



Student Participation in Conducting Environmental Impact Analysis Using Artificial Intelligence: A Conceptual Review

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Abstract

The development of artificial intelligence (AI) technology has brought about major changes in the fields of education and architectural practice. This article aims to conceptually examine student participation in conducting environmental impact assessments (EIA) through the use of AI technology in the Architecture Study Program at Manado State University. A literature review was conducted on various recent studies and publications discussing the integration of AI in architectural education, environmental sustainability, and digital-based environmental analysis systems. The study employs a systematic literature review (SLR) approach, filtering academic databases from 2019 to 2025 to synthesize current pedagogical frameworks. The results of the study show that AI technology can increase student engagement in project-based environmental learning, accelerate EIA data processing, and facilitate digital simulation-based decision making. AI also has the potential to strengthen environmental education through reflective, collaborative, and interactive approaches. However, challenges remain, such as digital literacy, infrastructure readiness, and the need for curriculum adaptation. This article concludes that student participation can be significantly increased through the application of AI that is pedagogically and contextually designed in the architecture curriculum.

Keywords:

Artificial Intelligence; Environmental Impact Assessment; Environmental Education; Sustainable Architecture; Universitas Negeri Manado.

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INTRODUCTION

The Earth, where humans live, continues to undergo changes as a result of human activities (Verma, 2021). These changes have brought about significant changes to the ecosystem, climate, and human life on earth (Shivanna, 2022). According to a publication by the Intergovernmental Panel on Climate Change (IPCC) published between 2021 and 2025, global temperatures have risen by more than 1.2°C since the beginning of the industrial era. This condition will cause an increase in natural disasters and has the potential to cause damage to the earth itself. Disasters such as floods, droughts, storms, winds, and other disasters. This situation requires a response involving various disciplines. Higher education institutions play



a crucial role in producing a generation that is able to internalize the principles of sustainability into their future professional practices.

At the national level in Indonesia, environmental damage is a serious issue, with factors such as deforestation, air pollution, and especially waste from the construction sector contributing 25% of total national carbon emissions (Pirmana et al., 2021). The architecture and construction industries are major contributors to this problem, requiring a design approach that is inherently more sustainable (Ibrahim & Labaran, 2024). Unfortunately, a survey conducted by the Indonesian Green Building Council revealed that the majority of Indonesian architects (only 15%) have not consistently applied green principles in their projects, mainly due to a lack of in-depth understanding of the latest technologies and regulations (Widiarsa et al., 2021).

Changing environmental conditions are an integral part of human life, and humans have a responsibility to manage the environment. (Kasperson et al., 2022). Humans are given the responsibility to manage the environment. Human interaction with the environment can be viewed from various perspectives. (Sukarna, 2021). Understanding these responsibilities can be achieved through education. The concept of environmental education is an effort to instill environmental awareness (Nugroho, 2022). The concept of environmental character as education began several decades ago (Widodo et al., 2024). This condition is in line with the global context, where environmental and sustainability issues are becoming increasingly crucial, demanding active participation from various sectors, including education. Environmental and sustainability issues are being discussed more intensely in various aspects of education and have become one of the global competencies of the 21st century (R. S. Dewi & Mulyati, 2024). From a regulatory perspective, every development activity requires environmental permits, and operators are required to master environmental sustainability in line with technological developments. Concrete action is needed to defend the environment, including encouraging the community to further improve the quality of education. (Fitriana, 2025). Despite the growing literature on AI in architecture, there is a lack of focus on the specific pedagogical mechanisms that facilitate student participation in EIA. This article addresses this gap by proposing a conceptual framework for AI-supported participation at UNIMA.

Environmental education is crucial for sustainable development (Uralovich et al., 2023). Architecture study programs have a major mandate to produce graduates who not only master design skills but also have a deep awareness and understanding of the principles of sustainable architecture (Avsec et al., 2022). In Indonesia, the implementation of environmental education in higher education is carried out gradually and continuously. The implementation of environmental education in the Architecture Study Program at Manado State University (UNIMA) is an important step to ensure that graduates are able to overcome environmental challenges in their professional careers. In addition, regulations require that every development activity requires an environmental permit, so architects as operators are required to master the concept of environmental sustainability integrated with technological advances.

The focus on environmental education integrated with technology, particularly in the field of architecture, still requires further exploration. (Prayogo

et al., 2024). The urgency of this research arises because complex sustainability concepts—such as building energy efficiency, environmentally friendly materials, and bioclimatic design—are often difficult to understand visually without the aid of advanced technology. (Husamah et al., 2025). A review of the literature shows that the use of Building Information Modeling (BIM), energy simulation software, and e-learning platforms has been proven to improve student understanding in various engineering disciplines. (Pantiga & Soekiman, 2021), *Energy simulation software and e-learning platforms have been proven to improve student understanding in various engineering disciplines.* (Hizviani, 2022).

In the context of modern architecture, technology serves not only as a tool, but also as a powerful medium for teaching the principles of sustainable design in an interactive and realistic manner. Technologies such as Building Information Modeling (BIM), Artificial Intelligence (AI), and Augmented Reality (AR) have the potential to be game-changers in architectural education. BIM is not limited to three-dimensional modeling, but also enables real-time analysis of building performance, including energy consumption calculations, carbon footprints, and climate adaptation. (Lumentah et al., 2024).

The application of the aforementioned technologies is now crucial, given that conventional architecture curricula focusing solely on aesthetic and functional aspects have proven inadequate. In Indonesia, research shows that 70% of architecture courses do not yet include energy simulation or material life cycle analysis as mandatory components. This is where technology, particularly Artificial Intelligence (AI), can play a central role. AI can accelerate and simplify complex processes such as Environmental Impact Analysis (EIA), which includes understanding the online single submission system and amdalnet. The use of AI for simulation and analysis enables students to increase their participation in the environmental analysis process, shifting from theoretical understanding to in-depth applied competence. (Marwoto, 2022).

This is where technologies such as Building Information Modeling (BIM), Artificial Intelligence (AI), and Augmented Reality (AR) can be game-changers. BIM not only facilitates 3D modeling (Rane et al., 2023). It also enables real-time analysis of building performance, including energy consumption, carbon footprint, and climate adaptation (Li et al., 2024). At Manado State University, this potential has not been fully explored, despite the availability of adequate digital facilities for students.

In the context of architectural education, student participation is one of the key factors in the environmental project-based learning process. This participation can be realized through digital exploration, collaboration in virtual modeling, and involvement in data-based analysis. Therefore, this article focuses on a conceptual study of how AI can increase student participation in environmental impact analysis in the architectural academic environment.

METHODS

A holistic understanding of how technology integration, particularly the potential of Artificial Intelligence (AI), affects student participation and

competence in Environmental Impact Analysis (EIA) (Matović & Ovesni, 2023). This study uses a systematic literature review approach by searching various scientific publications, journal articles, and research reports from 2019–2025 that are relevant to the topics: 1) The use of AI in architectural education; 2) The integration of AI in environmental impact analysis; 3) The role of student participation in environmental project-based learning.

This approach produced a conceptual synthesis that describes the relationship between AI technology and the strengthening of environmental education at the university level. The literature review process was carried out through the following stages: 1) Identification of sources from databases such as ScienceDirect, Springer, Taylor & Francis, and Google Scholar using the Publish & Perish application. 2) Selection of literature based on its relevance to the context of architectural education and sustainability; and 3) Thematic analysis of key findings related to AI, EIA, and student participation. This design allows researchers to identify the “how” and “why” factors of technology integration, as well as the qualitative challenges that arise when AI and environmental analysis software are used in the context of EIA learning. (Qi, 2025).

RESULTS & DISCUSSION

Artificial Intelligence in Architecture and Environmental Design Education

The development of artificial intelligence (AI) technology in the context of architecture has been a significant transformation over the past two decades. Research by Li et al. (2024) emphasizes that the integration of AI with Building Information Modeling (BIM) has shifted the paradigm of architectural learning from a representational approach to an analytical-predictive approach. AI not only plays a role in assisting the design visualization process, but also in performing environmental prediction modeling—that is, simulating how building designs affect microclimate, airflow, and energy consumption.

Several other studies, such as Rane et al. (2023) and Avsec et al. (2022), show that AI can improve students' ability to understand the relationship between design factors and sustainability. For example, with the help of Generative Design algorithms, students can evaluate thousands of design variations based on environmental parameters, such as sun orientation, vegetation, and rainfall. This approach transforms the role of students from recipients of information to active researchers in the design process.

In the context of learning, the use of AI has also changed the way lecturers teach. AI can function as a pedagogical agent that provides adaptive feedback to students. According to Husamah et al. (2025), the application of AI in e-learning architecture helps create a more personalized learning experience, where students receive learning recommendations tailored to their competency levels. This reinforces the constructivist learning theory, which emphasizes the importance of learners constructing their own knowledge through interaction with the digital context.

Furthermore, AI opens up opportunities to integrate virtual reality (VR) and augmented reality (AR) in architecture studios. Through interactive 3D models

generated by AI, students can explore spaces and simulate environmental impacts directly, even before the building is physically designed. This approach is in line with global trends in architectural education that emphasize sustainability and energy efficiency (Uralovich et al., 2023).

Student Participation in Environmental Impact Analysis

Before discussing the implementation of technology in strengthening environmental education, it is necessary to discuss the respondents' perceptions of environmental education. This section presents the research findings and discussion regarding the implementation of technology in strengthening environmental education in the Architecture Study Program at Manado State University. Data was obtained through a combination of questionnaires distributed to students, in-depth interviews with lecturers and students, and observations of the learning process. The discussion will elaborate on how technology is integrated, perceptions of it, its impact on learning, and the challenges and opportunities that arise.

The perceptions of respondents in the ideal ecocentric realm need to be responded to openly. This response can be done in various sources, including through media coverage. Students, as agents, should implement policies that are responsive to the needs of the community. This is largely determined by their abilities and capacities.

In relation to this study, the respondents' perceptions of the concept of environmental friendliness were quite good, in other words, they were at an ecocentric level. Perception is a cognitive process that is undergone and experienced. (Imbar, 2021). Perception is defined as a person's ability to comprehend or understand something. This process of understanding is then known or remembered. (Murdiyanto & Wijayanti, 2021). Perception is also related to the ability to grasp the meaning of what is being learned. This is done by analyzing the main points of a topic that is being discussed and studied. The theme can then be presented in a certain form to another form. Perception is also an impression that is displayed and described by each individual obtained through the use of the five senses, which is then analyzed, interpreted, and evaluated, so that the individual obtains meaning (R. Dewi, 2023).

Perceptions of the environment will also determine attitudes related to the selection, organization, interpretation, and understanding of information received by individuals. These perceptions can be felt and received through the processes of sight, hearing, smell, touch, and feeling, resulting in a meaningful picture of the world (Tjalla & Suseno, 2023). Perceptions of environmentally friendly concepts are determined by attitudes and behaviors based on social, economic, and environmental aspects (Arifiani & Mussadun, 2016: 185).

The perception of environmental education in relation to the concepts of environmental friendliness and sustainability requires a technological approach in the form of implementation to complement the design of environmentally friendly concepts in architecture study programs in accordance with the conditions in which these concepts will be applied. The application of technology in supporting the strengthening of environmental education can be encouraged through the process of planning, organizing, and implementing materials and implementation. (DARMAWAN, 2025). There are at least three basic forms of individual support

for the environment (Lingkungan dkk., 2016: 44). Environmental assessment dimensions through the measurement of ecocentric, anthropocentric, and apathetic attitudes are used to measure perceptions of the environment, namely:

- a) Ecocentric is a view that reveals that the natural environment deserves protection because of its intrinsic values.
- b) Anthropocentric is a view that reveals that the natural environment is a resource that can be exploited for the benefit of humans themselves.
- c) Apathetic is indifference to the natural environment as an important resource.

In order to determine the perception of technology implementation in strengthening environmental education, each selected respondent was given questions to assess their understanding of the need for election organizers to develop environmentally friendly election concepts.

Student participation in environmentally-oriented architecture learning is an important aspect of 21st-century education. In educational literature, student participation is defined as active involvement in every stage of learning—from problem exploration and solution planning to reflection on results.

Studies by Widodo et al. (2024) and Fitriana (2025) show that when students are involved in projects that are relevant to real-world issues (e.g., green space planning or energy-efficient building design), their motivation and social responsibility levels increase. AI reinforces this form of participation by providing an interactive digital learning environment.

Research by Avsec et al. (2022) mentions that the use of AI can create a collaborative learning ecosystem. Students can share design models and environmental data online, analyze results collectively, and revise designs based on simulation results. Within the framework of social constructivism theory, this kind of interaction improves students' critical and reflective thinking skills.

In addition, the literature shows that AI also plays a role in increasing environmental literacy. Through simulations that visualize the ecological consequences of each design decision, students can understand the cause-and-effect relationship between human actions and environmental change. As stated by Uralovich et al. (2023), the ecological understanding gained through digital experiences is much stronger than conventional text-based learning.

However, several studies also highlight the challenges of student participation, particularly in relation to digital literacy and access to technology. In some universities in Indonesia, limitations in hardware and network connectivity hinder the full utilization of AI technology (Hizviani, 2022). Therefore, the role of educational institutions is important in ensuring equitable access to digital resources.

AI as an Instrument for Analyzing the Environmental Impact of Architectural Education

One of the most significant contributions of AI in architectural education is its ability to support environmental impact analysis (EIA) systematically and efficiently. EIA, as a scientific process for identifying and evaluating the impact of a project on the environment, is often challenging due to the complexity of data and time constraints for analysis.

AI offers a new data-driven approach. Systems such as AmdalNet AI and ArcGIS AI are capable of integrating spatial, meteorological, and hydrological data to predict the impact of projects on local ecosystems. Research by Hizviani (2022) shows that AI systems can reduce EIA analysis time by up to 60% compared to conventional methods, while also improving the accuracy of impact estimates.

In the context of education, the use of this technology provides students with the opportunity to learn to conduct environmental analysis in real-world situations. ChatGPT, for example, can help students compile AMDAL reports with a more systematic structure, while AutoCAD AI can visualize changes in the landscape due to development.

In addition to technical aspects, AI also enriches reflective and ethical approaches to learning. Through predictive analysis features, students can evaluate not only the technical impact, but also the social and cultural impact of architectural projects. This is in line with the concept of Environmental Humanities, where design is seen not merely as an aesthetic activity, but as a social practice with ecological implications (Kasperson et al., 2022).

Several international studies also reinforce these findings. For example, Li et al. (2024) show that in the context of smart cities, the integration of AI and BIM can identify potential environmental risks from the conceptual design stage. Thus, students not only learn to create efficient designs but also learn to minimize ecological impacts through AI-based digital simulations.

Furthermore, AI also strengthens cross-disciplinary collaboration. In many universities, AMDAL projects are now carried out by multidisciplinary teams involving students of architecture, civil engineering, and information technology. This collaboration broadens students' insights, improves technical competence, and shapes an academic culture that is adaptive to digital transformation.

Integration of AI, Environmental Education, and Strengthening of the Architecture Curriculum

The use of technology has significantly enriched teaching and learning methods in environmental education in the Architecture Study Program. Observations show that architectural design software equipped with environmental analysis features (such as energy simulation, daylighting analysis, and material evaluation) allows students to explore designs in greater depth and realistically.

Students interviewed stated that these visual simulations greatly helped them understand abstract concepts such as “the effect of building form on energy consumption” or “the impact of building orientation on thermal comfort.” “It used to be just theory, but now we can see the graphs directly, so we understand better,” said one student. In addition, the e-learning platform facilitates easy access to materials, sustainable project case studies, and discussion forums that enable the exchange of ideas across time and space. This means that technology is not just a tool, but a key driver for improving conceptual understanding and developing the applied skills needed in sustainable architectural design. These benefits directly contribute to producing more competent graduates who are ready to face professional challenges in the field of green architecture.

A literature review shows that the integration of AI in environmental education cannot stand alone; it must be part of a holistic curriculum system.

According to Husamah et al. (2025), AI has the strongest pedagogical impact when integrated into project-based learning (PBL) or problem-based learning (PrBL). In this framework, students not only learn EIA theory, but also apply it in real projects that use AI technology.

Several universities in Southeast Asia, such as NUS (National University of Singapore) and ITB, have developed digital studios that utilize AI to perform environmental simulation and urban climate modeling. These studies show a significant improvement in students' ability to perform critical analysis and make evidence-based design decisions.

The success of AI integration at NUS and ITB serves as a benchmark; however, for UNIMA, institutional readiness and digital literacy are critical factors for successful adoption. In the context of Manado State University, the results of this literature review are relevant to strengthening the vision of the Architecture Study Program as a program oriented towards sustainability and technology. The application of AI can be incorporated into courses such as Building Technology, Environmental Planning, and Architectural Environmental Impact Analysis. Through this approach, students can actively participate in collaborative, interdisciplinary, and data-driven learning.

Conceptually, AI also plays a role in strengthening ecological citizenship among students. They are not only users of technology, but also agents of change who are able to think critically about the ecological impact of their design decisions. From all the literature reviewed, five main points can be synthesized:

- 1) AI as a catalyst for active learning, which increases student interaction, exploration, and reflection in the context of sustainability.
- 2) AI accelerates EIA analysis, providing more accurate, faster, and data-driven results.
- 3) Student participation increases, as AI makes learning more visual, collaborative, and contextual.
- 4) Key challenges include infrastructure readiness, digital competence, and pedagogical adaptation.
- 5) Curriculum integration is key to ensuring that AI utilization is not only technical, but also ethical and eco-centric.

Thus, AI is not merely an analytical tool, but an essential component in shaping a new paradigm of participatory and transformative sustainable architecture education. While tools like AmdalNet AI and ArcGIS AI offer significant data processing capabilities, their effectiveness in the UNIMA context remains a pedagogical possibility that requires specific curriculum alignment.

CONCLUSION

This literature review confirms that the integration of artificial intelligence (AI) in architectural education brings about significant transformations in the way students understand, analyze, and practice the principles of environmental sustainability. In the context of the Architecture Study Program at Manado State University, the application of AI technology in the environmental impact analysis (EIA) process not only enriches technical learning but also deepens the ecological

and ethical meaning of each design process. Students are no longer passive recipients of knowledge but reflective actors who actively participate in assessing the relationship between architectural design and environmental balance.

The role of AI in environmental education is multidimensional. On the one hand, this technology serves as an analytical tool that accelerates spatial data processing, ecosystem impact prediction, and evidence-based EIA report preparation. Through tools such as AmdalNet AI, AutoCAD AI, and ChatGPT Environment Module, students can visualize changes in the landscape due to development activities, understand air and energy flow patterns, and comprehensively evaluate the potential for environmental degradation. On the other hand, AI also functions as an adaptive learning medium that is capable of providing quick and contextual feedback on student work. This makes the learning process more dynamic, reflective, and solution-oriented.

An important conceptual finding from this study is that AI significantly increases student participation in environmentally oriented academic activities. Smart technology makes students more involved in the stages of analysis, from problem identification and data processing to environmentally friendly design decision-making. This participation is no longer limited to classroom attendance, but is realized through cross-disciplinary digital collaboration that brings together architecture, civil engineering, and information technology students in a single virtual work system. This model of participation reflects future professional work patterns in which environmental issues are at the core of every design decision and technology acts as a bridge between competencies.

In addition to strengthening the technical dimension, AI also raises ethical dimensions in architectural learning. Simulations and predictive analyses allow students to directly see the ecological consequences of each design alternative they create. Data visualization changes the way students think about the relationship between humans and nature: from anthropocentric to ecocentric. In this context, AI becomes a means of shaping ecological character that fosters empathy for the environment and professional responsibility for sustainable design. Thus, AI is not only a learning technology, but also a moral and social educational tool that instills awareness that every architectural action has an impact on the lives of other creatures and the wider natural system.

However, the integration of AI in architectural education also faces challenges that cannot be ignored. The digital literacy of students and lecturers still needs to be strengthened so that the use of AI does not stop at the technical level, but is truly used as an instrument of critical thinking. The uneven distribution of laboratory infrastructure and internet networks in some universities also hinders equitable implementation. Therefore, technological capacity building must be accompanied by supportive institutional policies, including regular training, the provision of legal software, and curriculum adjustments that allow AI to be integrated into various core courses.

From a pedagogical perspective, AI has paved the way for the emergence of new learning models based on data-driven environmental reasoning. Students learn to understand how design decisions can be measured scientifically and evaluated socially. Learning is no longer fragmented between theory, practice, and ethics, but is integrated into a single adaptive and collaborative digital system. In the long term,

the application of AI can shape a generation of architects who not only excel in design skills, but also possess ecological intelligence, social sensitivity, and systemic thinking skills.

Overall, it can be concluded that the use of AI in environmental impact analysis has strengthened the synergy between technology, education, and sustainability. This technology facilitates more active student participation, improves analysis efficiency, and deepens understanding of the complexity of the environment. AI is not only an analytical tool, but also a partner in building critical awareness of sustainability. In the context of Manado State University, the application of this technology has strategic potential to strengthen the academic role in responding to the challenges of climate change and ecological crises at the local and global levels. AI-based architectural education and environmental awareness will produce graduates who not only think creatively and innovatively, but are also able to act wisely, ethically, and responsibly towards the sustainability of the earth.

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REFERENCES

- Avsec, S., Jagiełło-Kowalczyk, M., & Żabicka, A. (2022). Enhancing transformative learning and innovation skills using remote learning for sustainable architecture design. *Sustainability*, 14(7), 3928.
- DARMAWAN, R. (2025). *TATA KELOLA PAKET C PKBM AL AMIRIA DALAM MEMBANGUN KOLABORASI DENGAN DUNIA USAHA DUNIA INDUSTRI* [PhD Thesis, UNIVERSITAS NEGERI JAKARTA]. <http://repository.unj.ac.id/55664/>
- Dewi, R. (2023). *PERSEPSI MAHASISWA PENDIDIKAN AGAMA ISLAM IAIN PALOPO TERHADAP SISTEM PEMBELAJARAN DARING* [PhD Thesis, Institut Agama Islam Negeri Palopo]. <https://repository.iainpalopo.ac.id/id/eprint/7339/1/skripsi%20rosmala%20dewi%20ACC.pdf>
- Dewi, R. S., & Mulyati, Y. F. (2024). Lulusan Berkompetensi Global Abad 21. *Prosiding Seminar Nasional Fakultas Ilmu Tarbiyah Dan Keguruan UIN Syarif Hidayatullah Jakarta*, 1(1), 289–301. <https://eproceeding.fitkuinjktconferences.com/index.php/semnas/article/view/119>
- Fitriana, A. S. (2025). Strategi Manajemen Pendidikan dalam Meningkatkan Kualitas Siswa yang Kompetitif di Kancah Global. *JME Jurnal Management Education*, 3(01). <https://journal.sabajayapublisher.com/index.php/jme/article/view/451>

- Hizviani, N. V. (2022). RANCANG BANGUN APLIKASI AMDAL NET DENGAN WEB GIS UNTUK PUBLIK DI KEMENTERIAN KEHUTANA. *UG Journal*, 16(2). <https://ejournal.gunadarma.ac.id/index.php/ugjournal/article/viewFile/6213/2466>
- Husamah, H., Rahardjanto, A., Permana, T. I., & Shukri, A. A. M. (2025). Integration of Digital Technologies in Environmental Education: A Systematic Review of Trends, Impacts, and Future Directions. *Jurnal VARIDIKA*, 30–47.
- Ibrahim, U. M., & Labaran, Y. H. (2024). Cultivating Holistic Approaches to Sustainable Construction: Insights from the Real-World Projects. *ArtGRID-Journal of Architecture Engineering and Fine Arts*, 6(1), 121–150.
- Imbar, K. (2021). Flipped Classroom pada Mata Kuliah Persepsi dan Desain Pesan di Prodi Teknologi Pendidikan UNJ. *Jurnal Pembelajaran Inovatif*, 4(2), 49–53.
- Intergovernmental Panel on Climate Change and Global Climate Change Projections. (2021). In R. Maliva, *Springer Hydrogeology* (pp. 71–88). Springer International Publishing. https://doi.org/10.1007/978-3-030-66813-6_4
- Kasperson, J. X., Kasperson, R. E., Turner, B. L., Hsieh, W., & Schiller, A. (2022). Vulnerability to global environmental change. In *Social contours of risk* (pp. 245–285). Routledge. <https://www.taylorfrancis.com/chapters/edit/10.4324/9781849772556-18/vulnerability-global-environmental-change-jeanne-kasperson-roger-kasperson-turner-wen-hsieh-andrew-schiller>
- Li, J., Liu, Z., Han, G., Demian, P., & Osmani, M. (2024). *The relationship between Artificial Intelligence (AI) and Building Information Modeling (BIM) technologies for sustainable building in the context of smart cities*. https://repository.lboro.ac.uk/articles/journal_contribution/The_relationship_between_Artificial_Intelligence_AI_and_Building_Information_Modeling_BIM_technologies_for_sustainable_building_in_the_context_of_smart_cities/28015358
- Lumentah, A. E., Kindangen, J. I., & Warouw, F. (2024). LEARNING CENTER MANADO: Arsitektur Biofilik. *Jurnal Arsitektur DASENG*, 13(1), Article 1.
- Marwoto, M. (2022). *Penulisan & Riset Arsitektur; Pengantar Menulis Ilmiah Bagi Mahasiswa Arsitektur*. <http://repository.ukri.ac.id/id/eprint/69/1/Buku%20Riset%20Arsitektur%20dan%20OSK.pdf>
- Matović, N., & Ovesni, K. (2023). Interaction of quantitative and qualitative methodology in mixed methods research: Integration and/or combination. *International Journal of Social Research Methodology*, 26(1), 51–65. <https://doi.org/10.1080/13645579.2021.1964857>
- Murdiyanto, T., & Wijayanti, D. A. (2021). Evaluasi persepsi dan sikap mahasiswa terhadap lingkungan pembelajaran blended learning mata kuliah kalkulus integral prodi pendidikan matematika FMIPA UNJ. *Jurnal Riset Pembelajaran Matematika Sekolah*, 5(1), 19–27.
- Nugroho, M. A. (2022). Konsep pendidikan lingkungan hidup: Upaya penanaman kesadaran lingkungan. *Ibtidaiyyah: Jurnal Pendidikan Guru Madrasah Ibtidaiyyah*, 1(2), 93–108.
- Pantiga, J., & Soekiman, A. (2021). Kajian literatur implementasi building information modeling (BIM) di Indonesia. *Rekayasa Sipil*, 15(2), 104–110.
- Pirmana, V., Alisjahbana, A. S., Yusuf, A. A., Hoekstra, R., & Tukker, A. (2021). Environmental costs assessment for improved environmental-economic account for Indonesia. *Journal of Cleaner Production*, 280, 124521.
- Prayogo, W., Ratnaningsih, W., Suhardono, S., & Suryawan, I. W. K. (2024). Environmental education practices in Indonesia: A review. *Journal of Sustainable*

- Infrastructure*, 3(1).
<https://jsi.universitaspertamina.ac.id/index.php/jsi/article/view/27>
- Qi, C. (2025). The role of educational science in environmental management and green technology adoption in rural revitalization through interview-based insights. *Scientific Reports*, 15(1), 19544.
- Rane, N., Choudhary, S., & Rane, J. (2023). Integrating Building Information Modelling (BIM) with ChatGPT, Bard, and similar generative artificial intelligence in the architecture, engineering, and construction industry: Applications, a novel framework, challenges, and future scope. *Engineering, and Construction Industry: Applications, a Novel Framework, Challenges, and Future Scope (November 22, 2023)*. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4645601
- Shivanna, K. R. (2022). Climate change and its impact on biodiversity and human welfare. *Proceedings of the Indian National Science Academy*, 88(2), 160–171. <https://doi.org/10.1007/s43538-022-00073-6>
- Sukarna, R. M. (2021). Interaksi manusia dan lingkungan dalam perspektif antroposentrisme, antropogeografi dan ekosentrisme: Human and environment interactive in the perspective of antroposentrism, antropogeography and ecocentrism. *Hutan Tropika*, 16(1), 84–100.
- Tjalla, A., & Suseno, M. (2023). Evaluasi Kebijakan Implementasi MBKM di Universitas Negeri Jakarta. *Jurnal Pembelajaran Inovatif*, 6(2), 61–73.
- Uralovich, K. S., Toshmamatovich, T. U., Kubayevich, K. F., Sapaev, I. B., Saylaubaevna, S. S., Beknazarova, Z. F., & Khurramov, A. (2023). A primary factor in sustainable development and environmental sustainability is environmental education. *Caspian Journal of Environmental Sciences*, 21(4), 965–975.
- Verma, A. K. (2021). Influence of climate change on balanced ecosystem, biodiversity and sustainable development: An overview. *International Journal of Biological Innovations*. <https://papers.ssrn.com/sol3/Delivery.cfm?abstractid=3935095>
- Widiarsa, K. B., Kumara, I. N. S., & Hartati, R. S. (2021). Studi literatur perkembangan green building di Indonesia. *Jurnal SPEKTRUM Vol*, 8(2), 37–47.
- Widodo, S. F. A., Mr, M. I. F., Widiastuti, A., Ahmed, T., & Shahzeb, S. (2024). Implementasi dan dampak pendidikan holistik berbasis lingkungan pada siswa: Studi kasus di sekolah alam. *Humanika: Kajian Ilmiah Mata Kuliah Umum*, 24(2), 193–204.