2025

SciEd
SEAQIS Journal of Science Education

SEAQIS Journal of Science Education (SciEd)
ISSN: 2987-8101 | E-ISSN: 2964-7533
Vol: 5, No: 2, PP: 23-33
www.journal.qitepinscience.org

Research Paper Open Accsess

The Impact of Experiential Learning on Climate Change Awareness in Sustainability Education: A Systematic Review

Ariyoga Pratama[1*], and Euis Nursaadah[1]

[1]*Master of Science Education Program, Faculty of Teacher Training and Education, University of Bengkulu, Bengkulu 38122, Indonesia*

[*]*Corresponding author, e-mail: ariyoga@unib.ac.id*

Article history:
Received: February 12, 2025
Revised: June 2, 2025
Accepted: June 24, 2025

Abstract

This systematic review evaluates the effectiveness of experiential learning methods, including hands-on activities, in enhancing climate change awareness among high school students within sustainability education. By comparing these approaches to traditional lecture-based instruction, the review identifies key facilitators and barriers to their implementation in educational settings. The study follows the PICO framework to define the Population, Intervention, Comparison, and Outcome, and uses the PROMPT mnemonic to assess the Presentation, Relevance, Objectivity, Methodology, Provenance, and Timeliness of the included studies. From 579 initial records, 25 studies met the inclusion criteria, spanning a range of geographic regions and intervention types. The findings indicate that experiential learning significantly improves students' climate change awareness by fostering engagement, real-world application, and collaborative learning. However, challenges such as limited resources, insufficient teacher training, and curricular constraints hinder broader adoption. This review highlights the value of integrating experiential learning into high school sustainability curricula and calls for further research on long-term impacts, culturally responsive practices, and the development of effective assessment tools and teacher support systems.

Keywords: Sustainability education, hands-on activities, experiential learning, climate change awareness, high school education

Introduction

Climate change represents one of the most critical challenges of our time, with profound environmental, economic, and social implications. As global temperatures rise and extreme weather events become increasingly common, equipping future generations with the knowledge, skills, and motivation to address these issues is more urgent than ever (Mebane et al., 2023). Education plays a central role in cultivating climate change awareness, particularly among students in both K–12 and higher education settings, who are at formative stages of cognitive and social development. Embedding sustainability education into school and campus curricula offers a strategic pathway to foster environmental literacy and promote meaningful engagement with climate-related challenges (Campos-Ugaz et al., 2022).

Traditional pedagogical approaches—characterized by passive learning, textbook reliance, and a focus on rote memorization—

often fall short in engaging students with the complexity and urgency of climate change (Tumanggor et al., 2022). These methods can create a disconnect between theoretical content and real-world application, limiting students' ability to internalize and act upon sustainability concepts (Harıadı et al., 2024). In contrast, experiential learning—including hands-on activities, project-based learning, field experiences, and simulations—provides interactive, student-centred alternatives that actively involve learners in constructing knowledge (Jiang et al., 2024). Such approaches have been shown to enhance engagement, critical thinking, and the retention of climate-related concepts by grounding learning in authentic contexts (Cabello & Savec, 2018).

Numerous studies highlight how experiential learning fosters deeper understanding, environmental responsibility, and proactive attitudes (Handoko et al., 2019). Activities such as outdoor education, community-based projects, or environmental simulations not only clarify abstract climate concepts but also help students recognize their role in contributing to sustainable solutions (Chen & Chang, 2024). These immersive experiences can cultivate a lasting sense of agency and stewardship that traditional methods often fail to achieve.

However, despite these documented benefits, experiential learning remains underutilized in many educational institutions. Barriers such as insufficient resources, limited teacher training, and institutional resistance to pedagogical innovation can hinder broader implementation. Additionally, much of the existing literature is fragmented, with studies varying in educational level, geographic scope, and intervention type (Abulibdeh, 2024).

To address this gap, this systematic review synthesizes current evidence on the impact of experiential learning methods, including hands-on activities, in enhancing climate change awareness across both school and university settings. By evaluating key facilitators and barriers, this review aims to provide actionable insights for educators, administrators, and policymakers seeking to strengthen sustainability education through active learning strategies.

Methodology

1. Protocol:

This systematic review was conducted in accordance with the PICO framework, with an initial protocol outlining the review's objectives, eligibility criteria, and methodology (Thapa et al., 2024). To ensure a structured and critical appraisal of the included studies, we employed the PROMPT mnemonic, which evaluates Presentation, Relevance, Objectivity, Method, Provenance, and Timeliness (Santos-Hermosa & Sánchez, 2010). The review focuses on assessing the effectiveness of hands-on activities and experiential learning methods (Intervention) in enhancing climate change awareness (Outcome) among school and university students (Population), in comparison to conventional learning methods (Comparison). This population is particularly important, as students in both K–12 and higher education are at a formative stage in developing sustainability attitudes and will play a pivotal role in future environmental decision-making.

2. Eligibility Criteria:

Studies included in this review were required to meet specific eligibility criteria. First, the population of interest was school and university students. Second, the intervention must involve hands-on activities or experiential learning methods aimed at promoting sustainability education and climate change awareness. Third, studies needed to include a comparison group utilizing conventional learning methods, such as lectures or textbook-based instruction. Finally, eligible studies were required to report measurable outcomes related to students' climate change awareness, knowledge, attitudes, or behaviours. We included both quantitative (e.g., randomized controlled trials, quasi-experimental designs,

surveys) and qualitative studies (e.g., case studies, interviews, focus groups) that provided empirical evidence. Only studies published in English between December 2014, and December 2024 were considered, reflecting a decade of research following the 2015 Paris Agreement, which marked a global shift toward integrating climate change education into policy and curricula (Jamarani et al., 2024).

3. Information Sources and Search Strategy:

A comprehensive search strategy was developed to identify relevant studies across multiple databases, including Scopus, and Sinta. The search terms included combinations of keywords such as "sustainability education," "hands-on activities," "experiential learning," "climate change awareness," and "school." Boolean operators (AND, OR) were employed to refine the search results. The search was conducted in two phases: an initial search in November 2024 to develop the study protocol, followed by a more extensive search in December 2024 to capture any additional relevant studies published during that period (Jamarani et al., 2024).

The search yielded a total of 579 records, which were imported into Mendeley Desktop for reference management. Duplicate entries were removed, and the remaining records were screened for relevance based on titles and abstracts. The search strategy was designed to be inclusive, capturing a wide range of studies related to the impact of hands-on and experiential learning on climate change awareness. Additionally, a manual search of the reference lists of included articles was conducted to identify any further relevant studies that may not have been captured in the initial database search (Santos-Hermosa & Sánchez, 2010).

4. Data Charting and Synthesis of Results:

Data extraction was performed using a standardized charting form to ensure consistency and comprehensiveness. Key information was collected from each study, including author(s), year of publication, study design, sample size, intervention details, comparison methods, and outcomes related to climate change awareness. The extracted data were then synthesized qualitatively, focusing on the themes and patterns that emerged from the studies. This synthesis aimed to highlight the effectiveness of hands-on and experiential learning methods in enhancing students' understanding of climate change and their attitudes toward sustainability (Mebane et al., 2023).

In addition to qualitative synthesis, a descriptive analysis was conducted to summarize the findings across studies. This included calculating effect sizes where applicable and categorizing the outcomes based on the type of intervention and the context in which it was implemented. The synthesis of results aimed to provide a comprehensive overview of the current state of research on this topic, identifying both the strengths and limitations of existing studies. By analysing the data in this manner, the review sought to draw meaningful conclusions about the impact of innovative teaching methods on climate change awareness among school and university students, ultimately informing future educational practices and policies (Pena-Vega et al., 2022).

Results and Discussion

The search of the database, along with the manual examination of reference lists and hand searching, yielded 579 reports. After eliminating duplicates and completing the title and abstract screening, 43 papers were found to be eligible for review (Thapa et al., 2024). The eligibility assessment process resulted in the inclusion of 25 papers in this scoping review (see Table 1 and Figure 1).

Table 1 Summary of included publications.

Author(s), Year, Country	Article Type	Sampling Methods, Study Design, Data Collection Tools	Participant Profile
Kinoshita et al., 2019, Indonesia	Empirical Study	Convenience sampling, Cross-sectional design, Questionnaire surveys	University students
Zidny & Eilks, 2020, Indonesia	Conceptual Paper	Purposive sampling, Case study, post-intervention questionnaire	High school and university students
Paristiowati et al., 2022, Indonesia	Empirical Study	Purposive sampling, Qualitative design, Interviews, observations, reflective journals	Preservice chemistry teachers
Antronico et al., 2023, Italy	Empirical Study	Voluntary questionnaire, Survey design, Descriptive statistics	High school students
Ika Sari et al., 2024, Indonesia	Quantitative Study	Stratified sampling, Regression analysis, Questionnaire surveys	Early childhood educators and students
Bailey et al., 2022, USA	Mixed Methods Study	Purposive sampling, Pre-post design, Structured surveys and focus groups	High school students
Piscitelli & D'Uggento, 2022, Italy	Empirical Study	Convenience sampling, Cross-sectional design, Questionnaire surveys	High school students
Harris et al., 2022, USA	Empirical Study	Purposive sampling, Mixed-methods design, Tactile teaching tools	Middle school to master's level students
Bishoge et al., 2022, Tanzania	Empirical Study	Convenience sampling, Cross-sectional design, Questionnaire surveys	Secondary school students
Giardino et al., 2022, EU	Review Paper	Stratified sampling, Case study, Pedagogical documentation	High school students
Haimovich et al., 2022, Israel	Review Paper	Purposive sampling, Case study, Virtual Escape Room evaluation	High school chemistry students
Tumanggor et al., 2022, Indonesia	Qualitative Study	Purposive sampling, Structured interviews, Observations	High school students
Zjalic et al., 2023, Italy	Pilot Study	Convenience sampling, Pre-post survey, Structured questionnaires	High school students
Martinez-Mirambell et al., 2023, Spain	Empirical Study	Semi-structured interviews, Active learning sessions	Secondary school students
Goel et al., 2023, India	Empirical Study	Convenience sampling, Cross-sectional design, Offline questionnaire surveys	Middle and high school students
Kluczkovski et al., 2024, UK	Program Evaluation	Teacher surveys, Student blogs, Mixed-data collection	High school students
Abulibdeh et al., 2024, Global Perspective	Scoping Review	Literature review	Institutions transitioning to zero-carbon campuses
Chen & Chang, 2024, Taiwan	Mixed Methods Study	Purposive sampling, Quasi-experimental design, pre-post-tests, Interviews	Graduate students
Martinez-Mirambell et al., 2023, Spain	Empirical Study	Semi-structured interviews, Active learning sessions	Secondary school students
Jiang et al., 2024, USA	Technology Evaluation	Usability testing, Mixed-methods evaluation, Observations	University students
Wekerle et al., 2024, Germany	Quantitative Study	Structural equation modelling, Student evaluations	University students
Harıadı et al., 2024, Indonesia	Comparative Study	Statistical surveys, TGMD-2 instrument	Preschool children

Hsiao et al., 2022, Taiwan	Empirical Study	Mixed-methods approach; surveys and interview	High school students
Mebane et al., 2023, Italy	Empirical Study	Quantitative study; Surveys and educational programs	High school students
Campos-Ugaz et al., 2022, Peru	Review Paper	Qualitative approach; bibliometric	Across institutions

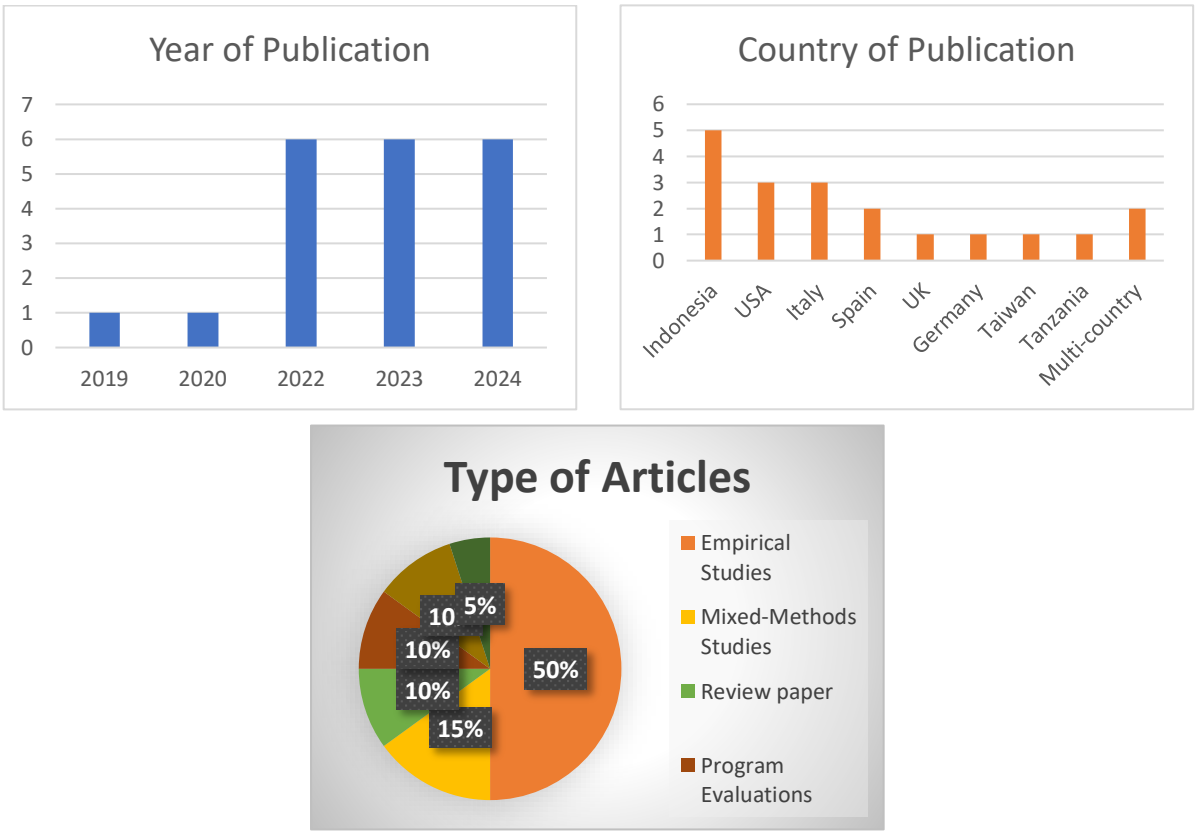

Figure 1 Characteristics of included publications. a. Year of publication. b. Country of publication. c. Type of articles.

a. Characteristics of included publications

1. Year of Publication

The research studies span a wide timeframe from 2019 to 2024, reflecting a growing interest in sustainability and education. Early studies, such as those by Kinoshita et al (2019), lay foundational insights, while more recent publications, including (Harıadı et al., 2024) and (Jiang et al., 2024), emphasize advanced approaches like experiential learning and mixed-reality science labs. There is a notable surge in publications from 2022 onward, showing an increased global recognition of integrating sustainability concepts in education.

2. Country of Publication

The studies represent diverse geographical contexts, including Indonesia (Zidny & Eilks, 2020); (Ika Sari et al., 2024), the USA (Harris et al., 2022); Jiang et al., 2024), and Italy (Antronico et al., 2023); Zjalic et al., 2023). Other contributions come from Spain, the UK, Germany, and Taiwan, highlighting the global scope of sustainability education. This diversity reflects the universal importance of addressing climate change through educational interventions tailored to regional needs.

3. Article Types

The reviewed articles include a mix of empirical studies (Kinoshita et al., 2019; Martínez-Mirambell et al., 2023), program evaluations (Kluczkovski et al., 2024), and

scoping reviews (Abulibdeh, 2024). Mixed-methods and qualitative approaches (Chen & Chang, 2024; Tumanggor et al., 2022) provide a robust understanding of both the outcomes and contextual influences of these educational practices.

4. Sampling Methods, Study Design, and Data Collection Tools

Sampling methods vary from purposive sampling (Chen & Chang, 2024) to convenience sampling (Harris et al., 2022), reflecting flexibility in study designs. Data collection tools include pre-post-tests, structured surveys, and observational techniques, ensuring comprehensive data triangulation. Quasi-experimental designs (Chen & Chang, 2024) and usability evaluations (Jiang et al., 2024) offer advanced methodological insights for measuring educational impact.

5. Participant Profile

The participants range from preschoolers (Harıadı et al., 2024) to university students (Kinoshita et al., 2019; Jiang et al., 2024), with a significant focus on high school students (Piscitelli & D'Uggento, 2022; Zjalic et al., 2023). Educators and pre-service teachers (Zidny & Eilks, 2020) also feature prominently, emphasizing the need to equip teachers with the tools and knowledge for sustainability education.

b. Exploring the Importance of Hands-on and Experiential Learning in High School Sustainability Education

1. Effectiveness of Hands-on and Experiential Learning

Hands-on and experiential learning methods, as demonstrated in several studies, effectively enhance student engagement and awareness of sustainability issues. For instance, research on aquaponics in schools (Kluczkovski et al., 2024) highlighted how interactive activities fostered environmental awareness and practical knowledge about sustainability. Similarly, the use of clay modelling to teach biology vocabulary (Bailey et al., 2022) showed that students were actively engaged and experienced positive emotional and behavioural outcomes. Plogging, which combines physical activity with litter collection (Martínez-Mirambell et al., 2023), not only raised environmental awareness but also encouraged students to reflect on their role in improving their surroundings. These examples illustrate that hands-on learning creates an immersive environment where students can connect theoretical knowledge to tangible actions, making sustainability concepts more relatable and memorable.

2. Comparison of Hands-on vs. Traditional Methods

Studies comparing hands-on learning to traditional methods provide compelling evidence for the superiority of experiential approaches. For instance, research involving STEAM education (Hsiao et al., 2022) compared traditional project-based learning (PBL) with a cognitive-affective interaction model (CAIM) and found that hands-on activities significantly enhanced students' creativity, critical thinking, and hands-on performance. Similarly, the use of clay modelling in research (Bailey et al., 2022) was compared to traditional sentence-writing exercises, revealing that kinesthetic activities fostered equal or better learning outcomes while also engaging students emotionally. These comparisons highlight how experiential methods go beyond rote memorization, allowing students to develop deeper connections to the material and fostering skills that are essential for addressing complex sustainability challenges.

3. Participant Engagement

Hands-on and experiential methods have been shown to significantly enhance participant engagement across different demographics. In research involving high school students in Jakarta (Tumanggor et al., 2022), ecological behaviour was explored through structured interviews and observations, demonstrating that hands-on interventions, like building eco-projects,

improved students' environmental consciousness. Similarly, an urban health education program in Italy (Zjalic et al., 2023) used interactive sessions to boost student awareness of urban health challenges, with post-intervention assessments revealing a significant improvement in knowledge retention. Such methods actively involve students in the learning process, transforming them from passive recipients of information to active participants, which is crucial for cultivating long-term interest in sustainability education.

4. Behavioural and Attitudinal Changes

Behavioural and attitudinal shifts are critical outcomes of hands-on learning. Research on youth climate action (Pena-Vega et al., 2022) revealed that participatory projects led by students often achieved higher success rates, fostering a sense of civic responsibility. Another study (Piscitelli & D'Uggento, 2022) on sustainable behaviours among high school students showed that activities like turning off faucets or volunteering significantly influenced their daily choices. Plogging interventions (Martínez-Mirambell et al., 2023) further demonstrated how hands-on activities could shift students' attitudes towards environmental care. These findings underscore the power of experiential learning in not only imparting knowledge but also in shaping behaviours and attitudes necessary for climate action.

5. Development of Environmental Competencies

Experiential learning directly supports the development of essential environmental competencies. For example, research involving a summer course for preservice chemistry teachers (Paristiowati et al., 2022) found that project-based learning enhanced skills such as collaboration, communication, and critical thinking. Similarly, aquaponics education (Kluczkovski et al., 2024) equipped students with practical skills in food sustainability and climate change mitigation. By participating in hands-on projects, students gain competencies that prepare them to address real-world environmental challenges, bridging the gap between theoretical knowledge and practical application.

6. Link to Climate Change Awareness

Several studies explicitly link hands-on methods to improved climate change awareness. A pilot program in Italy (Mebane et al., 2023) used participatory workshops to enhance students' understanding of climate change's emotional and environmental impacts. Another study (Zjalic et al., 2023) on urban health education highlighted how interactive interventions fostered a deeper comprehension of climate-related health issues. These findings suggest that experiential methods make abstract climate change concepts more accessible, enabling students to connect global issues to their personal lives and communities. This contextual understanding is essential for fostering proactive attitudes toward climate action.

7. Cultural and Contextual Relevance

Integrating local cultural and environmental contexts into experiential learning enhances its relevance, relatability, and impact by connecting abstract sustainability concepts to students lived experiences. This contextual grounding fosters deeper engagement and a stronger sense of ownership over environmental issues. For example, one study integrated Indigenous knowledge into chemistry education, illustrating how blending Indigenous and Western scientific perspectives enriched students' understanding of sustainability and promoted respect for traditional ecological wisdom (Zidny & Eilks, 2020). Another study focused on geoheritage-based activities in European geoparks, where students explored local geological features and environmental challenges, fostering both local engagement and broader environmental consciousness (Giardino et al., 2022). These examples show how culturally and geographically grounded

learning can deepen students' appreciation of the interconnected nature of environmental challenges and solutions, ultimately strengthening the effectiveness of climate change education.

8. Policy Implications and Scalability

Program evaluations provide valuable insights into scaling hands-on learning methods for broader impact. For example, research on aquaponics education (Kluczkovski et al., 2024) identified logistical challenges and proposed solutions for integrating such programs into national curricula. Similarly, a bibliometric review of environmental education (Campos-Ugaz et al., 2022) emphasized the need for policy frameworks that prioritize experiential learning. By addressing challenges and leveraging these insights, policymakers can create scalable programs that integrate hands-on methods into sustainability education, thereby achieving systemic improvements in climate awareness and action.

9. Challenges and Recommendations

While hands-on methods are highly effective, they come with challenges such as logistical complexities (Kluczkovski et al., 2024) and increased cognitive load (Bailey et al., 2022). Addressing these challenges requires careful planning, such as providing teacher training and designing age-appropriate activities. For example, research on clay modelling (Bailey et al., 2022) recommended instructional strategies to reduce cognitive load, while studies on aquaponics (Kluczkovski et al., 2024) suggested improvements in logistical support. By overcoming these hurdles, educators can maximize the benefits of experiential learning for sustainability education.

10. Interdisciplinary Connections

Hands-on learning naturally supports interdisciplinary education, combining science, technology, social studies, and arts. For instance, research on STEAM education (Hsiao et al., 2022) showed how integrating science and art through project-based learning fostered creativity and problem-solving skills. Similarly, indigenous knowledge integration in chemistry lessons (Zidny & Eilks, 2020) bridged cultural and scientific perspectives. These interdisciplinary approaches not only make learning more engaging but also equip students with the diverse skills needed to tackle multifaceted environmental challenges.

Limitations

This review has several limitations. First, the scope of studies was constrained to those available in specific databases, potentially excluding relevant research from less accessible sources. Second, the variability in study designs and methodologies, such as sampling methods and data collection tools, limited direct comparisons between studies. Lastly, the geographical representation was uneven, with a significant focus on specific regions like Southeast Asia and Europe, while other regions were underrepresented.

Conclusion

Hands-on and experiential learning methods are essential for fostering meaningful and impactful sustainability education. The studies reviewed provide compelling evidence that these approaches enhance climate change awareness by making abstract concepts more relatable and actionable. Activities like aquaponics, plogging, and indigenous knowledge integration not only educate students but also inspire them to take practical steps toward addressing environmental challenges.

Moreover, experiential learning cultivates critical thinking, creativity, and collaboration skills that are vital for solving complex sustainability problems. By actively engaging students in the learning process, these methods ensure deeper knowledge retention and a stronger emotional connection to environmental issues. This emotional engagement is key to instilling long-term behavioural changes that support climate resilience and sustainable living.

Integrating experiential learning into educational frameworks requires strategic planning and policy support. Scalable models, such as those presented in program evaluations, demonstrate how logistical challenges can be addressed effectively. Policymakers and educators should prioritize these methods to create robust, interdisciplinary curricula that empower students to lead sustainable transformations within their communities.

In conclusion, hands-on and experiential learning methods are not just educational tools but transformative strategies that equip the next generation with the skills, mindset, and motivation needed to confront climate change. Expanding access to these methods across diverse geographical and socio-economic contexts will be crucial for achieving global sustainability goals.

References

Abulibdeh, A. (2024). Towards zero-carbon, resilient, and community-integrated smart schools and campuses: A review. *World Development Sustainability*, *5*. https://doi.org/10.1016/j.wds.2024.100193

Antronico, L., Coscarelli, R., Gariano, S. L., & Salvati, P. (2023). Perception of climate change and geo-hydrological risk among high-school students: A local-scale study in Italy. *International Journal of Disaster Risk Reduction*, *90*. https://doi.org/10.1016/j.ijdrr.2023.103663

Bailey, R., Kim, D., Bochenko, M. J., Yang, C., Dees, D. C., & Jung, J. (2022). The use of clay modeling to increase high school biology vocabulary learning. *Journal of Research in Innovative Teaching and Learning*, *15*(2), 232–244. https://doi.org/10.1108/JRIT-07-2021-0053

Bishoge, O. K., Aremu, A. K., Ajayi, D. D., & Mfinanga, S. (2022). The efforts made to solve environmental health problems in developing countries. A case from Mtwara town in Tanzania. *Journal of Public Health and Development*, *20*(2), 253–266. https://doi.org/10.55131/jphd/2022/200219

Cabello, V. M., & Savec, V. F. (2018). Out of school opportunities for science and mathematics learning: Environment as the third educator. *Lumat*, *6*(2), 3–8. https://doi.org/10.31129/LUMAT.6.2.353

Campos-Ugaz, W. A., Saavedra-López, M. A., Sierra-Liñan, F., Garay-Argandoña, R., Aguilar, O. O. Á., Hernández, R. M., & Rodríguez-Vargas, M. C. (2022). Education in environmental health: scientific contributions of the last 20 years. *Boletin de Malariologia y Salud Ambiental*, *62*(5), 1067–1078. https://doi.org/10.52808/bmsa.7e6.625.021

Chen, P., & Chang, Y. C. (2024). Incorporating creative problem-solving skills to foster sustainability among graduate students in education management. *Cleaner Production Letters*, *7*. https://doi.org/10.1016/j.clpl.2024.100082

Giardino, M., Justice, S., Olsbo, R., Balzarini, P., Magagna, A., Viani, C., Selvaggio, I., Kiuttu, M., Kauhanen, J., Laukkanen, M., & Perotti, L. (2022). ERASMUS+ Strategic Partnerships between UNESCO Global Geoparks, Schools, and Research Institutions: A Window of Opportunity for Geoheritage Enhancement and Geoscience Education. *Heritage*, *5*(2), 677–701. https://doi.org/10.3390/heritage5020038

Goel, A., Iyer-Raniga, U., Jain, S., Addya, A., Srivastava, S., Pandey, R., & Rathi, S. (2023). Student Perceptions of Environmental Education in India. *Sustainability (Switzerland)*, *15*(21), 1–22. https://doi.org/10.3390/su152115346

Haimovich, I., Yayon, M., Adler, V., Levy, H., Blonder, R., & Rap, S. (2022). "The Masked Scientist": Designing a Virtual Chemical Escape Room. *Journal of*

Chemical Education, *99*(10), 3502–3509. https://doi.org/10.1021/acs.jchemed.2c00597

Handoko, R., Widiastuti, I., & Pambudi, N. A. (2019). The development of an experiential learning module for fluid mechanics subject. *AIP Conference Proceedings*, *2202*(1). https://doi.org/10.1063/1.5141669

Harris, F. R., Sikes, M. L., Bergman, M., Goller, C. C., Hasley, A. O., Sjogren, C. A., Ramirez, M. V., & Gordy, C. L. (2022). Hands-on immunology: Engaging learners of all ages through tactile teaching tools. *Frontiers in Microbiology*, *13*, 1–8. https://doi.org/10.3389/fmicb.2022.966282

Harıadı, I., Fadhlı, N., Yudasmara, D., Wınarno, M. E., & Taufık, T. (2024). Comparing the Manipulative Movement of Preschool Children in Religious and Conventional Education Settings. *International Journal of Disabilities Sports and Health Sciences*, *7*(2), 475–481. https://doi.org/10.33438/ijdshs.1385464

Hsiao, H. S., Chen, J. C., Chen, J. H., Zeng, Y. T., & Chung, G. H. (2022). An Assessment of Junior High School Students' Knowledge, Creativity, and Hands-On Performance Using PBL via Cognitive–Affective Interaction Model to Achieve STEAM. *Sustainability (Switzerland)*, *14*(9). https://doi.org/10.3390/su14095582

Ika Sari, G., Winasis, S., Pratiwi, I., Wildan Nuryanto, U., & Basrowi. (2024). Strengthening digital literacy in Indonesia: Collaboration, innovation, and sustainability education. *Social Sciences and Humanities Open*, *10*, 101100. https://doi.org/10.1016/j.ssaho.2024.101100

Jamarani, A., Haddadi, S., Sarvizadeh, R., Haghi Kashani, M., Akbari, M., & Moradi, S. (2024). Big data and predictive analytics: A sytematic review of applications. In *Artificial Intelligence Review,* *57*(7). https://doi.org/10.1007/s10462-024-10811-5

Jiang, Y., Hamadani, K., Ng, K., Ahmadinia, A., Aquino, A., Palacio, R., Huang, J., Macshane, J., & Hadaegh, A. (2024). Developing scalable hands-on virtual and mixed-reality science labs. *Virtual Reality*, *28*(4), 1–14. https://doi.org/10.1007/s10055-024-01062-4

Kinoshita, A., Mori, K., Rustiadi, E., Muramatsu, S., & Kato, H. (2019). Effectiveness of incorporating the concept of city sustainability into sustainability education programs. *Sustainability (Switzerland)*, *11*(17), 1–23. https://doi.org/10.3390/su11174736

Kluczkovski, A., Ehgartner, U., Pugh, E., Hockenhull, I., Heaps-Page, R., Williams, A., Thomas, J. M. H., Doherty, B., Bryant, M., & Denby, K. (2024). Aquaponics in schools: Hands-on learning about healthy eating and a healthy planet. *Nutrition Bulletin*, *49*(3), 327–344. https://doi.org/10.1111/nbu.12689

Martínez-Mirambell, C., Boned-Gómez, S., Urrea-Solano, M., & Baena-Morales, S. (2023). Step by Step towards a Greener Future: The Role of Plogging in Educating Tomorrow's Citizens. *Sustainability (Switzerland)*, *15*(18), 1–15. https://doi.org/10.3390/su151813558

Mebane, M. E., Benedetti, M., Barni, D., & Francescato, D. (2023). Promoting Climate Change Awareness with High School Students for a Sustainable Community. *Sustainability (Switzerland)*, *15*(14), 1–15. https://doi.org/10.3390/su151411260

Paristiowati, M., Rahmawati, Y., Fitriani, E., Satrio, J. A., & Hasibuan, N. A. P. (2022). Developing Preservice Chemistry Teachers' Engagement with Sustainability Education through an Online, Project-Based Learning

Summer Course Program. *Sustainability (Switzerland)*, *14*(3). https://doi.org/10.3390/su14031783

Pena-Vega, A., Cohen, M., Flores, L. M., Le Treut, H., Lagos, M., Castilla, J. C., Gaxiola, A., & Marquet, P. (2022). Young People Are Changing Their Socio-Ecological Reality to Face Climate Change: Contrasting Transformative Youth Commitment with Division and Inertia of Governments. *Sustainability (Switzerland)*, *14*(22). https://doi.org/10.3390/su142215116

Piscitelli, A., & D'Uggento, A. M. (2022). Do young people really engage in sustainable behaviors in their lifestyles? *Social Indicators Research*, *163*(3), 1467–1485. https://doi.org/10.1007/s11205-022-02955-0

Santos-Hermosa, G., & Sánchez, J. E. (2010). Searching for academic information. *Openaccess.Uoc.Edu*. http://openaccess.uoc.edu/webapps/o2/handle/10609/125427

Thapa, R. K., Weldon, A., Freitas, T. T., Boullosa, D., Afonso, J., Granacher, U., & Ramirez-Campillo, R. (2024). What do we Know about Complex-Contrast Training? A Systematic Scoping Review. *Sports Medicine - Open*, *10*(1). https://doi.org/10.1186/s40798-024-00771-z

Tumanggor, R. O., Subekti, S., & Dariyo, A. (2022). The Study of Ecological Behavior of Youth in High School X in Jakarta. *IOP Conference Series: Earth and Environmental Science*, *1105*(1). https://doi.org/10.1088/1755-1315/1105/1/012025

Wekerle, C., Daumiller, M., Janke, S., Dickhäuser, O., Dresel, M., & Kollar, I. (2024). Putting ICAP to the test: how technology-enhanced learning activities are related to cognitive and affective-motivational learning outcomes in higher education. *Scientific Reports*, *14*(1), 1–8. https://doi.org/10.1038/s41598-024-66069-y

Zidny, R., & Eilks, I. (2020). Integrating perspectives from indigenous knowledge and Western science in secondary and higher chemistry learning to contribute to sustainability education. *Sustainable Chemistry and Pharmacy*, *16*. https://doi.org/10.1016/j.scp.2020.100229

Zjalic, D., Perilli, A., Nachira, L., Lanza, T. E., Santoli, G., Paladini, A., Ricciardi, W., & Cadeddu, C. (2023). Increasing urban health awareness in adolescents using an interactive approach: evidence from a school-based pre-post pilot study in Rome, Italy. *BMC Public Health*, *23*(1), 1–9. https://doi.org/10.1186/s12889-023-15778-6