Transformation of Environmental Education in Pesantren: Integration of Islamic Values and STEAM Approach

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Abstract

This study investigates the influence of pesantren, Indonesia's oldest Islamic educational institution, on practicing environmental education based on Islamic values. This study adopts the method of library research, in which it uses secondary data from scientific books, journal articles, research reports, official documents, and Islamic texts. Three main aspects of the analysis include the theological basis of environmental responsibility in the Qur'an, the global and local context of environmental education, and pesantren education in terms of structure and culture. Khalifah, Mizan, and Hifdz al-bah are considered sustainable, ethical frameworks. The findings revealed that pesantren encountered major challenges in combining modern environmental education but possess special strengths like solid moral principles, local values, and close relationships between teachers and students. These include the constraints of the curriculum, the lack of resources, and teachers not being trained for this type of interdisciplinary and STEAM (Science, Technology, Engineering, Arts, Mathematics) methodologies. Notwithstanding these barriers, pesantren can adapt traditional religious teaching to meet contemporary sustainability demands through curriculum reform, community-based initiatives, and partnerships with external funders. The model developed in this study shows that pesantren can be a transformative institution to promote sustainability with a potent amalgamation of Islamic ethical values and modern forms of education. This may lead to a transformative education approach for sustainability from pesantren. The new model underscores systematic curriculum development, teacher capacity-building, and external partners that can help support resource provision. As moral and educational forces in society, pesantren are expected to play important roles in local and global sustainability,

shouting to the Sustainable Development Goals (SDGs), especially in quality education and climate action.
Keywords: Pesantren; Environmental education; Islamic values; STEAM education

Introduction

Education has an important role in building young people's awareness of various global challenges, including environmental issues that are increasingly fundamental. In the view of [1] Issues such as climate change, pollution, environmental degradation, and biodiversity loss have become major problems that require attention from various sectors, including educational institutions. more [2] Emphasizes that the function of education is not only the knowledge aspect but also to instill awareness and skills in facing ecological challenges by instilling sustainability values as the core of learning.

With its extraordinary biodiversity, Indonesia is responsible for sustainably maintaining and utilizing its natural resources. However, pressures caused by deforestation, environmental degradation, and the impacts of climate change are worsening the situation.[3]Environmental education is important in building ecological awareness in this context, especially through a holistic, contextualized, and local culture-based approach. [4]. Integrating science, technology, arts, and cultural values is key to producing solutions relevant to local needs. [5].

Pesantren, one of Indonesia's oldest Islamic educational institutions, has significant potential in supporting environmental education. Apart from being a center of religious education, Pesantren also plays an important role in shaping the character of the younger generation based on moral and spiritual values.[6] In recent decades, pesantren have started to adopt the general education curriculum. However, the lack of integration between religious values and modern scientific approaches remains a major challenge, especially in dealing with complex environmental issues. [7]

[1] Marco Rieckmann, "Education for Sustainable Development Goals (SDGs)," in *European Conference on Educational Research 2017*, 2017.
[2] Stephen Sterling, "Transformative Learning and Sustainability: Sketching the Conceptual Ground," *Learning and Teaching in Higher Education* 5, no. 11 (2011): 17–33.
[3] (Purnomo, et al, 2020)
[4] Daniella Tilbury, "Environmental Education for Sustainability: A Force for Change in Higher Education," in *Higher Education and the Challenge of Sustainability: Problematics, Promise, and Practice* (Springer, 2004), 97–112.
[5] (Rubini, et al, 2016)
[6] Sandi Kurniawan, "Integrasi Islam Dan Sains Dalam Pendidikan Pesantren Mahasiswa: Studi Multikasus Di Pesantren Mahasiswa Universitas Islam Indonesia Yogyakarta Dan Ma'had Al-Jami'ah Universitas Islam Negeri Maulana Malik Ibrahim Malang" (Universitas Islam Negeri Maulana Malik Ibrahim, 2024).
[7] Masturin, "Religious Education in Agricultural Environments: Integrating Islamic Teachings and Agricultural Practices for Holistic Student Development," *Religious Education*, 2023, 1–18.

The STEAM (Science, Technology, Engineering, Arts, Mathematics) approach has been globally recognized as an innovative educational paradigm that can equip learners with 21st-century skills, such as critical thinking, creativity, and problem-solving [8]. In the context of pesantren, this approach has great potential to connect Islamic values with scientific and technical competencies, resulting in a generation of students who can understand and overcome environmental challenges creatively and integrated [9]. Through the STEAM approach, learners are not only trained to master science and technology but also invited to internalize spiritual values that are relevant in responding to global challenges. [10].

However, implementing the STEAM approach in Pesantren faces various obstacles. The main obstacles are the Pesantren curriculum, which is still dominated by traditional religious education, limited resources, and a lack of teacher training. [11]. In addition, the lack of focus on environmental issues in the pesantren curriculum results in santri not having an adequate understanding of sustainability. [12]Therefore, a STEAM-based ecological education model that integrates Islamic values with a scientific approach is needed, making it relevant to local needs and global challenges.

This research provides a contextual STEAM-based ecological education model, which is situational and based on the social and cultural karakteristics of pesantren. This model, in its implementation, is expected to be able to integrate Islamic spiritual dimensions with scientific dimensions in the learning process and produces a generation of santri with ecological awareness and balanced intellectual intelligence. Santri who previously only had theoretical skills are expected to master practical technical abilities and spiritual values so they can help solve broader and more diverse environmental issues that have rapid developments and global impacts.

[8] Kurt Henry Becker and Kyungsuk Park, "Integrative Approaches among Science, Technology, Engineering, and Mathematics (STEM) Subjects on Students' Learning: A Meta-Analysis," *Journal of STEM Education: Innovations and Research*, 2011.
[9] Rose Amnah Abd Rauf and Hutkemri Zulnaidi, "Development and Validation of the Quran–Science, Technology, Engineering, Art, And Mathematics (Q-STEAM) Module," *STEM Education* 4, no. 4 (2024): 346–63.
[10] Cassie F Quigley and Dani Herro, "'Finding the Joy in the Unknown': Implementation of STEAM Teaching Practices in Middle School Science and Math Classrooms," *Journal of Science Education and Technology* 25 (2016): 410–26.
[11] Azam Syukur Rahmatullah, "Kyai's Psychological Resilience in the Perspective of Pesantren: Lesson from Indonesia," *Jurnal Pendidikan Islam* 10, no. 2 (2021): 235–54.
[12] (Sutrisno, et al, 2023)

This study also intends to contribute to the literature regarding the STEAM approach, particularly the impetus for implementing the STEAM approach in faith-based traditional education like pesantren. Although STEAM has been widely applied to various fields of education, the application of STEAM integrated with Islamic-based education in pesantren is rare. Thus, this study provides a valuable contribution in bridging that gap. Based on the practical recommendations given, this study is expected to contribute to the improvement of pesantren curriculum so that it can adopt sustainability education, which has not been addressed in the future.

This research's uniqueness includes the novelty offered, a combination of Islamic spiritual values and STEAM approach to overcome a complex and series of environmental problems. Relevance of this model's application is not just for pesantren in Indonesia, but also it can be used as a good reference for other religious education institutions in the world which have similar challenges to give birth to a generation that is more sensitive to environmental issues. This educational model can not only have a positive impact on pesantren education in Indonesia but also has the potential to make contributions towards the development of Islamic value-based education that responds to global challenges in the 21st century.

Research Methodology

This study uses a library research approach to explore the role of pesantren in environmental education based on Islamic values [13]. This methodology explores and analyses secondary data from various scientific sources, such as books, journal articles, research reports, official documents, and Islamic texts. Library research was chosen because of its relevance in examining the theories, concepts, and frameworks of Islamic values related to environmental education and supporting the development of contextualized education models in pesantren.

Data sources in this study include literature that discusses three main domains: (1) Islamic teachings on ecological responsibility, such as the concepts of Khalifah, Mizan, and hifdz al-bah; (2) environmental education studies in the global and local contexts, including sustainability approaches in the education curriculum; and (3) the dynamics of pesantren education, including curriculum structure, traditional values, and the challenges

[13] Barbara M Wildemuth, *Applications of Social Research Methods to Questions in Information and Library Science* (Bloomsbury Publishing USA, 2016).

and potential of modern education integration such as STEAM (Science, Technology, Engineering, Arts, and Mathematics). The literature used was obtained from online databases such as Google Scholar, JSTOR, and ScienceDirect, as well as relevant Islamic classical references.

The data were analyzed using content analysis. A critical review of each literature source was conducted to identify patterns, relationships, and differences in the perspectives raised [14]. In-depth analyses based on key themes, such as Islamic values in environmental education, the practical challenges of an environment-based curriculum in pesantren, and the possibility of STEAM integration, were applied to deliver a comprehensive theoretical synthesis. Triangulation was conducted by comparing findings from various literature sources to ensure data validity and enrich the research results. This methodology not only aims to understand the contribution of Islamic values to environmental education but also provides theory-based recommendations for optimizing the role of pesantren in supporting sustainability.

The Role of Islamic Boarding Schools in Environmental Education

Pesantren, the oldest Islamic educational institution in Indonesia, has a unique and strategic position in shaping the character of the younger generation based on moral and spiritual values. With an academic approach based on Islamic values, pesantren function as centers of religious teaching and ethical and moral shaping institutions that can be an important foundation in environmental education [15]. Islamic teachings emphasize the importance of maintaining the balance of nature and utilizing resources wisely to provide a strong theological basis to support environmental sustainability [16]. Values such as responsibility as a caliph on earth, the importance of preventing damage (*fasad*), and efforts to maintain ecosystem balance (*Mizan*) provide an ethical foundation for Islam-based environmental education.

The challenges faced by pesantren in supporting environmental education are quite complex. The current pesantren curriculum is still dominated by traditional religious

[14] Wildemuth.
[15] Ficky Adi Kurniawan, "Implementasi Kegiatan Supervisi Untuk Meningkatkan Profesionalitas Guru BK Di Sekolah," *Jurnal Guru Panrita* 1, no. 1 (2024).
[16] Abdul Rahim Karim and Hendi Sugianto, "MEASURING THE FUTURE NEEDS OF ISLAMI EDUCATION THROUGH THE ROLE OF ARTIFICIAL INTELLIGENCE," in *PROCEEDING OF INTERNATIONAL CONFERENCE ON EDUCATION, SOCIETY AND HUMANITY*, vol. 1, 2023, 861–70.

education emphasizing normative and theological aspects. At the same time, contemporary issues, such as climate change, environmental degradation, and sustainability, have not been fully integrated into the learning process [17]. This dependence on conventional perspectives leads to the santri's lack of knowledge about global environmental problems applicable to their everyday activities. Moreover, the integration of environmental education into the pesantren system is also hampered by the low level of teacher training in science and the environment and the lack of supporting resources such as laboratories and relevant teaching materials [18].

On the other hand, pesantren have advantages that can be utilized to overcome these challenges. The pesantren tradition that prioritizes local values, independence, and discipline provides a strong basis for integrating environmental education. In addition, pesantren can deliver sustainability messages effectively due to the close relationship between teachers (kiai) and santri, which allows the delivery of sustainability values through personal and communal approaches. In this context, Islamic teachings can be contextualized to address environmental challenges, for example, by teaching hide al-bah (environmental preservation) as part of the broader maqashid sharia (sharia objectives).

Integrating environmental education into pesantren can be done through a systematic curriculum approach based on Islamic values. For example, teaching about the importance of preserving natural resources can be linked to Qur'anic and hadith arguments, such as the command not to overuse water (Q.S. (Al-A'raf: 31) and the prohibition of damaging the earth (Q.S. Al-Baqarah: 205). In addition, pesantren can utilize local potential to implement environmental education, such as community-based waste management programs, tree planting, or the application of environmentally friendly technology in the environment. This kind of initiative increases the ecological awareness of santri and provides practical skills relevant to sustainability needs.

Analytically, the pesantren potential of environmental education is located at the intersection between spiritual value and the problem to be solved. This dual prominence of moral and technical dimensions should create integration between the two, thereby making pesantren a model of the educational innovation framed by these two dimensions.

[17] Masturin, "Religious Education in Agricultural Environments: Integrating Islamic Teachings and Agricultural Practices for Holistic Student Development."
[18] Humiras Betty Marlina Sihombing, Edy Dharma, and Desmalia Purba, "Training and Working Environment on Science Teachers Performance," *Jurnal Penelitian Pendidikan IPA* 9, no. 8 (2023): 6458–64.

This is why strategic efforts are needed to formulate an environmental education model that is contextual and relevant to pesantren. This can range from curricular revision and training teachers in science and technology to partnering with external institutions to ensure sufficient resources.

If pesantren can optimize their role, they can maximize the students' capacity to respond to environmental challenges and contribute significantly to sustainable development at the local and global levels. Environmental education based on Pesantren is expected to be an example of integrating Islamic values with appropriate approaches related to sustainability and contributing to achieving the Sustainable Development Goals (SDGs) in quality education and climate action. Therefore, pesantren are not only buildings for spiritual development but are also the locus for generating changes of awareness and responsibility towards environmental sustainability.

STEAM-based Ecology Learning Plan

In Pesantren, STEAM-based ecology learning is intended to teach contextualized learning experiences based on local wisdom and integrate them with an interdisciplinary approach. Santri is guided to understand the basic principles of ecology, create STEAM-based ecological education concepts, and assess and produce solutions to address typical rural environmental problems in an integrated manner. STEAM is an educational method that integrates Science, Technology, Engineering, Arts, and maths.

The program uses a highly visualization-centered learning style. Students use various media, including pictures, diagrams, videos, and infographics, to visualize ecological concepts and develop analytical and visual skills.

1. Ecology, Human as Caliph

   At this early stage, learners are introduced to the principles of ecology and the concept of human responsibility as a caliph. This material is rooted in Islamic principles, specifically Khalifah (guardian of the earth) and Mizan (balance), and relates to environmental protection. Students watch a short video on local ecosystems and global issues, including climate change and deforestation. Then, the students were asked to discuss the values related to environmental conservation in Islam and draw a diagram of the Khalifah concept (the role of humans as Khalifah). The activity ends with creating a group visual concept map representing their ecological responsibilities.

2. Introduction to STEAM in the Ecological Context of Pesantren

   The next stage introduces STEAM elements to the students through interactive visualization. The teacher explains how each STEAM element contributes to understanding and managing the ecosystem. For example, students can observe the water cycle and photosynthesis as part of science, understand sensor-based irrigation technology, and explore efficient compost design. Art and maths are integrated through aesthetically pleasing landscape design and calculating water needs in the pesantren courtyard. In group discussions, the students create interactive diagrams that connect STEAM elements to environmental challenges in the pesantren, such as waste management or irrigation.

3. Science and Technology Exploration for Pesantren Ecology

   In the third stage, students use technology and science to understand environmental issues deeply. This activity begins with visual observations through short documentary films about ecosystem processes, such as carbon and water cycles in the pesantren environment. They are also introduced to simple technologies that can help address environmental issues, such as rainfall gauges or rainwater harvesting systems. Santri is then asked to create visual diagrams depicting simple technologies to reduce water waste or improve the environmental quality of the pesantren.

4. Ecological Solutions at the Intersection of Engineering and Art

   The students learn to create ecological solutions that combine engineering and art at this stage. They learn about eco-friendly techniques such as green architecture and compost systems and how art can complement and strengthen these solutions. One example is inviting students to plan a productive and beautiful organic garden. This activity lets them understand how artistic and technical values can work together to produce ecologically sustainable solutions.

5. Evaluation and Development of STEAM Model in Pesantren Ecology

   In the final step, the students assess and showcase their STEAM-based projects. They work in groups to sketch a poster depicting what their proposed ecological solution would look like, such as a new irrigation design or an aesthetically pleasing organic garden. This allows the students to demonstrate their analytical and collaborative skills at the same time. Teachers and students together assess the

models that are considered effective and relevant in maintaining the pesantren ecosystem from the various models that have been proposed.

6. Final Evaluation

Third, the assessment is conducted through a visual project exhibition at the pesantren or an open presentation using pictures, diagrams, and multimedia presentations. The evaluation is based on understanding STEAM integration in the pesantren ecology, the ability to design practical solutions, and creativity in integrating Islamic values and modern approaches.

STEAM Integration in Pesantren-Based Ecology Learning

Pesantren-based ecological education has the strategic potential to build environmental awareness based on religious values and scientific principles. Pesantren can combine theological and scientific approaches to solving local ecological problems as an Islamic value-based educational institution. The STEAM-based (Science, Technology, Engineering, Arts, and Maths) Pesantren Ecology Learning Plan is designed to integrate Islamic values, ecological principles, and interdisciplinary skills required in a modern context.

The STEAM approach has been widely recognized as an effective educational method for improving critical thinking, creativity, and problem-solving skills [19]. In pesantren, this approach can be reinforced with Islamic values such as Khalifah (guardian of the earth) and Mizan (balance), which emphasize the importance of maintaining ecosystem balance as part of spiritual responsibility [20].

The above lesson plan was developed to provide project-based and visual learning experiences to santri, aiming to understand ecological principles and formulate and evaluate innovative solutions to ecological challenges in pesantren.

1. STEAM Approach in the Context of Pesantren Education

For instance, the STEAM approach can provide a sound platform for improving learners' environmental literacy and critical.[21] This methodology is significant in the pesantren field, as it allows for the fusion between scientific

[19] Todd R Kelley and J Geoff Knowles, "A Conceptual Framework for Integrated STEM Education," *International Journal of STEM Education* 3 (2016): 1–11.
[20] Seyyed Hossein Nasr, "Man and Nature: The Spiritual Crisis of Modern Man," 1968.
[21] Gillian H Roehrig et al., "Beyond the Basics: A Detailed Conceptual Framework of Integrated STEM," *Disciplinary and Interdisciplinary Science Education Research* 3 (2021): 1–18.

disputes presented on paper after science and practice in the community in assisting local ecological issues.

For example, the activities in section 2 of the lesson plan introduce STEAM elements through direct observation of the local ecosystem in the pesantren. The discussion on using environmentally friendly technologies, such as sensor-based irrigation systems, aligns with Roehrig research, which shows that introducing technology in education can improve learners' analytical skills.[22]

In addition, art in STEAM provides a relevant aesthetic dimension to build a functional and beautiful ecosystem. For example, in part 4, students are invited to design an organic garden by considering aesthetics and ecological functions. The study of Quigley supports the idea that integrating art into learning enhances learners' creativity in formulating innovative solutions.[23]

2. Islamic Values as the Basis of Ecological Education

Islamic values are an important foundation in ecological education in pesantren. The concept of Khalifah asserts that humans have a moral responsibility to maintain the balance of the ecosystem, as explained in the Qur'an (QS. Al-Baqarah: 30). This principle is translated in the learning plan in Week 1, where students are invited to understand ecology through an Islamic perspective.[24] Discussion of Islamic values, such as Khalifah and Mizan, provides a spiritual basis and strengthens students' motivation to contribute to environmental conservation.[25]

Using visual media, such as life cycle diagrams and infographics on ecological responsibility, strengthens santri's understanding of this principle. Mayer's research shows that visualization effectively facilitates understanding complex concepts such as ecology, especially for learners with visual learning styles.[26]

3. Effectiveness of Visual Learning Styles in STEAM Education

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[22] Roehrig et al.
[23] Cassie F Quigley et al., "Connected Learning in STEAM Classrooms: Opportunities for Engaging Youth in Science and Math Classrooms," *International Journal of Science and Mathematics Education* 18 (2020): 1441–63.
[24] Maslani et al., "Ecopedagogy in Action: An Ethnographic Exploration of Environmental Preservation Strategies in Pesantren," *Jurnal Pendidikan Islam* 9, no. 2 (2023): 211–22, https://doi.org/10.15575/jpi.v9i2.29347.
[25] Quigley et al., "Connected Learning in STEAM Classrooms: Opportunities for Engaging Youth in Science and Math Classrooms."
[26] Richard E Mayer, "Incorporating Motivation into Multimedia Learning," *Learning and Instruction* 29 (2014): 171–73.

This lesson plan prioritizes visual learning styles through infographics, diagrams, videos, and concept maps. In section 3, for example, students are invited to observe the water and carbon cycle through visual documentation. Mayer's research confirms that multimedia learning rich in visualization can improve learners' memory and understanding of the material taught.[27]

In addition, visual tasks such as drawing diagrams of composting systems or eco-friendly landscape designs provide project-based learning experiences that involve cognitive skills and creativity. This method aligns with the project-based learning approach and effectively improves problem-solving skills.[28]

4. Evaluation and Implication of STEAM Model in Pesantren Ecology

Evaluation is an integral part of this lesson plan. In sections 5 and 6, students are asked to present their visual projects and evaluate the effectiveness of the proposed solutions. The project-based evaluation process allows students to measure the practical impact of their design solutions, such as irrigation systems or organic gardens.

Research by Syahmani demonstrated that a project-based evaluation method during STEAM learning enhanced the learners' conceptual understanding and critical thinking ability. This evaluation in the context of pesantren can be used to formulate an ecological action plan appropriate to local needs.[29]

STEAM-Based Pesantren Ecology Learning Plan is an actualization of an educational innovation that integrates Islamic values, ecological values, and interdisciplinary disciplines to teach about environmental awareness and 21st-century skills. Thanks to this method, Santri no longer only learns about ecological concepts but can also create real-life embodiments to cope with ecological problems in their surroundings. Recent studies confirm that STEAM integration positively affects the development of learners in environmental literacy, critical thinking, and creativity.

This lesson plan implementation effort in Pesantren will be able to be a role model for other educational institutions in curriculum development related to future world

[27] Mayer.
[28] Mayer.
[29] Syahmani Syahmani et al., "STEAM Approach to Improve Environmental Education Innovation and Literacy in Waste Management: Bibliometric Research," *Indonesian Journal on Learning and Advanced Education (IJOLAE)* 3, no. 2 (2021): 130–41.

challenges, especially ecology. Further studies are required to assess the long-term effects of this model on students' environmental behavior and consciousness.

How the STEAM Approach in Pesantren Education is a Challenge

There are various structural, cultural, and technical challenges in implementing the STEAM (Science, Technology, Engineering, Arts, and Maths) approach in pesantren. One of the critical issues in this study is that the pesantren curriculum is still very much orientated towards traditional Islamic education, such as mastery of the yellow Islamic classic books (kitab kuning) and normative values. While necessary for building a strong spiritual base, this curriculum marginalizes science- and technology-based education, an essential building block of STEAM. In addition, environmental issues such as sustainability are ignored mainly in formal pesantren education, so students are not adequately informed about ecological issues. This shows the void that exists in their curriculum. When discussing its progressive revision era, the new revision is a future call based on gutless sustainability, the essence of Islam.

Another major obstacle is the lack of resources, especially in rural pesantren. The lack of access to essential facilities such as laboratories, teaching tools, and digital technology makes implementing project-based learning and scientific experiments challenging. Furthermore, pesantren teachers have extensive religious knowledge but have received little to no training in modern pedagogy such as STEAM. This gap limits them from enabling interdisciplinary learning, which requires technological expertise and collaborative pedagogy. There should be programs for continuous professional development for teachers to increase their potential in integrating STEAM principles into the education system.

In addition, cultural barriers and lack of external relations complicate the process. Pesantren are often conservative, which is why they are bound to old traditions and established teaching methodologies, meaning that they consider modern approaches such as STEAM as foreign elements or incompatible with their values. Collaborating with governments, universities, and NGOs can promote STEAM by providing the needed resources, training, and funding. Pesantren can integrate STEAM programs simply by conducting interesting projects relevant to the surrounding community, which can be done gradually and according to each pesantren. This can ultimately align Islamic

education with global sustainability goals and build a more holistic and future-ready education system.

Conclusion

Islamic boarding schools have a strategic role in Islamic values-based environmental education, which integrates spiritual, moral, and ecological dimensions. As the oldest educational institution in Indonesia, pesantren not only educates the younger generation in the mastery of religious values but also has the potential to become a center for the formation of sustainability awareness. Islamic teachings such as *Khalifah* (stewardship), *Mizan* (balance), and *Hifdz al-bah* (environmental preservation) provide a strong theological basis to support the integration of environmental education. However, challenges in curricula that are less adaptive to sustainability issues, limited resources and infrastructure, and lack of teacher training are significant obstacles to optimizing this role.

Overcoming these barriers requires a strategy that involves revising the curriculum based on Islamic values and sustainability, strengthening teacher training with interdisciplinary approaches such as STEAM (Science, Technology, Engineering, Arts, and Maths), and collaborating with external agencies to support resources. With this holistic approach, pesantren can become relevant agents of change in supporting the Sustainable Development Goals (SDGs), particularly in quality education and climate action. Pesantren-based environmental education can also be an integrative model that addresses local needs and global challenges.

Future research is recommended to explore the effectiveness of pesantren-based environmental education models through quantitative and qualitative approaches, which measure the impact of integrating Islamic teachings and STEAM approaches on the ecological awareness of santri. In addition, action studies can focus on developing teacher training based on the local context of pesantren to improve their pedagogical capacity in integrating sustainability into learning. Longitudinal research is also needed to analyze the long-term changes resulting from environmental education in pesantren, both at the individual and institutional levels. Finally, interdisciplinary collaboration with environmental scientists, educators, and theologians is important to design innovative models that integrate green technologies with Islamic values, thus creating practical and relevant solutions to global sustainability challenges.

Bibliography

Abd Rauf, Rose Amnah, and Hutkemri Zulnaidi. "Development and Validation of the Quran–Science, Technology, Engineering, Art, And Mathematics (Q-STEAM) Module." *STEM Education* 4, no. 4 (2024): 346–63.

Becker, Kurt Henry, and Kyungsuk Park. "Integrative Approaches among Science, Technology, Engineering, and Mathematics (STEM) Subjects on Students' Learning: A Meta-Analysis." *Journal of STEM Education: Innovations and Research*, 2011.

Karim, Abdul Rahim, and Hendi Sugianto. "MEASURING THE FUTURE NEEDS OF ISLAMI EDUCATION THROUGH THE ROLE OF ARTIFICIAL INTELLIGENCE." In *PROCEEDING OF INTERNATIONAL CONFERENCE ON EDUCATION, SOCIETY AND HUMANITY*, 1:861–70, 2023.

Kelley, Todd R, and J Geoff Knowles. "A Conceptual Framework for Integrated STEM Education." *International Journal of STEM Education* 3 (2016): 1–11.

Kurniawan, Ficky Adi. "Implementasi Kegiatan Supervisi Untuk Meningkatkan Profesionalitas Guru BK Di Sekolah." *Jurnal Guru Panrita* 1, no. 1 (2024).

Kurniawan, Sandi. "Integrasi Islam Dan Sains Dalam Pendidikan Pesantren Mahasiswa: Studi Multikasus Di Pesantren Mahasiswa Universitas Islam Indonesia Yogyakarta Dan Ma'had Al-Jami'ah Universitas Islam Negeri Maulana Malik Ibrahim Malang." Universitas Islam Negeri Maulana Malik Ibrahim, 2024.

Maslani, Abdul Qadir, Asep Muhyidin, and Wahyu Hidayat. "Ecopedagogy in Action: An Ethnographic Exploration of Environmental Preservation Strategies in Pesantren." *Jurnal Pendidikan Islam* 9, no. 2 (2023): 211–22. https://doi.org/10.15575/jpi.v9i2.29347.

Masturin. "Religious Education in Agricultural Environments: Integrating Islamic Teachings and Agricultural Practices for Holistic Student Development." *Religious Education*, 2023, 1–18.

Mayer, Richard E. "Incorporating Motivation into Multimedia Learning." *Learning and Instruction* 29 (2014): 171–73.

Mudaningrat, Ajeng, Aditya Marianti, and Arif Widiyatmoko. "Development of STEAM-Based Belawa Tortoise Conservation E-Supplement to Improve Higher Order Thinking Skills in High School Ecosystem Material." *Unnes Science Education Journal* 13, no. 1 (2024).

Nasr, Seyyed Hossein. "Man and Nature: The Spiritual Crisis of Modern Man," 1968.

Purnomo, Eko Priyo, Rijal Ramdani, Lubna Salsabila, and Jin-Wook Choi. "Challenges of Community-Based Forest Management with Local Institutional Differences between South Korea and Indonesia." *Development in Practice* 30, no. 8 (2020): 1082–93.

Quigley, Cassie F, and Dani Herro. "'Finding the Joy in the Unknown': Implementation of STEAM Teaching Practices in Middle School Science and Math Classrooms."

Journal of Science Education and Technology 25 (2016): 410–26.

Quigley, Cassie F, Dani Herro, Calli Shekell, Heidi Cian, and Lori Jacques. "Connected Learning in STEAM Classrooms: Opportunities for Engaging Youth in Science and Math Classrooms." *International Journal of Science and Mathematics Education* 18 (2020): 1441–63.

Rahmatullah, Azam Syukur. "Kyai's Psychological Resilience in the Perspective of Pesantren: Lesson from Indonesia." *Jurnal Pendidikan Islam* 10, no. 2 (2021): 235–54.

Rieckmann, Marco. "Education for Sustainable Development Goals (SDGs)." In *European Conference on Educational Research 2017*, 2017.

Roehrig, Gillian H, Emily A Dare, Joshua A Ellis, and Elizabeth Ring-Whalen. "Beyond the Basics: A Detailed Conceptual Framework of Integrated STEM." *Disciplinary and Interdisciplinary Science Education Research* 3 (2021): 1–18.

Rubini, B, D Ardianto, I D Pursitasari, and I Permana. "Identify Scientific Literacy from The Science Teachers'perspective." *Jurnal Pendidikan IPA Indonesia* 5, no. 2 (2016): 299–303.

Sihombing, Humiras Betty Marlina, Edy Dharma, and Desmalia Purba. "Training and Working Environment on Science Teachers Performance." *Jurnal Penelitian Pendidikan IPA* 9, no. 8 (2023): 6458–64.

Sterling, Stephen. "Transformative Learning and Sustainability: Sketching the Conceptual Ground." *Learning and Teaching in Higher Education* 5, no. 11 (2011): 17–33.

Sutrisno, Sutrisno, Isrohmawati Isrohmawati, Emi Bahrul Munif, Jemmy Jemmy, and Abdul Wahab. "Instilling Character Education Through Habituation at School with the Help of Parents." *Journal Emerging Technologies in Education* 1, no. 6 (2023): 386–97.

Syahmani, Syahmani, Ellyna Hafizah, Sauqina Sauqina, Mazlini Bin Adnan, and Mohd Hairy Ibrahim. "STEAM Approach to Improve Environmental Education Innovation and Literacy in Waste Management: Bibliometric Research." *Indonesian Journal on Learning and Advanced Education (IJOLAE)* 3, no. 2 (2021): 130–41.

Tilbury, Daniella. "Environmental Education for Sustainability: A Force for Change in Higher Education." In *Higher Education and the Challenge of Sustainability: Problematics, Promise, and Practice*, 97–112. Springer, 2004.

UNDP, SCBD. "UNEP-WCMC (2021)." *Creating a Nature-Positive Future: The Contribution of Protected Areas and Other Effective Area-Based Conservation Measures. New York: UNDP*, 2021.

Wildemuth, Barbara M. *Applications of Social Research Methods to Questions in Information and Library Science*. Bloomsbury Publishing USA, 2016.