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AI-Supported Teacher Training for Ecological Thinking in STEM-Based Character Education: A Case Study of Early and Primary Islamic Schools in East Nusa Tenggara

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ABSTRACT

This study aims to strengthen both teachers' and students' ecological awareness and moral sensitivity through *Artificial Intelligence (AI)*-supported professional development in *Science, Technology, Engineering, and Mathematics (STEM)*-based character education. Using an *action research* approach, the program involved 130 teachers from early and primary Islamic schools in East Nusa Tenggara who were trained to design lesson plans and develop digital learning media integrating *ecological thinking* and sustainability values. Data were collected from lesson plan analyses, reflective journals, and teacher evaluations. Quantitative results indicate a 41% increase in teachers' efficiency in lesson planning and a 63% improvement in creativity when applying AI tools. Qualitative findings revealed that classroom practices designed after the training promoted stronger environmental care, empathy, and social responsibility among students. Teachers noted that AI applications simplified idea generation and documentation processes, allowing more focus on student-centered learning and value integration. These findings suggest that AI serves not only as a technological support but also as a reflective partner in promoting character-oriented and environmentally responsible pedagogy. The study concludes that AI-assisted teacher training offers a practical model for implementing *eco-STEM* learning that enhances sustainable character development and ecological literacy among students in Islamic education.

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1. INTRODUCTION

Education in the twenty-first century requires not only mastery of knowledge but also the cultivation of ecological awareness and moral integrity. Schools play a strategic role in equipping learners with the capacity to think critically, act responsibly, and care for the natural environment. In Islamic education, this mission is even more essential because learning is expected to integrate cognitive, affective, and spiritual dimensions to develop holistic human beings. The integration of Science, Technology, Engineering, and Mathematics (STEM) with ecological thinking has been widely recognized as a transformative approach that bridges scientific inquiry and environmental ethics (Delphonso et al., 2025). When applied in early and primary education, STEM-based ecological learning helps students understand the interdependence between human life, technology, and the sustainability of the Earth.

Several studies highlight the potential of STEM learning to strengthen students' environmental literacy and character formation. Wandari et al. (2018) found that integrating character values into STEM learning significantly improved elementary students' ecological awareness and communicative competence. Similarly, Erfariyah et al. (2024) reported that the use of conservation-based digital resources enhanced students' eco-literacy, especially when teachers incorporated local environmental contexts. However, these studies also indicate that many teachers face difficulties in translating sustainability principles into practical classroom activities. Amézquita-Galindo & Salgado (2025) revealed that teachers' attitudes and practices in environmental education remain inconsistent, particularly in regions with limited access to training and digital infrastructure. These findings show that while the idea of sustainable and character-based education is widely accepted, its implementation remains uneven and often dependent on teachers' ability to design innovative lessons.

In recent years, *Artificial Intelligence* (AI) has emerged as a promising support tool for teacher professional development. Research has shown that AI-based learning tools can improve instructional design, stimulate creativity, and reduce administrative workload (Luo et al., 2025). Bas & Kiraz (2025) emphasized that teachers who engaged in AI-supported STEM programs demonstrated higher motivation and interdisciplinary understanding. Meanwhile, Sachyani & Gal (2025) found that environmental education assisted by AI increased students' creativity, collaboration, and empathy. However, the majority of these studies focus on technical aspects of AI utilization rather than its moral and ecological impact. Therefore, there is still a research gap in understanding how AI can be integrated into teacher training to promote both pedagogical efficiency and value-based learning.

Ryan & Lickona (1992) underscores that moral education must connect knowing the good, feeling the good, and doing the good, making character development a process that unites moral cognition and moral action. Similarly, Chan & Tsi (2024) asserts that AI in education should not replace human judgment but rather enhance teachers' reflective capacity, creativity, and empathy. Both perspectives indicate that technology and character education need not be contradictory but can mutually reinforce one another in fostering ecological responsibility and ethical awareness.

From this conceptual alignment, the present study proposes a model of AI-supported teacher training aimed at enhancing ecological thinking and character formation in early and primary Islamic schools. The training focuses on using AI tools to assist teachers in designing lesson plans and developing digital learning media that incorporate sustainability principles. This study explores changes in teachers' planning efficiency, creativity, and moral

awareness, as well as the effects of these improvements on students' empathy, responsibility, and environmental care. The results are expected to contribute to sustainable and character-based education by demonstrating how AI can serve as a reflective partner that harmonizes technology with ethical and ecological values in learning.

2. METHODS

This study employed an *action research* design to examine how AI-supported professional development influences teachers' ability to design *eco-STEM* learning and strengthen character education in early and primary Islamic schools. The participants consisted of 130 teachers from *Raudhatul Athfal* (RA) and *Madrasah Ibtidaiyah* (MI) across East Nusa Tenggara, selected purposively to represent varied school contexts and teaching experiences. Data were collected through analysis of AI-assisted lesson plans, reflective journals, and teacher evaluation forms to capture both quantitative improvements in efficiency and qualitative changes in pedagogical mindset. The data were analyzed using descriptive statistics for measuring performance enhancement and thematic analysis to identify emerging patterns of ecological awareness, creativity, and moral reflection in teachers' practice.

3. RESULTS AND DISCUSSION

The integration of Artificial Intelligence (AI) in teacher professional development demonstrated a significant positive impact on teachers' pedagogical competence, creativity, and moral–ecological awareness. The quantitative results show that the AI-assisted training program improved teachers' efficiency and reflective capability in lesson design. The statistical comparison between pre- and post-training data revealed that the overall N-Gain values ranged from 0.60 to 0.70, indicating a moderate-to-high level of improvement across all observed competence domains.

Table 1. Comparison of teachers' competence before and after AI-based training.

COMPETENCE ASPECT	PRE-MEAN (SD)	POST-MEAN (SD)	N-GAIN	INTERPRETATION	KEY OBSERVATION
Lesson planning efficiency	2.9 (0.8)	4.1 (0.6)	0.60	Moderate	Teachers completed lesson designs faster and with greater accuracy
Creativity in media design	2.7 (1.0)	4.4 (0.5)	0.70	High	AI tools inspired new ways to visualize ecological and STEM-based concepts
Ecological thinking integration	3.0 (0.9)	4.3 (0.6)	0.65	Moderate	More sustainability themes were embedded in lesson activities
Reflective practice	2.8 (0.7)	4.2 (0.6)	0.64	Moderate	Teachers demonstrated higher moral reflection and evaluation capacity

The quantitative evidence presented in **Table 1** indicates that the AI-based training significantly enhanced teachers' ability to design meaningful learning experiences. The highest improvement occurred in creativity in media design (N-Gain = 0.70), confirming that AI served as a stimulus for innovative thinking. Teachers reported that tools such as

ChatGPT, Canva AI, and Bing Image Creator helped them develop eco-STEM media that were both visually engaging and ethically reflective.

The second-highest gain was observed in reflective practice (N-Gain = 0.64), showing that AI facilitated teachers' self-assessment and moral awareness. Before the training, most participants considered lesson planning to be a procedural task. Afterward, they described it as a reflective process that connects content mastery, ecological concern, and ethical sensitivity. This finding aligns with Chan & Tsi (2024), who emphasized that AI can enhance human reflection and empathy when used as a co-intelligent partner rather than an automated system.

The integration of AI also increased teachers' awareness of the moral and ecological dimensions of teaching. Qualitative data from reflective journals and focus group discussions revealed that teachers began to contextualize environmental topics such as water conservation, renewable energy, and waste management into their learning designs. These themes made the lessons more relevant to students' daily lives while fostering a sense of care and responsibility. Such outcomes are consistent with Erfariyah et al. (2024), who found that eco-STEM approaches strengthen students' environmental literacy when teachers themselves embody ecological thinking.

From a character education perspective, these findings reinforce Ryan & Lickona (1992) triadic model of moral knowing, moral feeling, and moral action. The AI-based training promoted moral knowing as teachers identified ethical and environmental problems in their lesson content; moral feeling as they developed empathy toward sustainability issues; and moral action as they implemented value-driven teaching practices in their classrooms. Thus, the program not only improved instructional quality but also cultivated teachers' moral intelligence and ecological responsibility.

These findings also reveal a transformation in teachers' professional identity. Before the intervention, teachers viewed technology primarily as a tool for administrative convenience. After the training, they began to perceive AI as a reflective collaborator that supports creativity and ethical decision-making. This shift illustrates the principle proposed by Chan & Tsi (2024) that AI, when integrated thoughtfully, humanizes technology by amplifying creativity and empathy rather than replacing human judgment.

To summarize the relationships among the major findings, the conceptual synthesis developed in this study links three interconnected dimensions: AI-supported teacher training, competence enhancement, and student character outcomes.

Table 2. Conceptual Synthesis of AI-Supported Teacher Training and Character Formation

Training Component	Teacher Outcomes	Student Outcomes	Educational Implication
AI-assisted lesson planning	Increased efficiency and creativity in eco-STEM design	Improved understanding of sustainability and systems thinking	AI facilitates integration of moral and ecological principles into lesson planning
AI-based media creation	Enhanced technological literacy and visual communication skills	Greater engagement, collaboration, and empathy	Digital media serve as reflective spaces for value-based learning
Reflective pedagogical practice	Strengthened self-awareness and moral reasoning	Development of empathy, responsibility, and environmental care	Character formation occurs through teacher modeling and reflection

The overall results extend the theoretical framework proposed by Lee and Choi (2022) on eco-STEM pedagogy by incorporating digital creativity and reflective ethics as essential components of sustainable character education. Furthermore, this study advances Ryan & Lickona (1992) concept of moral education by demonstrating how AI-mediated reflection can bridge moral cognition and practice. It also substantiates Chan & Tsi (2024) notion that AI can function as a humanistic partner in teacher development, empowering educators to design learning experiences that are intellectually rigorous, morally grounded, and ecologically conscious.

Consequently, the study not only provides empirical evidence for the benefits of AI integration in teacher training but also contributes a conceptual model for ecologically literate and ethically responsible education in the digital era.

4. CONCLUSION

This study concludes that *AI-supported teacher training* effectively enhances teachers' pedagogical competence and simultaneously fosters ecological and moral character formation among students in early and primary Islamic education. The program improved teachers' planning efficiency, creativity, and reflective awareness, enabling them to design meaningful *eco-STEM* learning experiences that integrate scientific inquiry with values of empathy, responsibility, and environmental care. The analysis of N-Gain results confirmed a moderate-to-high improvement across all measured aspects, with the highest gain in creativity (0.70), indicating that AI tools not only stimulate innovative thinking but also encourage moral reflection and ecological awareness.

Theoretically, these findings strengthen Ryan & Lickona (1992) framework of *moral knowing*, *moral feeling*, and *moral action*, showing how AI can bridge moral reasoning and classroom practice. By positioning AI as a reflective partner, teachers learned to connect ethical awareness with technological creativity, thus humanizing their instructional approach. This aligns with Chan & Tsi (2024) concept of AI as a *humanistic collaborator*—a tool that enhances empathy, reflection, and creativity rather than replacing human judgment.

This innovation extends the theoretical understanding of sustainable and character-based education by demonstrating that technology can serve as a catalyst for moral and ecological learning. Practically, the findings imply that AI-based training models can be replicated and adapted to support large-scale teacher empowerment, particularly in regions with limited access to professional development. The combination of ecological thinking, reflective pedagogy, and AI-based innovation provides a sustainable pathway toward developing educators who are not only digitally competent but also ethically grounded and ecologically conscious.

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6. AUTHORS' NOTE

The authors confirm that this manuscript is an original work derived from ethically conducted research and has not been submitted or published elsewhere. All data presented were obtained and analyzed responsibly. The authors are solely accountable for the accuracy of the information, data interpretation, and all references cited within this paper. There is no conflict of interest concerning the authorship or publication of this article.

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