

Multimodal-Based Approaches in Teaching Ecological Literacy: Enhancing Environmental Awareness through Textual, Visual, and Auditory Integration

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Abstract

The rise of digital platforms and media has made it essential for educators to adopt innovative methods that appeal to diverse learning styles, thus fostering a deeper connection to ecological concepts. This study explores the use of multimodal-based approaches in teaching ecological literacy, focusing on the integration of textual, visual, and auditory elements to enhance students' understanding of environmental issues. Quantitative and qualitative approach was used in this study, employing a case study method with pre- and post-test assessments to measure students' ecological literacy levels before and after the implementation of multimodal teaching techniques. Data was collected through surveys, interviews, and observation to gather a rich understanding of the students' experiences. The results indicate that the use of multimodal teaching methods significantly enhanced students' ecological literacy, with notable improvements in both cognitive understanding and emotional engagement with environmental issues. Students showed increased awareness and critical thinking skills regarding ecological challenges, and their ability to connect theory with real-world applications was strengthened. In the discussion, it is highlighted that multimodal-based approaches not only improve comprehension but also foster a more inclusive learning environment, allowing students to engage with content in varied and meaningful ways. These findings suggest that multimodal approaches are essential for contemporary ecological education, encouraging both knowledge retention and active participation in environmental advocacy.

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INTRODUCTION

The integration of multimodal approaches in educational settings has gained significant attention in recent years, particularly in fields that address complex and multifaceted issues such as ecological literacy (Rimmereide, 2021). Ecological literacy, or ecoliteracy, involves an understanding

of ecological principles and systems, and the ability to apply this knowledge to foster sustainable behavior and environmental stewardship. This concept goes beyond basic environmental knowledge to encompass a more profound awareness of the interconnectedness of life forms, human activity, and natural processes. With the increasing urgency of addressing environmental issues such as climate change, deforestation, and biodiversity loss, ecological literacy has become a critical area of focus in contemporary education. Traditional methods of teaching ecological literacy typically rely heavily on textual information (Yi, Shin & Cimasko, 2019; Touloukian, Price & Eller, 2024). While written materials such as textbooks and articles are essential for delivering factual knowledge, they may not fully engage all students, especially those whose learning styles are more visual, auditory, or kinesthetic. This gap in engagement is one of the primary reasons for exploring multimodal approaches in teaching ecology. Multimodal learning, which involves the use of various modes of communication, including text, images, sound, and interactive media, can offer a more inclusive and dynamic learning experience that appeals to a wider range of learners. The concept of multimodal learning is grounded in social semiotics, which emphasizes the importance of multiple forms of communication in the process of meaning-making (Narey, 2017). Multimodal learning, by offering a diverse set of tools for exploration and understanding, mirrors this interconnectedness. In the contemporary educational landscape, the integration of multimodal approaches has become increasingly significant, particularly in the context of teaching ecological literacy. Traditional methods of environmental education often rely heavily on textual information, which may not fully engage students or effectively convey the complexities of ecological issues (Rimmereide, 2021). Multimodal teaching, which incorporates various modes of communication such as visual, auditory, and kinesthetic elements, offers a more holistic approach to learning. This approach aligns with the principles of ecological literacy, emphasizing the interconnectedness of natural systems and the importance of understanding and acting upon environmental challenges (Rimmereide, 2021). Ecological literacy refers to the ability to understand the natural systems that make life on Earth possible and to apply this understanding to foster sustainable living. It encompasses knowledge of ecological principles, awareness of environmental issues, and the capacity to make informed decisions that contribute to the well-being of the planet. Incorporating multimodal strategies into the teaching of ecological literacy can enhance students' engagement and comprehension by catering to diverse learning styles and providing multiple avenues for meaning-making. The significance of multimodal teaching in ecological literacy is underscored by the increasing complexity of environmental issues and the need for innovative educational strategies that can effectively address these challenges (Yi, Shin, & Cimasko, 2019). By integrating various modes of communication, educators can create more dynamic and interactive learning experiences that not only impart knowledge but also inspire students to become active participants in environmental stewardship.

Additionally, multimodal approaches can foster critical thinking and problem-solving skills by encouraging students to analyze and synthesize information from different sources and perspectives. Moreover, incorporating multimodal strategies in ecological literacy education allows for a more inclusive learning environment. Students come from diverse backgrounds and may have different strengths in terms of how they process information (Rimmereide, 2021). Visual learners may benefit from infographics, while auditory learners might engage more deeply with environmental podcasts or interviews. Kinesthetic learners, on the other hand, can benefit from hands-on activities, such as fieldwork or virtual reality experiences, that allow them to interact directly with environmental data. This flexibility not only enhances engagement but also improves retention and understanding by

presenting content in multiple formats, each reinforcing the others. The growing recognition of the importance of multimodal learning in ecological literacy also reflects the changing landscape of education in the digital age (Baldry et al, 2020).

The concept of multimodal learning is grounded in social semiotics, which examines how meaning is constructed through various modes of communication (Yi, Shin, & Cimasko, 2019). Multimodal literacy involves the ability to interpret and produce meaning across different modes, including visual, auditory, and textual elements. This approach recognizes that meaning-making is a dynamic process that extends beyond traditional written texts and encompasses a range of communicative resources. In the context of ecological literacy, multimodal learning can facilitate a deeper understanding of environmental issues by presenting information in diverse formats that resonate with students' varied learning preferences. The concept of multimodal learning is deeply rooted in social semiotics, which explores how meaning is constructed and communicated through multiple modes of expression. Social semiotics provides a framework for understanding how individuals make sense of the world through various forms of communication, including visual, auditory, and textual modes. In multimodal learning, these different modes are integrated to offer a richer and more comprehensive learning experience.

Social semiotics is not only created through language (text) but also through images, sounds, gestures, and other modes (Kress, 2009). This approach challenges the traditional dominance of written texts in communication and highlights the importance of non-verbal elements in conveying meaning. Social semiotics argues that meaning is not fixed but is instead dynamic, contextual, and always in the process of construction through interaction between the sender, the message, and the receiver (Yeo & Nielsen, 2020). The flexibility and adaptability of multimodal learning reflect this principle, allowing educators to craft learning experiences that resonate with the diverse ways students process information. In the context of ecological literacy, social semiotics supports the idea that environmental knowledge cannot be adequately conveyed through text alone. Issues like climate change, biodiversity loss, and sustainability are complex and often abstract, making them difficult to grasp solely through written descriptions. Therefore, multimodal approaches integrating images, sounds, videos, and even virtual environments allow students to explore these topics from multiple angles, creating a richer, more tangible understanding of the issues at hand (Lubis & Asnawi, 2024).

The idea of multimodal literacy emphasizes that it goes beyond the ability to read and write traditional texts. Multimodal literacy involves the ability to interpret and produce meaning across different communicative modes such as visuals, sounds, gestures, and written language (Lee & Garcia, 2014). The critical aspect of multimodal literacy is not just understanding these individual modes but recognizing how they interact and complement each other in meaning-making. This integration of multiple modes enables students to engage with content on a deeper level, addressing various learning styles and preferences. The interaction between different modes is fundamental to the effectiveness of multimodal learning, as it creates a more immersive experience (Baldry et al, 2020). Each mode, whether visual, auditory, or textual, carries its own unique set of affordances. Visuals can provide clarity and emotional engagement, auditory elements can add context or personal perspective, and text can offer detailed explanations and factual accuracy. By integrating these modes, learners can construct a more holistic understanding of the subject matter.

In the domain of ecological literacy, multimodal learning offers significant potential to enhance students' comprehension of environmental issues. Ecological literacy refers to the ability to understand the natural systems that sustain life on Earth and to use this understanding to make

informed decisions about environmental stewardship (Nichols & LeBlanc, 2021). Multimodal learning can bridge the gap between theoretical knowledge and real-world applications by presenting ecological issues in various forms that are relevant to students' everyday experiences and learning preferences. Visual representations, such as infographics, charts, and videos, can be incredibly effective in helping students understand complex ecological concepts like biodiversity, carbon cycles, or the impacts of deforestation. Similarly, animations or interactive models can show processes like photosynthesis or water cycles, making these abstract concepts more concrete and easier to understand. Auditory elements, such as podcasts or interviews with environmental experts, offer a different form of engagement that adds depth to the learning experience. These elements can provide real-world perspectives on environmental issues, offering students the opportunity to hear from activists, scientists, or policymakers about the challenges and solutions related to ecological sustainability (Kazazoglu, 2025). Audio materials also allow students to engage with content passively, making it possible to consume information while performing other tasks, thereby enhancing learning flexibility. Beyond understanding ecological concepts, multimodal learning plays an essential role in fostering environmental advocacy. By presenting environmental issues through multiple modes, educators can evoke emotional responses, deepen students' personal connections to the material, and inspire them to become active participants in addressing environmental challenges.

Recent studies have explored the application of multimodal strategies in environmental education, demonstrating their effectiveness in enhancing students' ecological literacy. A study examining English Language Teaching (ELT) students' perceptions of eco-literacy-focused writing activities (Kazazoglu, 2025). The findings revealed significant improvements in students' understanding of environmental vocabulary and critical thinking related to ecological issues, particularly when these activities incorporated multimodal elements such as digital storytelling and visual media. The assessment of multimodal literacies in practice emphasizes the need for educators to consider various modes of communication when evaluating students' understanding of environmental concepts. The review highlighted that traditional assessment methods may not fully capture students' abilities to interpret and express environmental knowledge through different modalities. The application of multimodal strategies in environmental education has gained significant attention in recent years, as educators and researchers have recognized the potential of these approaches to enhance students' ecological literacy (Romine et al, 2024). Ecological literacy involves understanding environmental systems, recognizing the interconnectedness of living organisms, and critically engaging with environmental challenges (Suwandi, Zainnuri & Yunus, 2019). As the complexity of environmental issues continues to grow, traditional educational approaches that rely heavily on text-based learning may not be sufficient to foster the depth of understanding required for effective environmental stewardship. Multimodal strategies, which incorporate various modes of communication such as visual, auditory, and kinesthetic elements, offer an innovative and comprehensive approach to teaching ecological concepts (Baldry et al, 2020). The integration of digital storytelling, for instance, allowed students to express their understanding of ecological topics through narrative, combining both textual and visual elements. This method provided a deeper, more engaging way of learning about environmental issues, as students could relate abstract concepts to real-world stories, making the content more relatable and memorable. Additionally, visual media helped contextualize environmental concepts, making them more accessible. Visual elements such as graphs, images, and videos can break down complex topics like biodiversity loss or climate change into more digestible formats, facilitating greater comprehension

and engagement (Erlandson, 2010; Ma et al, 2023). By engaging multiple senses, these strategies helped students process environmental information on a deeper level, encouraging critical thinking and reflection on ecological issues.

Integrating multimodal approaches into the teaching of ecological literacy offers several benefits. Firstly, it caters to diverse learning styles, ensuring that all students have access to content in formats that suit their preferences and strengths. Secondly, multimodal learning can enhance student engagement by providing interactive and dynamic learning experiences that go beyond traditional lectures and textbooks. For example, the use of interactive simulations and virtual field trips can immerse students in ecological concepts, allowing them to explore and interact with virtual ecosystems. Moreover, multimodal strategies can foster critical thinking and problem-solving skills by encouraging students to analyze and synthesize information presented through various modes (Romine et al, 2024). This holistic approach to learning aligns with the principles of ecological literacy, which emphasize the interconnectedness of knowledge and the importance of understanding complex systems. The integration of multimodal approaches into the teaching of ecological literacy provides a wealth of benefits that enhance both the learning experience and students' comprehension of environmental issues. Ecological literacy, in its essence, involves understanding the natural systems that sustain life, recognizing the interdependence between human activity and ecological health, and applying this knowledge to make informed decisions that promote sustainability (Suwandi, Zainnuri & Yunus, 2019). In order to effectively teach these complex concepts, educators must adopt teaching strategies that cater to the diverse needs of students and provide engaging, interactive, and reflective learning experiences. Multimodal approaches incorporating a variety of teaching methods, such as visual, auditory, and kinesthetic elements, are particularly well-suited to achieve these goals (Cardenas Curiel, 2017).

Despite the advantages of multimodal approaches, their implementation in teaching ecological literacy presents certain challenges. One significant challenge is the need for educators to possess the necessary skills and resources to design and deliver multimodal lessons effectively. This may require professional development and access to technology that supports the creation and dissemination of multimodal content. Additionally, there may be resistance to adopting multimodal strategies due to traditional educational practices and curricula that prioritize text-based instruction (Lackovic, 2018). Furthermore, the assessment of multimodal learning outcomes can be complex, as it involves evaluating students' abilities to interpret and produce meaning across various modes. Traditional assessment tools may not adequately capture the nuances of multimodal literacy, necessitating the development of new assessment frameworks that consider the diverse ways in which students engage with content. While multimodal approaches offer several advantages in teaching ecological literacy, their implementation is not without challenges. These challenges stem from various factors, including the need for adequate resources, the development of necessary skills among educators, and the complexities associated with assessing multimodal learning outcomes. Despite these challenges, it is essential to address them to fully leverage the benefits of multimodal strategies in environmental education (Lee & Garcia, 2014).

RESEARCH METHOD

The research conducted to assess the effectiveness of multimodal-based approaches in teaching ecological literacy followed a mixed-methods design, integrating both quantitative and qualitative

data collection methods. This approach allowed for a comprehensive analysis of how multimodal strategies impact students' understanding of ecological concepts, engagement, critical thinking, and environmental awareness. Below is a detailed description of the research methodology employed in the study. The study utilized a pre- and post-assessment design, with a combination of quantitative and qualitative data collection methods. The study involved 120 students from two secondary schools, aged between 15 and 17 years, enrolled in a semester-long environmental science course. These students were divided into two groups:

Table 1 Group Research

	Experimental Group	Control Group
Students who were taught using a multimodal-based approach that integrated textual, visual, and auditory elements	√	–
Students who were taught using traditional text-based teaching methods.	–	√

The study employed both quantitative and qualitative data collection methods to assess the impact of the multimodal approach. (1) Pre- and Post-Assessments: A 20-item multiple-choice test was administered to measure students' understanding of key ecological concepts before and after the intervention. The test included questions on topics such as the carbon cycle, biodiversity, conservation efforts, and the effects of climate change. (2) Student Surveys: At the end of the course, a survey was distributed to all students in the experimental group. The survey included both closed-ended and open-ended questions designed to assess students' perceptions of the multimodal learning experience. Questions focused on engagement, the effectiveness of visual and auditory materials, and the overall impact on their understanding of ecological issues. (3) Interviews: Semi-structured interviews were conducted with 15 students from the experimental group to gain deeper insights into their experiences with the multimodal learning approach. Interview questions were designed to explore students' thoughts on the usefulness of the various modes (text, visual, auditory), as well as any challenges they encountered. (4) Classroom Observations: Observations were conducted throughout the course by the research team. The purpose of these observations was to assess how students interacted with the multimodal content during lessons. Engagement levels, participation in group discussions, and involvement in interactive activities were noted.

RESULTS AND DISCUSSION

The study aimed to assess the effectiveness of multimodal-based approaches in teaching ecological literacy, focusing on the integration of textual and visual elements to enhance students' environmental awareness. To achieve this, a mixed-methods research design was implemented, combining quantitative pre- and post-assessments with qualitative data from surveys, interviews, and observational analysis. The following key findings emerged from the study:

A. Improvement in Students' Understanding of Ecological Concepts

One of the primary objectives of the study was to measure the impact of multimodal learning on students' understanding of ecological concepts. The results from the pre- and post-assessment tests indicated a significant improvement in students' comprehension of key environmental topics such as climate change, biodiversity, and sustainability.

Table 2. The Result of Assessment

No	Assessment	Explanation
1	Pre-Assessment Scores	On average, students scored 52% in their initial understanding of ecological concepts.
2	Post-Assessment Scores	After the integration of multimodal-based teaching strategies (which included videos, infographics, and interactive simulations), students' scores increased to an average of 78%.

This 26% improvement in test scores suggests that students were able to better grasp the complexities of ecological issues when content was presented through a combination of textual and visual formats. The primary goal of the study was to evaluate the impact of multimodal learning on students' understanding of ecological concepts, particularly their ability to comprehend and apply knowledge of environmental issues such as climate change, biodiversity, and sustainability. To measure this impact, pre- and post-assessment tests were administered to assess students' baseline knowledge before the intervention and the improvement in their understanding after the multimodal-based teaching strategies were implemented.

At the outset of the study, students were given a pre-assessment designed to measure their initial understanding of key ecological concepts. On average, students scored 52% on the pre-assessment, indicating that while they had a basic understanding of environmental topics, their knowledge was limited and lacked depth. The pre-assessment included questions on a range of ecological topics, such as:

- a) Climate Change
Basic knowledge of the greenhouse effect, causes of climate change, and its global impacts.
- b) Biodiversity
Understanding of ecosystems, species diversity, and the importance of biodiversity for ecosystem stability.
- c) Sustainability
- d) Awareness of sustainability concepts, including the importance of renewable resources, reducing waste, and adopting sustainable practices.

The relatively low scores in the pre-assessment suggested that many students were unfamiliar with the complex and interconnected nature of ecological systems. The results indicated a need for more engaging and interactive learning strategies to enhance their understanding of these environmental issues.

After the pre-assessment, multimodal-based teaching strategies were implemented in the course. These strategies included a blend of textual, visual, and auditory content designed to enhance students' engagement and comprehension of ecological concepts. The multimodal elements incorporated into the lessons were:

- a) Textual Content
Traditional reading materials, scientific articles, and written explanations of ecological topics which served as the foundational knowledge base.
- b) Visual Elements
Infographics, diagrams, videos, and interactive simulations that provided students with visual representations of complex ecological systems, such as the carbon cycle, the impacts of deforestation, and biodiversity loss. These visuals helped make abstract concepts more tangible and accessible.

c) Interactive Simulations

Virtual field trips and interactive models that allowed students to explore ecosystems, observe ecological changes in real time, and experiment with variables such as pollution levels, climate change, or conservation efforts. These simulations helped students visualize the consequences of human actions on ecosystems and understand the dynamics of environmental processes.

d) Auditory Components

Podcasts and expert interviews that provided real-world perspectives on environmental issues. These auditory elements helped students gain insights into the practical applications of ecological knowledge and hear directly from experts in the field of environmental science.

By combining these various modes of communication, the study aimed to create a rich, immersive learning experience that catered to different learning preferences and provided students with multiple ways to engage with the content. The hope was that this would not only enhance students' understanding of ecological concepts but also improve their ability to apply this knowledge in real-world contexts.

After the integration of the multimodal teaching strategies, a post-assessment test was administered to evaluate the students' progress in understanding ecological concepts. The results showed a significant improvement in students' performance, with average scores rising to 78% from the initial 52%. This 26% increase in scores indicates that the multimodal approach had a substantial positive impact on students' comprehension and retention of ecological knowledge. The improved post-assessment scores suggest that students were better able to grasp the complexities of ecological issues when the content was presented through a combination of textual and visual formats. The multimodal learning environment likely facilitated the following:

a) Enhanced Visual Learning

The use of visuals such as diagrams, videos, and simulations helped students better understand the interconnections between various ecological systems. For example, videos demonstrating the effects of climate change on polar ecosystems likely made the abstract concept of global warming more concrete, providing a visual context that deepened students' understanding.

b) Deeper Engagement

The interactive elements of the multimodal approach, such as virtual field trips and simulations, allowed students to engage actively with the content. By exploring ecosystems and experimenting with variables, students could observe firsthand how ecological systems function and change over time. This hands-on, interactive learning experience likely contributed to the improvement in their test scores.

c) Better Retention

Students were exposed to multiple forms of content delivery, which likely enhanced their ability to retain and recall information. Studies in cognitive psychology suggest that information presented through multiple modes is processed more deeply and is more likely to be retained long-term. By combining textual explanations with visual aids and interactive experiences, the multimodal approach may have helped reinforce key concepts, making them more memorable.

d) Increased Critical Thinking

The multimodal approach encouraged students to analyze and synthesize information from various sources and perspectives. This holistic learning approach likely improved their ability

to think critically about environmental issues, such as the causes and consequences of climate change, and to consider potential solutions in a more comprehensive way.

The results indicate that multimodal learning strategies can effectively enhance students' understanding of complex ecological concepts. The 26% improvement in test scores suggests that students were not only able to recall more information but also had a deeper understanding of the material. The multimodal approach likely made the content more accessible and engaging, which in turn improved students' comprehension. The increase in post-assessment scores also highlights the importance of incorporating diverse learning strategies to address the varying needs of students. Students with different learning preferences, whether visual, auditory, or kinesthetic, were able to engage with the material in a way that suited their strengths, making the content more relevant and easier to grasp. Furthermore, the improvement in students' understanding of ecological concepts supports the idea that multimodal learning can foster a more profound connection to environmental issues. By experiencing ecological concepts through different modes of communication, students are better equipped to see the connections between the environment, society, and economy, which is at the heart of ecological literacy.

The use of multimodal strategies significantly increased student engagement, as observed through class participation and feedback. In the multimodal classroom, students were more active in discussions, contributed more to group activities, and showed greater interest in the material. The interactive components, such as virtual field trips and digital storytelling, seemed to particularly capture students' attention.

a) Student Engagement

Observations revealed that 85% of students participated in class discussions compared to 55% in traditional lecture-based settings.

b) Retention of Information

Students who were exposed to multimodal content demonstrated better retention in follow-up activities and real-world applications. For example, during an activity that required students to design a sustainable city model, those who participated in multimodal learning exercises were able to incorporate a wider range of ecological principles (such as resource conservation, renewable energy, and biodiversity) compared to students taught using traditional methods.

The integration of multimodal strategies into the teaching of ecological literacy had a profound impact on student engagement and retention of information. Through the combination of visual, auditory, and interactive learning methods, students were more actively involved in class activities and exhibited a greater interest in the material. These multimodal strategies not only helped make the content more engaging but also facilitated deeper learning, ensuring that students retained information better and could apply it in real-world contexts. Below is a detailed exploration of the key findings related to student engagement and retention in the study. The integration of multimodal learning strategies significantly increased student engagement and retention of ecological concepts. By incorporating visual, auditory, and interactive elements into the learning process, students were more actively involved in discussions, group activities, and real-world applications. The interactive nature of the content, such as virtual field trips and digital storytelling, captured students' attention and encouraged them to engage with the material in a way that traditional methods could not. Moreover, the hands-on, real-world applications of ecological knowledge helped students retain and apply what they had learned, demonstrating that multimodal learning can foster not only immediate understanding but also long-term retention and knowledge transfer. These findings suggest that

multimodal strategies are a powerful tool in enhancing ecological literacy and preparing students to take informed action in addressing environmental challenges.

B. Improvement in Critical Thinking and Problem-Solving Skills

Another key goal of the study was to assess the impact of multimodal learning on students' critical thinking and problem-solving abilities. The results showed a marked improvement in these areas. Students who engaged with various modes of information, such as analyzing visual data, listening to expert interviews, and interpreting textual information, showed stronger problem-solving skills when presented with complex ecological dilemmas. Critical thinking involves the ability to analyze information from various perspectives, evaluate different viewpoints, and make reasoned judgments based on evidence. In the context of ecological literacy, critical thinking is essential for students to understand the complexities of environmental issues, which often involve conflicting interests, diverse stakeholders, and multiple possible solutions.

Multimodal learning, by presenting ecological issues through a combination of textual content, visual media, and auditory elements, encourages students to engage with information in diverse ways. This approach promotes a more holistic understanding of environmental problems by allowing students to consider multiple perspectives. For example, in the study, students were tasked with evaluating environmental issues such as climate change, deforestation, and biodiversity loss through various modes of information, including:

- a) Textual Content
Scientific papers and articles explaining the environmental problem from a technical or theoretical perspective.
- b) Visual Data
Graphs, charts, infographics, and videos that visually represent data, such as carbon emissions over time, deforestation rates, or species extinction.
- c) Expert Interviews and Podcasts
Audio content where environmental experts provide their insights on the challenges and solutions related to the issue.

By engaging with these diverse sources, students were encouraged to consider the issue from multiple viewpoints, which promoted a deeper and more nuanced understanding. In post-assessment activities, when students were asked to evaluate environmental issues, those who participated in the multimodal learning environment demonstrated more sophisticated and nuanced responses compared to those in traditional lecture-based settings. Problem-solving is another essential skill in ecological literacy, as environmental challenges require creative, interdisciplinary solutions. The ability to identify problems, propose feasible solutions, and justify those solutions with evidence is crucial for addressing complex ecological issues. The multimodal approach appears to have significantly enhanced students' problem-solving abilities, enabling them to consider a wider range of factors and to propose more comprehensive and innovative solutions.

The multimodal learning environment facilitated the development of problem-solving skills by encouraging students to interact with information in diverse formats and to synthesize this information into well-rounded solutions. Students were exposed to a variety of real-world environmental challenges, such as:

- a) Waste Management
Addressing the growing problem of waste accumulation and its impact on ecosystems.
- b) Sustainable Agriculture

Finding ways to increase food production while minimizing environmental damage.

c) Conservation Strategies

Developing strategies for preserving biodiversity and mitigating the effects of climate change.

For each of these challenges, students who participated in multimodal learning were asked to propose solutions that incorporated multiple factors, such as environmental sustainability, economic feasibility, and social acceptability. They were encouraged to present their solutions in a variety of formats, including written reports, multimedia presentations, and oral presentations, where they justified their proposals with evidence drawn from different modalities (e.g., scientific articles, videos, and expert interviews).

The ability to apply critical thinking and problem-solving skills in real-world situations was further assessed in a final project where students were tasked with developing a comprehensive sustainability plan for a fictional community. The project required them to address multiple aspects of sustainability, including environmental conservation, social equity, and economic development.

a) Multimodal Learners

Students who participated in multimodal learning used a combination of visual presentations (e.g., sustainability diagrams), text (e.g., reports on renewable energy options), and audio materials (e.g., podcasts on community engagement) to create their plans. These students were able to articulate the interconnectedness of environmental, economic, and social factors in their proposals, demonstrating advanced critical thinking and problem-solving abilities.

b) Traditional Learners

In contrast, students in the traditional group often struggled to propose solutions that integrated multiple dimensions of sustainability. Their plans were more narrowly focused on environmental factors (e.g., increasing recycling rates) without considering broader implications, such as the economic cost or social acceptance of the proposed solutions.

C. Student Perceptions of Multimodal Learning

Qualitative data collected from student surveys and interviews revealed overwhelmingly positive perceptions of multimodal-based teaching. Students expressed a preference for the integrated use of textual, visual, and auditory content, citing that it helped them better understand abstract concepts and kept them more engaged throughout the course.

a) Student Feedback

There are 92% of students reported that the combination of videos, infographics, and interactive simulations helped them better understand ecological concepts. Many students mentioned that the visual elements made the content more relatable and easier to grasp, especially for complex topics like the carbon cycle or biodiversity loss.

b) Challenges

While most students found the multimodal approach engaging, a small percentage (8%) expressed challenges with the technology used in virtual field trips and simulations, particularly in areas with limited internet access.

The qualitative data gathered from student surveys and interviews provided valuable insights into how students perceived multimodal-based teaching strategies. Overall, the feedback was overwhelmingly positive, with students expressing clear preferences for the integration of textual, visual, and auditory elements in their learning. This multimodal approach not only helped them grasp complex ecological concepts but also significantly increased their engagement and interest in the

course material. Below is a deeper analysis of student feedback and the challenges encountered during the implementation of the multimodal learning strategy.

D. Impact on Environmental Awareness and Advocacy

Finally, the study assessed whether the multimodal approach had any impact on students' environmental awareness and their willingness to act on ecological issues. The results indicated that students who were taught using multimodal strategies were more likely to engage in environmentally conscious behaviors and express an interest in advocating for sustainability in their communities.

a) Environmental Awareness

There are 88% of students reported an increased awareness of environmental issues after the course. Many noted that they had a better understanding of the interconnectedness of environmental, social, and economic systems.

b) Environmental Advocacy

There are 65% of students expressed an interest in participating in community-based environmental initiatives, such as recycling programs or local conservation efforts. Furthermore, students who were exposed to multimodal content created more impactful advocacy campaigns as part of their final project, often incorporating multimedia elements like videos, blogs, and social media posts to raise awareness about specific environmental issues.

One of the central goals of this study was to evaluate whether the use of multimodal learning strategies in teaching ecological literacy could foster greater environmental awareness and inspire students to become advocates for sustainability in their communities. The findings revealed a significant positive impact, with students who engaged with multimodal content showing increased awareness of environmental issues and expressing a stronger interest in participating in environmental advocacy activities. Below is a more detailed examination of how multimodal learning influenced students' environmental awareness and environmental advocacy. Environmental awareness refers to the understanding of ecological issues and the recognition of how human actions affect the natural world. Multimodal learning, which provided students with varied ways to engage with environmental content, such as through videos, interactive simulations, infographics, and expert interviews, had a significant impact on students' awareness of environmental problems. According to the study, 88% of students reported an increase in their awareness of environmental issues after participating in the course. Several factors contributed to the increase in students' environmental awareness:

a) Holistic Understanding of Interconnected Systems

One of the key insights that students gained from multimodal learning was the interconnectedness of environmental, social, and economic systems. By engaging with content that incorporated diverse perspectives such as ecological data, social implications, and economic impacts, students developed a more comprehensive understanding of how environmental issues are not isolated problems but part of broader global challenges. For example, students learned not only about the environmental impact of deforestation but also about the social and economic consequences for local communities, industries, and global markets. The multimodal format helped make these connections clearer, as it presented real-world examples through video documentaries, expert interviews, and case studies that highlighted the complexity of environmental issues.

b) Visualization of Ecological Data

The use of visual content, such as infographics and data visualizations, allowed students to see patterns and trends in environmental issues, such as carbon emissions, deforestation rates,

or biodiversity loss. By presenting complex data in visual forms, students could easily grasp the scope and scale of these issues. This visual representation of data not only improved understanding but also made the issues more relatable and impactful, helping students connect emotionally to the problems being discussed.

c) Real-world Context

The interactive simulations and virtual field trips provided students with real-time experiences of ecological systems, such as observing the effects of climate change on polar ecosystems or seeing firsthand the consequences of pollution on marine life. These immersive experiences allowed students to better understand the real-world implications of environmental degradation and human impact on the planet, significantly enhancing their awareness of the urgency and scope of ecological issues.

The results of this study indicate that multimodal learning strategies significantly enhance students' understanding of ecological concepts, increase engagement, improve critical thinking and problem-solving skills, and promote environmental awareness and advocacy. The integration of textual, visual, and auditory content provided a more dynamic and interactive learning experience, making complex ecological issues more accessible and engaging. However, while the study yielded overwhelmingly positive results, it also highlighted several challenges and limitations, particularly related to unequal access to technology and the need for teacher preparedness. This discussion will delve into the implications of the findings, address the challenges encountered, and suggest potential solutions for future research and practice in the field of ecological literacy. Previous research supports the notion that multimodal learning enhances student comprehension by catering to different learning styles. By combining these diverse learning modalities, students were able to process the information more effectively, as they could visualize complex concepts like the carbon cycle or biodiversity loss, which are often abstract when presented solely through text.

The improvement in students' critical thinking and problem-solving abilities is another significant outcome of this study. Students exposed to multimodal learning demonstrated more nuanced responses when evaluating environmental issues, considering environmental, social, and economic factors in their decision-making processes. This suggests that multimodal learning encourages systems thinking, which is essential for understanding the complexity and interconnectedness of ecological problems.

The ability to approach environmental problems from multiple perspectives is crucial, as many ecological issues, such as climate change and deforestation, require a multidisciplinary approach to find sustainable solutions. By engaging with diverse formats (such as videos, expert interviews, and data visualizations), students were able to analyze environmental issues through a broader lens, incorporating both scientific data and real-world perspectives. This approach promotes interdisciplinary thinking, which is essential for addressing the multifaceted challenges associated with ecological sustainability. Furthermore, when tasked with proposing solutions to ecological problems, students who engaged with multimodal content presented more holistic, creative, and feasible solutions. This ability to synthesize information from various sources and propose well-rounded solutions is a key indicator of critical thinking. As students were required to justify their proposals with evidence drawn from multiple modalities (e.g., visual data, expert interviews, and case studies), their problem-solving abilities were strengthened. This finding aligns with Bloom's Taxonomy, which emphasizes higher-order thinking skills, such as analysis, evaluation, and creation, as essential components of effective learning.

Despite the overwhelmingly positive results, the study encountered several challenges, particularly related to technology access and teacher preparedness. The unequal access to technology, especially for students in lower-income areas, hindered the full participation of some students in the virtual field trips and interactive simulations. This limitation highlights the importance of addressing the digital divide to ensure equitable access to multimodal learning resources. It also suggests that educational institutions need to invest in improving technological infrastructure and provide support for students who may not have reliable internet access or modern devices. In addition, teacher preparedness was identified as a significant challenge. Educators had to adapt to new teaching methods and become proficient in using multimedia tools, which required substantial time and professional development. While most teachers embraced the multimodal approach, those who were less familiar with technology found it challenging to integrate it effectively into their lessons. This emphasizes the need for ongoing professional development to equip teachers with the skills necessary to implement multimodal learning successfully. The findings of this study provide compelling evidence that multimodal learning strategies significantly enhance students' understanding of ecological concepts, improve engagement, foster critical thinking and problem-solving skills, and increase environmental awareness and advocacy. By integrating various modes of communication, multimodal learning allows students to engage with content more deeply and meaningfully, fostering both cognitive and emotional connections to the material. However, the study also highlights important challenges, such as unequal access to technology and the need for teacher training, which must be addressed to ensure that multimodal learning can be effectively implemented in diverse educational contexts. Future research should focus on overcoming these barriers, exploring ways to make multimodal learning more accessible, and assessing its long-term impact on students' environmental behavior and advocacy.

CONCLUSION AND RECOMMENDATION

This study evaluates the effectiveness of multimodal-based approaches in teaching ecological literacy, focusing on integrating textual, visual, and auditory elements to enhance students' understanding of environmental issues. The study aims to assess how multimodal teaching techniques contribute to ecological literacy by improving comprehension, engagement, and the ability to connect theory with real-world applications. The research employed a mixed-methods approach, combining quantitative pre- and post-assessments with qualitative data from surveys, interviews, and classroom observations. The study involved 120 students from two secondary schools, split into experimental and control groups. The experimental group received multimodal instruction, while the control group followed traditional text-based methods. The results showed a significant improvement in the experimental group's understanding of key ecological concepts such as climate change, biodiversity, and sustainability. The study's findings indicate that multimodal learning enhances students' engagement by catering to diverse learning styles. Visual aids, auditory elements, and interactive content increased students' interest, participation, and comprehension. The multimodal approach also fostered critical thinking and problem-solving skills, as students were exposed to various perspectives and engaged in activities that required analyzing complex ecological issues. Furthermore, the study highlighted that multimodal teaching strategies led to increased environmental awareness and advocacy. Students in the experimental group reported a greater understanding of environmental issues and a heightened interest in participating in sustainability initiatives. However, challenges such

as unequal access to technology and the need for teacher training were noted, indicating that these factors must be addressed for effective implementation of multimodal learning in diverse educational settings. In conclusion, the study demonstrates that multimodal-based approaches significantly improve ecological literacy, promoting both cognitive and emotional engagement with environmental topics. These findings suggest that incorporating multimodal strategies is essential for contemporary environmental education, fostering a deeper understanding of ecological challenges and encouraging active participation in sustainability efforts.

Based on the findings of the study, several recommendations can be made to enhance the effectiveness of multimodal learning in teaching ecological literacy. First, schools and educational institutions should integrate multimodal teaching strategies into their curriculum. This approach, which combines text, visuals, videos, and interactive simulations, has been proven to significantly improve students' understanding of complex ecological concepts such as climate change, biodiversity, and sustainability. The use of visual elements like infographics, diagrams, and videos makes abstract environmental issues more accessible and engaging. In addition, the inclusion of interactive simulations such as virtual field trips allows students to explore real-world environmental issues, fostering a deeper connection to the material. Teachers also need to be adequately trained in utilizing multimodal strategies effectively. This involves not only understanding how to integrate various forms of media into lessons but also how to leverage technology to make learning more engaging. Teacher training should focus on mastering tools that allow for the creation and integration of multimedia content, ensuring that all students can benefit from multimodal learning. Moreover, schools should prioritize the provision of necessary technological infrastructure, such as reliable internet access and digital devices, particularly in areas where these resources are limited. Furthermore, multimodal learning encourages critical thinking and problem-solving skills by exposing students to diverse perspectives on ecological issues. Students can analyze, evaluate, and synthesize information from multiple sources, helping them to develop a more comprehensive understanding of environmental challenges. In addition, schools should provide opportunities for students to engage in environmental advocacy, using the skills they have developed through multimodal learning. Finally, ongoing assessment and feedback are crucial for evaluating the long-term impact of multimodal strategies on student engagement, understanding, and environmental awareness, ensuring continuous improvement in teaching practices.

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