuan menunjukkan bahwa AI mendukung pembelajaran ekologi melalui pesan yang dipersonalisasi, simulasi interaktif, agen percakapan, dan umpan balik berkelanjutan. Namun, perubahan perilaku yang berkelanjutan membutuhkan budaya sekolah yang mendukung, pembentukan nilai yang dipandu guru, dan proyek-proyek ekologi. Model yang diusulkan mengintegrasikan desain pesan, komunikasi yang didukung AI, umpan balik, penguatan tindakan, pembiasaan nilai, dan tata kelola etis untuk mempromosikan perilaku ekologis yang berkelanjutan.

Kata kunci: *AI; kesadaran ekologi; komunikasi pendidikan; komunikasi instruksional; pendidikan lingkungan*

A. Introduction

There is a well-documented problem at the center of environmental education: students who can accurately describe climate change, waste accumulation, and ecosystem degradation often do not change how they live. They know. They do not act. Global data underscore the urgency of this gap. Ahmad et al. (2024)report that although more than 90% of surveyed youth worldwide express concern about environmental issues, fewer than 30% report consistently engaging in pro-environmental behavior. In Indonesia, national survey data indicate that while environmental awareness among secondary school students has increased steadily, measurable behavioral indicators such as waste sorting compliance and energy conservation practices remain low across sampled schools (Nisa et al., 2025). This disconnect between knowledge and behavior has been studied from motivational, psychological, and curricular angles, but one angle receives less attention than it deserves: communication design (Arif et al., 2025; Sari & Saputra, 2025; Wiese et al., 2025). How messages about the environment are framed, through what channels they reach learners, what feedback is available after exposure, and how the institutional context reinforces or undermines what was learned are all communication variables, and they are all tractable.

This article takes that framing seriously. Environmental education is treated here as a problem of applied instructional communication, not just curriculum content. The theoretical anchoring is twofold. First, this study draws on instructional communication theory, which positions the design of message, channel, feedback, and relational context as the determinants of learning outcomes (Mottet et al., 2006). Second, it engages behavior change theory, particularly the Knowledge-Attitude-Behavior (KAB) model and its extensions, which explain why information alone is insufficient for behavioral change and what mediating conditions must be present (Bettinghaus, 1986). Together, these frameworks position AI not as a technological add-on but as a communication infrastructure that can supply the mediating conditions the KAB model identifies as necessary. The question is not only what to teach about ecology but also how to design the communicative conditions under which knowledge becomes relevant enough, reinforced enough, and practically supported enough to shift behavior (Annas et al., 2026; Shaheda et al., 2025). That reframing matters because it changes which tools and strategies are worth investing in, and it changes how we evaluate whether an intervention is working.

The knowledge-action gap is not new, but it is persistent. Students who can reproduce definitions of pollution, carbon cycles, and biodiversity loss do not automatically reduce consumption, sort waste, or choose lower-emission options (Anjarsari et al., 2025; Arif et al., 2025). Closing that gap requires instructional communication that builds both perceived relevance, the sense that the ecological problem is mine and nearby, and perceived capacity, the sense that my actions can matter. Neither emerges reliably from passive content delivery. Both require interaction, feedback, and repeated reinforcement embedded in a context that models and expects ecological practice (Azzahra et al., 2026; Shaheda et al., 2025).

Digital technologies expanded the channel options available to ecological educators. Onny (2025) documents the range in use: mobile applications, computer simulations, website-based learning environments, and social media campaigns have all been deployed to raise ecological awareness and deepen student engagement with environmental issues. The evidence suggests these tools can enrich the learning experience. But Onny (2025) is equally clear that technology access and learning quality are not the same thing. Without deliberate communication design, the availability of a platform does not produce the instructional conditions that shift behavior (Wang et al., 2024).

Artificial intelligence extends what digital technology can do in education by enabling adaptation. Where a website delivers the same content to every visitor, an AI-enabled system can adjust the pathway, pacing, and framing based on what it knows about the learner. Inuwa et al. (2025) document this in their systematic review of AI-driven personalized learning: systems built on indicators of learner needs, behavior, and prior knowledge can modify what is presented, how it is sequenced, and what support is offered. For ecological education, that adaptability is directly relevant. A learner in a coastal community may respond to messages about plastic accumulation in ways that differ from a learner in a drought-affected agricultural region; AI enables those frames to be matched to context rather than applied uniformly (Anjarsari et al., 2025; Shaheda et al., 2025; Wang et al., 2024).

Empirical evidence supports the case. Huang (2018) conducted a quasi-experiment with 186 university students over 16 weeks, using an AI teaching system for environmental education, and found significant gains in environmental knowledge, attitudes, and behavioral intentions compared to conventional instruction. Critically, Huang (2018) documents the mechanism: the system selected instructional strategies based on each student's knowledge structure and communicated results through the system interface, making AI a mediator of instructional sequence and feedback rather than simply a content repository. That distinction matters for this article's argument about communication design.

In Indonesia, where a significant portion of the reviewed literature originates, value integration has emerged as a distinct and productive pathway to ecological awareness (Sari & Saputra, 2025). Sulaiman (2024) reports that when AI-enabled learning environments embed ecological values in ways consistent with Islamic educational frameworks, both comprehension and environmental concern improve. Putri & Safitri (2025) extend the argument beyond technology to school culture: the environmental character education that produces sustained behavioral change in primary school students depends on daily routines, teacher modeling, classroom environment, project-based learning, outdoor activity, and institutional policy working together. Nengrom & Fatmawati (2023) further demonstrate this from an Indonesian IPS classroom context, showing that ethnoecology-based environmental management embedded in social studies learning builds students' ecological care at the school level. The whole school operates as a communication system, and the digital component works only when it connects to that system.

Three gaps in the literature justify the present study. First, the AI-in-education literature focuses heavily on personalization efficiency without framing AI explicitly as an instructional communication tool that connects message design, feedback cycles, and contextual reinforcement to ecological outcomes (Inuwa et al., 2025; Wang et al., 2024). Second, technology-based environmental education often reports on platforms and activities without specifying the communication framework that would convert attitude shifts into lasting behavioral change, particularly in contexts with unequal device and connectivity access (Onny, 2025; Sari & Saputra, 2025). Third, the locally grounded insight that habituation and school culture are decisive for behavioral outcomes has not been translated into an operationally explicit, ethically grounded communication model for AI-based ecological education (Putri & Safitri, 2025; Wang et al., 2024).

This article addresses those gaps through a PRISMA 2020-guided systematic literature review of the past decade's research. The synthesis produces a layered AI-Enabled Communication Model for Ecological Education, organized around the knowledge-to-action problem named in the title. The model connects message design, AI channels, feedback mechanisms, action reinforcement, and governance into a framework specific enough to guide program design and honest enough about what AI cannot do on its own. The principal contribution of this study is threefold: (1) it reconceptualizes AI as instructional communication infrastructure rather than a content delivery mechanism, grounding this reframing in both instructional communication theory and the KAB model; (2) it proposes a novel, operationally explicit, six-layer cyclical model that integrates ecological message design, AI-enabled personalization, iterative feedback, action reinforcement, and ethical governance into a unified framework; and (3) it bridges international and Indonesian empirical literature, translating locally grounded insights about school culture and value integration into a design framework applicable in low-resource and high-resource settings alike. To the authors' knowledge, no prior model has integrated these dimensions with this degree of operational specificity and ethical grounding.

B. Methods

The study adopts an interpretive-constructivist paradigm that shaped every stage of the review design and analysis. Ecological awareness is understood here as a construction of meaning formed through instructional communication, social interaction, and institutional habituation, not as a fixed cognitive state measured by a single score (Buchcic, 2021). This paradigmatic commitment determined the inclusion criteria, the quality appraisal framework, and the thematic synthesis approach. The constructivist lens explains why the proposed model centers on message framing, feedback as dialogue, and institutional habituation rather than information transfer: if awareness is constructed through interaction and context, then the mechanisms through which that construction happens are the appropriate objects of synthesis and the appropriate targets of intervention design.

The research design is a systematic literature review (SLR) with thematic synthesis, reported in accordance with PRISMA 2020 (Page et al., 2021). Searches were conducted across five databases: Scopus, Web of Science (WoS), ERIC, Google Scholar, and the Indonesian Garuda/SINTA portal, limited to publications from 2016 to 2026. Searches ran from February 20 to 25, 2026 (CET). Backward and forward citation tracking on anchor articles supplemented the database searches.

The sample comprises 20 peer-reviewed studies that met all inclusion criteria. Eligible articles were required to: (1)be published between 2016 and 2026, (2) be peer-reviewed journal articles or conference proceedings, (3) address AI use in formal or nonformal educational contexts with relevance to environmental education or pro-environmental outcomes, (4) report on learning communication mechanisms such as personalization, interaction, feedback, or adaptive recommendation and/or ecological awareness outcomes including knowledge, attitudes, intentions, or behavior; and, (5) be available in full text in Indonesian or English. Excluded were editorials, popular opinion pieces, non-scientific materials, articles mentioning AI only in passing, purely technical AI studies, duplicate publications, and inaccessible full texts.

Database searches retrieved 612 records in total. After de-duplication, 487 remained for title-and-abstract screening, 412 were excluded as irrelevant because AI was not a substantive learning component, there was no connection to environmental or sustainability education, or no ecological outcome indicators were present. The 75 remaining articles entered full-text assessment; 55 were subsequently excluded because the full text was unavailable, the article did not report on learning communication mechanisms, or ecological outcome data were absent. Twenty studies met all inclusion criteria and entered the thematic synthesis (Inuwa et al., 2025; Onny, 2025; Page et al., 2021; Putri & Safitri, 2025).

Two instruments were used. First, a structured search string combined terms from three conceptual domains using Boolean operators applied to titles, abstracts, and keywords: (“artificial intelligence” OR AI OR “machine learning” OR “intelligent tutoring system*” OR “learning analytics” OR chatbot OR “generative AI” OR “large language model*”) AND (“education” OR “teaching” OR “learning” OR “instructional communication” OR “educational communication” OR pedagogy) AND (“ecological awareness” OR “environmental awareness” OR ecology OR “environmental education” OR sustainability OR “education for sustainable development” OR ESD OR “pro-environmental”).

Second, study quality was appraised using design-appropriate instruments adapted from established rubrics. Quantitative studies were assessed on clarity of research design, instrument validity and reliability, adequacy of sampling, control of bias, and completeness of outcome reporting. Qualitative studies were assessed on methodological fit, credibility of data sources, transparency of the analytic process, and transferability of findings. Review studies were assessed on search strategy transparency, explicitness of inclusion and exclusion criteria, quality appraisal of included studies, and rigor of synthesis.

Selection proceeded in three sequential stages. In Stage 1, results across all five databases were merged and de-duplicated using reference management software, yielding 487 unique records from an initial 612 retrieved. In Stage 2, two independent reviewers screened all 487 titles and abstracts against the inclusion criteria, excluding 412 records as irrelevant. In Stage 3, the same reviewers conducted full-text eligibility assessments on the remaining 75 articles. Disagreements at both screening stages were resolved through structured discussion; unresolved cases were referred to a third reviewer. All full-text exclusions were recorded with reasons to maintain traceability.

Quality appraisal was conducted independently by the same two reviewers following the instruments described above. Disagreements were resolved through structured discussion, with a third reviewer consulted for any unresolved cases. Quality ratings informed the interpretive weight given to each study: findings from higher-quality studies grounded the model's core claims; findings from weaker studies supplemented context or flagged areas of thin evidence. The full selection flow is documented in the PRISMA 2020 diagram (Figure 1).

Analysis employed thematic synthesis across the 20 eligible studies. Two independent reviewers inductively coded each study to identify AI communication mechanisms and contextual conditions mediating ecological awareness outcomes. Codes were generated directly from study content without imposing a predetermined framework, allowing patterns to emerge from the data. Emerging codes were grouped into descriptive themes and subsequently into analytical themes representing how AI mediates the meaning-making process about ecological issues.

Quality ratings informed the interpretive weight accorded to each study throughout the synthesis: findings from higher-quality studies grounded the model's core claims; findings from methodologically weaker studies supplemented contextual understanding or flagged areas where evidence remains thin. The synthesis produced a six-layer theoretical model connecting message design, AI-enabled channels, feedback loops, action reinforcement, value habituation, and ethical governance into an integrated communication framework for ecological education.

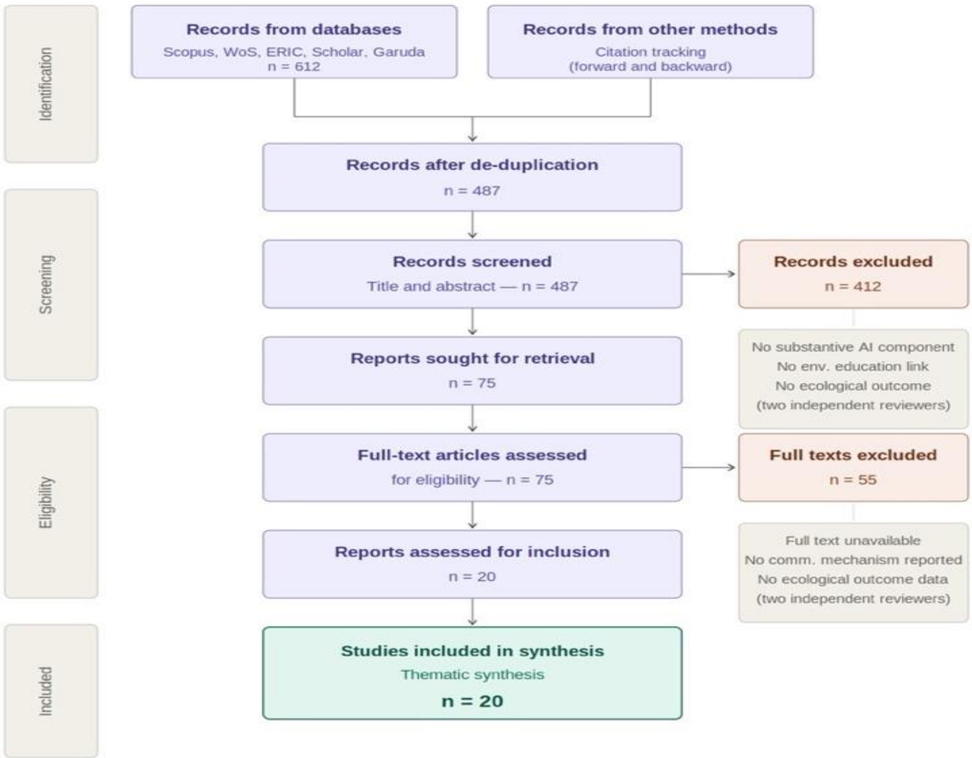

Figure 1. PRISMA 2020 flow diagram

C. Result and Discussion

The central finding of this synthesis is that AI produces meaningful effects on ecological awareness when it is positioned as communication infrastructure, not as a content delivery add-on. Across the reviewed studies, the systems that showed the strongest effects on knowledge, attitudes, and behavioral intention were those that mediated how ecological messages were composed, adapted to individual learners, and reinforced through repeated feedback cycles (Sari & Saputra, 2025; Wang et al., 2024). Systems that simply digitized existing content without adapting the communicative relationship between message and learner showed weaker effects.

That finding connects directly to the knowledge-action problem named in this article's title. Information-heavy environmental education reliably fails to change behavior not because students are indifferent but because ecological knowledge tends to feel abstract, distant, and unconnected to anything a student can actually do (Anjarsari et al., 2025). Changing that requires the learning experience to generate two things: a sense that the problem is locally real and personally relevant, and a sense that the learner has the capacity to respond. Both are communication problems before they are motivational problems, and both require sustained interaction rather than a single well-designed lesson (Azzahra et al., 2026; Shaheda et al., 2025).

Inuwa et al. (2025) identify personalization and adaptation as the mechanisms appearing most consistently in effective AI-driven learning systems. Applied to ecological education, those mechanisms allow AI to match environmental message framing to the learner's actual context, rather than broadcasting a generic message about global climate systems that may feel irrelevant to a student's daily decisions. That matching function is the first step in bridging knowledge and action: before a learner can plan an ecological behavior, the problem needs to feel proximate enough to warrant a response (Wang et al., 2024). Personalization, in other words, is not a feature added for engagement; it is a communication condition for relevance.

Huang's (2018) 16-week quasi-experiment with 186 university students provides the clearest empirical support for this argument in an explicitly ecological education context. Students using an AI teaching system showed significant gains in environmental knowledge and attitudes relative to the control group, and Huang (2018) describes the mechanism: the system selected instructional strategies based on each student's knowledge structure, adjusted the sequence and intensity of content accordingly, and delivered feedback through the system interface. AI functioned here as an instructional communication manager, not a passive content host, and the effects reflect that distinction. The same study also points to the limit: knowledge and attitude gains are not the same as behavioral change, and Huang (2018) does not claim otherwise.

That limit is where the local literature becomes indispensable. Sulaiman (2024) reports that AI can make learning more interactive and adaptive and that embedding ecological values consistent with religious education improves both comprehension and environmental concern. Putri & Safitri (2025) document what sustains behavioral change in primary school students once initial awareness exists: daily routines, teacher role modeling, a physically conditioned learning environment, school culture, project-based learning, outdoor activity, and institutional policy that expects ecological practice. None of those factors are supplied by an AI system. They are supplied by a school operating as a deliberate communication environment. This means AI strengthens the instructional communication layer of ecological education, but behavioral outcomes remain fragile without the institutional and cultural reinforcement that makes ecological action feel normal and expected (Azzahra et al., 2026).

The model proposed here organizes these findings into six connected layers. The first layer defines ecological awareness objectives that span knowledge, attitudes, behavioral intentions, and observable behavior, because a model that only targets knowledge will only produce knowledge gains. The second layer is contextual message design: ecological content must be framed around problems that feel locally real and locally actionable, because relevance is a precondition for reflection. The third layer is the AI channel, which performs personalization, delivers interactive experiences through simulation or dialogue, and facilitates iterative feedback. The fourth layer is the feedback and interaction mechanism, oriented toward reflection and action planning rather than corrective scoring. The fifth layer is action reinforcement and habituation, which ties digital learning to real school projects and routines. The sixth layer is ethical governance, covering privacy policy, bias auditing, equitable device and connectivity access, and teacher capacity building, because a system that excludes some students on economic or infrastructural grounds fails as a communication model regardless of its pedagogical design (Fauzi et al., 2025; Inuwa et al., 2025; Saputra et al., 2025).

Table 1. Model Components, Communication Mechanisms, and Operational Indicators

Model Layer	Communication Mechanism	Literature Basis	Operational Indicators
Ecological message design	Framing matched to learner context and local relevance	Personalization by learner needs, behavior, and prior knowledge is the dominant mechanism across AI-personalized learning SLRs (Inuwa et al., 2025).	Local cases selected adaptively; message relevance increases; identified misconceptions addressed iteratively.
AI-enabled interactive channels	Simulation and dialogic agents for active ecological reasoning	Mobile apps, simulations, website-based environments, and social media enrich experience and raise engagement (Onny, 2025).	Improved engagement and quality of cause-effect reasoning on reflection tasks.
Iterative feedback loop	Adaptive, reflective feedback oriented toward action planning	AI teaching systems in environmental education improve environmental knowledge and attitudes (Huang, 2018).	Feedback promotes reflection and micro-action planning; learning progress monitored across sessions.
Value integration and school culture	Norm reinforcement and habituated ecological practice	Integration of ecological values through curriculum and institutional support develops concern and action (Putri & Safitri, 2025; Sulaiman, 2024).	Digital tasks linked to real school projects; routines support sustained ecological practice.
Ethical governance and access equity	Trust, inclusion, and operational sustainability	Policy and governance challenges in AI implementation recur across SLRs (Inuwa et al., 2025; Saputra et al., 2025; Wiese et al., 2025).	Privacy and access SOPs; teacher training; content auditing; device and connectivity equity strategies.

1. Why Framing AI as Communication Infrastructure Matters

The distinction between AI as a content delivery platform and AI as communication infrastructure is not semantic. It carries practical consequences for how systems are designed, evaluated, and governed. A content delivery framing leads designers to ask whether the material is accurate, comprehensive, and accessible. A communication infrastructure framing leads them to ask whether the message is relevant to this learner in this context, whether the interaction supports active meaning-making, and whether the feedback loop is rich enough to sustain reflection over time. Those are different design questions, and they produce different systems. It is important to be explicit about how the proposed model differs from prior frameworks. Existing AI-in-education models, such as those reviewed by Inuwa et al. (2025) and Wang et al. (2024), focus primarily on personalization efficiency and adaptive sequencing. Environmental education frameworks, such as those reviewed by Onny (2025), describe technology-enhanced platforms but do not specify a communication architecture connecting message design to behavioral outcomes. Communication-centered education models (Mottet et al., 2006) specify the relational and feedback conditions for learning but were not developed with AI channels or ecological outcomes in mind. The present model is distinctive in three ways: (1) it explicitly bridges instructional communication theory and the KAB behavior change model within a single operational framework, (2) it incorporates ethical governance and access equity as structural, not optional, components, and (3) it integrates the school culture and value habituation insights from the Indonesian literature, which international models consistently omit. These distinctions make the model applicable to contexts where digital infrastructure is limited and where value alignment between home, school, and community is essential to behavioral change.

In the context of ecological education, the communication infrastructure framing addresses the knowledge-action gap more directly. Jafri et al. (2025), reviewing green education and sustainability training literature through a bibliometric and AI-assisted systematic review, find that the field remains fragmented and lacks a shared design vocabulary for connecting digital innovation, institutional policy, and behavioral outcomes. A communication model does not resolve that fragmentation, but it provides a shared design logic: ecological messages must be relevant before they can be persuasive, interactivity must support agency not just engagement, and feedback must point toward action not just correction (Wang et al., 2024).

This also clarifies what AI cannot do in ecological education. AI is not a moral agent. It does not teach values; it mediates how values already embedded in curriculum and teacher practice reach the learner. Sulaiman (2024) and Putri & Safitri (2025) both insist that value internalization requires a guided social space, and the model reflects that insistence: the teacher's role is defined as value guide and context curator, while AI handles personalization, interactivity, and feedback iteration (Balaji et al., 2025). Without clear curricular goals, personalization drifts toward content variation without direction. Without governance, data collection and automated feedback can generate distrust in communities with good reason to distrust institutional uses of learner data (García-López & Trujillo-Liñán, 2025).

2. What the Literature Does Not Yet Show

The most consistent limitation across the reviewed studies is heterogeneity in outcome measurement. Some studies measure knowledge; some measure attitudes; some measure behavioral intention; fewer track actual behavior over time. Huang (2018) provides strong evidence at the knowledge and attitude levels but is explicit that the study does not extend to sustained behavioral outcomes. That gap matters for a model organized around bridging knowledge and action. The action layer of the model therefore needs program-level behavioral indicators that go beyond reflective writing, for example, documented participation in waste reduction, observed sorting compliance, or verified involvement in school greening activities, calibrated so they do not become administrative burdens (Anjarsari et al., 2025).

A second limitation is inconsistent governance reporting. Many learning studies report on effectiveness metrics without documenting privacy policies, bias mitigation steps, or access equity strategies. This is not a peripheral issue. Onny (2025) identifies the access gap in technology-based ecological education explicitly, and Wiese et al. (2025) confirm that AI ethics considerations recur as a gap across the education literature. A model built on equitable communication cannot assume that all learners have equivalent access to devices, connectivity, or technically literate teachers. Design principles for low-resource contexts are not optional features; they determine whether the communication model reaches the students who most need effective ecological education.

A third limitation is the fragmentation between international and Indonesian literatures on this topic. International studies tend to report on AI system mechanics and cognitive outcome measurement. Indonesian studies tend to report on value integration, school culture, and habituation. Both bodies of literature are right about different aspects of the same problem. The proposed model tries to hold both together, but that synthesis rests on a relatively small number of local studies. More Indonesian empirical work that combines AI implementation with institutional culture analysis would substantially strengthen the model's basis.

3. Practical Implications

At the program planning stage, schools and universities need ecological awareness indicators that span behavior, not just knowledge. Sorting compliance rates, documented participation in environmental projects, and observed changes in consumption patterns within school premises are harder to measure than pre/post knowledge tests but are closer to what the model is actually trying to produce (Anjarsari et al., 2025). At the message design stage, ecological content should be framed around problems that are locally recognizable and locally actionable. A student in Jakarta's coastal districts should encounter messages about plastic in local waterways, not generic global statistics. AI enables that localization at scale; the curriculum needs to define the ecological priorities around which it localizes (Inuwa et al., 2025).

At the implementation stage, interactive simulations and dialogic AI agents should be used to make ecological cause-and-effect visible and manipulable, not just described. Experiencing the downstream consequences of an energy choice in a simulation is a different communicative act from reading about it (Onny, 2025; Saputra et al., 2025). At the feedback stage, AI should deliver prompts that move the learner toward planning a response, not just evaluating their answer. Guiding questions such as 'What could you change in your school this week based on what you just learned?' connect cognitive engagement to behavioral intention more directly than corrective scoring (Huang, 2018). At the reinforcement stage, digital learning should be tied to scheduled, visible ecological activities in the school: tree planting, waste audits, energy tracking, garden maintenance. Without that connection, the instructional communication stays digital and the behavioral change stays hypothetical (Putri & Safitri, 2025).

D. Conclusion

This study concludes that AI can help close the knowledge-action gap in ecological education when positioned as instructional communication infrastructure rather than content delivery technology. Grounded in instructional communication theory and the KAB behavior change model, the proposed six-layer cyclical AI-Enabled Communication Model reconceptualizes AI as a mediator in the chain from ecological message to ecological action. AI-enabled systems contribute most when they personalize message framing to learners' local contexts, provide interactive experiences that make ecological cause-and-effect tangible, and sustain iterative feedback supporting reflection. Lasting behavioral change, however, requires connecting those digital processes to school culture, teacher-guided value work, and real ecological projects. The model's principal contribution lies in unifying message design, AI-enabled channels, feedback loops, action reinforcement, value habituation, and ethical governance into a single operationally explicit framework, differentiating it from existing AI-in-education models that address personalization alone and from environmental education frameworks that specify platforms without a communication architecture for behavioral change.

Three limitations bound these conclusions: heterogeneous outcome measures make cross-study comparison difficult; governance and access equity reporting is inconsistent; and longitudinal evidence on sustained behavioral change remains scarce. For teachers, the model affirms that their role as value guides and context curators is irreplaceable. For administrators and policymakers, it calls for institutionalized ecological routines, AI procurement criteria requiring bias auditing, and offline functionality for low-connectivity schools. Future research should test each model layer through pre-registered design-based studies with behavioral outcome measures (waste sorting rates, project participation, energy use), validate a shared ecological awareness instrument spanning knowledge to behavior, and document equity effects in resource-limited schools. This study offers the field a theoretically grounded, ethically accountable communication model for AI-based ecological education, one that is specific enough to guide implementation, honest about AI's limits, and designed to be tested and improved across educational contexts.

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