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Diversifying Eco-Education: Pedagogical Tools for High Schools

CHALLENGES AND ALTERNATIVES IN TEACHING HIGH SCHOOL TEACHERS IN ECOLOGY: THE USE OF PEDAGOGICAL TOOLS TO DIVERSIFY TEACHING PRACTICE

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Abstract: Ecology teachers hold a pivotal role in shaping the environmental engagement of future generations. Starting from the need to face urgent environmental challenges, such as climate change and loss of biodiversity, the importance of an interdisciplinary and practical educational approach to form ecologically ethical decision-making citizens is highlighted. This study presents a summary of educational practices developed to promote student understanding and engagement with the principles of ecology. Educational practices focused on different aspects of ecology were developed. Each practice was created with simple, low-cost materials, facilitating replication in different educational contexts. The methods included creating materials, organizing game dynamics, and implementing activities in the classroom. In the results we present six pedagogical alternatives to teach ecology from individuals to ecosystems concepts, revealed that all practices were effective in promoting students' understanding of ecological concepts. Students report greater engagement and interest in classes, as well as a deeper understanding of ecological principles after participating in the proposed activities. Furthermore, the practices facilitated interaction between students, providing collaboration and teamwork. In conclusion, the educational practices developed were a valuable tool for promoting student understanding and engagement with the principles of ecology. The interdisciplinary and practical approach applied in these practices provided a more meaningful and engaging learning experience, training students to become ecologically conscious citizens capable of facing the environmental challenges of the 21st century.

Key-words: Ecological literacy; Educational innovation; Environmental education; Pedagogical strategies.

INTRODUCTION

In the face of climate change and habitat loss, there is an urgent need to revolutionize Ecology education (D'Avanzo 2003). Equipping educators and students to address these environmental issues is crucial for planetary survival (Spires *et al*. 2009). Conventional teaching methods may fall short in capturing the complexities of contemporary ecological challenges. Reflecting on and innovating educational strategies is essential, requiring a reevaluation of curricula and instructional techniques (Randler 2008). Alternative teaching methods integrate perspectives from diverse disciplines, emphasizing the interconnectedness of ecological systems (Zembylas 2007, Albuquerque *et al*. 2024). By reimagining Ecology education, we can empower individuals to navigate environmental challenges and become stewards of the environment, fostering a sustainable coexistence with nature.

Throughout the history of ecological education, traditional teaching methods have effectively conveyed fundamental ecological principles. However, the complexities of contemporary environmental issues require a more adaptable and dynamic approach, equipping students with critical thinking skills for real-world dilemmas (Motokane 2015, Byrne *et al*. 2025). This necessitates a critical examination of established teaching methodologies to discern the need for a transformative shift. Moving beyond rote memorization, inquiry-based learning approaches are essential, integrating interdisciplinary perspectives and hands-on fieldwork (Finn *et al*. 2002, Seniciato & Cavassan 2009, Hamilton-Ekeke 2007, Xiong *et al.* 2025). Recalibrating instructional methods is imperative in addressing urgent and complex environmental challenges, ensuring that education evolves to equip students who will be future teachers as effective environmental stewards (Maciel & Uhmann 2020, Cooke *et al*. 2021). By redefining how we teach Ecology is taught in science teacher training, we can cultivate environmentally literate individuals who are empowered to tackle the multifaceted challenges of our planet. This paradigm shift is not only a response to the current environmental state but also a proactive step towards a sustainable coexistence with nature.

While environmental consciousness is shaped by diverse factors such as media, culture, and family background, ecology teachers play a distinctive and pivotal role. They go beyond merely imparting information to fostering deep, structured connections with nature (Hale 1986, Krizek & Muller 2021). By cultivating critical agency, they empower students to understand complex environmental challenges and contribute to preservation and restoration, thus shaping a generation poised for informed action (Knapp & D'Avanzo 2010, Nordlund 2016). These educators are crucial in guiding society's response to pressing environmental challenges, preparing future leaders to address issues like climate change and biodiversity loss.

Recognizing the significance of their role, it is essential to support ecology teachers through access to resources, professional development, and institutional backing (Brando *et al*. 2009, Diesse *et al*. 2020). They are not only educators but also agents of change in environmental stewardship, influencing societal attitudes towards sustainability. In this dynamic educational landscape, innovative and interactive teaching strategies are essential to instill a profound understanding and appreciation for ecological principles in students. In this context of education, the presentation of innovative and alternative teaching strategies has become imperative, especially when addressing fundamental themes in Ecology. As educators, our objective transcends the mere dissemination of knowledge (Bernardo *et al*. 2013, Maciel & Uhmann 2020, Cooke *et al*. 2021, Molina-Torres 2021), we strive to instill a deep understanding and appreciation for ecological principles in our students. To achieve this, emphasis must be placed on practical and interactive approaches that captivate and engage them. High school educators play a crucial role in cultivating environmentally conscious generations (Kissling & Bell 2020, Gadella-Kamstra 2021). To enhance ecology education, it is needed to propose a shift towards participatory and experiential learning methods (Junior & Gonçalves 2013).

This article aims to explore the challenges of this educational transformation, advocating for dynamic teaching methods that adapt to our evolving planet (Bernardo *et al*. 2013, Maciel & Uhmann

2020, Cooke *et al.* 2021, Molina-Torres 2021). In this way, we present successful cases of teaching alternatives at different levels of organization in ecology in the training of science teachers. We will present concrete examples of the development and implementation of teaching methods in Ecology.

MATERIAL AND METHODS

The projects result from "General Ecology" classes of the degree course in Biological Sciences at the Federal University of Rondonópolis throughout the years 2019 to 2022. The proposals aimed to meet part of the discipline's curriculum as part of the curricular component "activity as practice curriculum". Based on the theoretical content presented, the students were divided into groups to select the topics to be covered. The steps involved the choice of themes by the teacher responsible for the subject, where the production of teaching alternatives, as well as the development and application of the pedagogical tools developed, were guided by him, and developed by regularly enrolled students. Throughout the process, students were guided in carrying out the activities, aiming to consider the theoretical context when developing the practice. After preparing the products, each group carried out the activity in the classroom, guiding the other students in developing the proposed activity. Always at the end of the presentations, discussions were held about the created product and practical implementation, aiming to identify positive points and possible adjustments. Furthermore, the use of research-based learning methodologies encourages students to ask questions, formulate hypotheses and carry out experiments, reflecting the scientific process. By participating in hands-on investigations, students develop analytical skills while solidifying their understanding of ecological principles.

RESULTS

We present the generated products that address aspects of the ecology of individuals, ecology of populations, ecology of communities and ecology of ecosystems. We bring the theoretical contextualization of the topic covered, as well as steps and procedures for carrying it out and pedagogical reflections on its use.

Ecological Niche board game

Ecological niche suggests that each species has a specific role in its environment, encompassing habitat, resource use, and interactions (Hutchinson 1959). However, understanding this concept fully can be challenging. Dor-Haim *et al*. (2011) found that students struggle with this complexity, suggesting it hampers biodiversity learning. An activity called "Ecological Niche" aims to address these challenges by providing hands-on experience to understand niche components. Students use cubes and cards representing resources and conditions to grasp the intricacies of species niches. It involves several key elements:

Habitat: The physical location where a species lives, impacted by climate, terrain, and resource availability, influencing its reproductive success and survival.

Eating Habits: The diet preferences of a species, shaping its position in the food chain and interactions with other organisms.

Behavior: Daily activities including feeding, reproduction, and social interactions, influenced by genetics, environment, and inter-species dynamics.

Ecological Interactions: Relationships among species such as competition, predation, and mutualism, pivotal in determining a species' niche and community structure.

Physiological and Behavioral Adaptations: Species-specific traits aiding survival and reproduction, encompassing physical characteristics and behavioral strategies.

To execute the ecological niche proposal, you can follow the following steps:

Preparation of Materials: Will need cardboard, species images, scissors, glue, and ecosystem visuals. Prepare cubes detailing information about different species and their respective ecological niches (Figure 1A), ensuring each cube has six faces representing various niche aspects. Create an informative card featuring images of diverse ecosystems and environmental resources. To construct the activity board illustrating resources and environmental conditions in the ecological niche (Figure 1B), follow these steps: Select cardboard of appropriate size for the board, choosing a contrasting color for optimal visibility; Gather images depicting various ecosystems (e.g., forests, deserts, oceans), printing them on A4 paper; Prepare images or drawings representing environmental resources like water, sunlight, and specific foods, organizing them for placement; Adhere images of different ecosystems around the cardboard's edge, creating a visual frame for the board; Place images or drawings of environmental resources at the board's center, distributing them evenly to represent the diversity of resources available in ecosystems (Figure 1B).

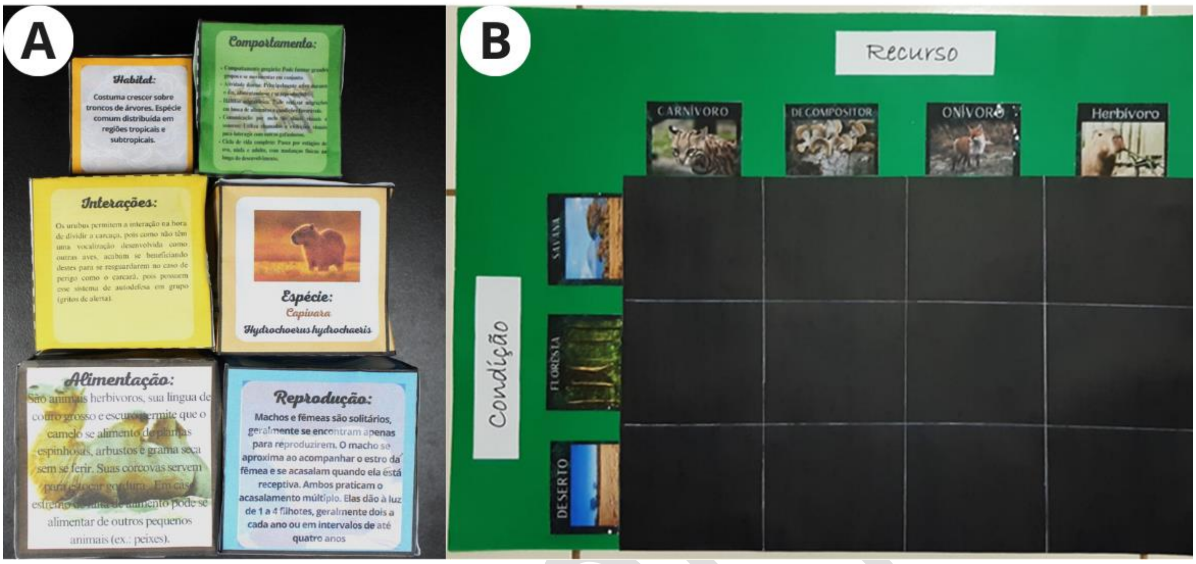

Figure 1. – (A) Informational cubes illustrating various aspects and sizes of ecological niches. (B) Cardboard representing two axes of the ecological niche: resources and ecological conditions. Resources exemplify food resources, and conditions exemplify climatic characteristics that compose biomes. Developed by the authors, 2023.

Paste or write the environmental conditions specific to each ecosystem below or next to the respective ecosystem image. This can include details such as high humidity and warm temperatures for a rainforest ecosystem, as well as high biodiversity. Environmental conditions can be represented by handwritten text or printed on paper based on preference and resource availability.

Class Division: Organize students into groups, aiming for an appropriate number of participants to facilitate interaction and collaboration; **Explanation of the Activity**: Provide students with an overview of the basic concepts of the ecological niche and its significance in understanding species-environment interactions. Introduce the materials to be used in the activity and clarify the rules and objectives; **Species Selection**: Allow each group to choose two species represented on the cubes. They can select randomly or through a guided choice process, depending on the activity's objective and the students' level of knowledge; **Analysis of Resources and Environmental Conditions**: Instruct groups to identify the resources and environmental conditions associated with their chosen species. They should analyze the information provided on the cubes to determine the essential resources and environmental conditions required for each species' survival; **Mounting on Information Card**: Guide groups to place the cubes on the cardboard board, arranging the species and information about their resources and environmental conditions; **Group Discussion and Presentation**: Foster discussion and debate among groups, encouraging the exchange of ideas. Each team should present their findings to the entire class after a group discussion. Be available to address questions, offer guidance, and promote active student involvement. Provide feedback on group presentations and prompt reflection on the information shared.

Sexual dimorphism cards

Sexual dimorphism, crucial in ecology and evolution, refers to morphological differences between males and females of the same species, revealing insights into sexual selection mechanisms (Hendrick *et al*. 1989, Slatkin 1984, Shine 1989). While various mechanisms may operate, sometimes concurrently, further research is needed to understand specific cases. Dimorphic characteristics, selected for reproductive success, include size, ornamentation, and behaviors optimizing partner competition (Andersson & Iwasa 1996, Berns 2013, Shine 1989). Pedagogically, teaching sexual dimorphism involves interactive activities to identify species exhibiting such differences. This approach fosters teacher-student engagement, translating scientific knowledge into accessible forms and contributing to transformative learning experiences. In the case of the current practice, an interactive game was chosen to present the theme of sexual dimorphism to the students. The result of the interactive game will be with the following materials: Cards with images of animals, cards with characteristics of sexual dimorphism, and cards with the names of the chosen groups.

Description of the Process: You'll need cardboard, scissors, printed figures, glue, and contact paper; **Execution**: Begin by selecting 4 to 5 animal groups (e.g., mammals, birds, arthropods, reptiles and amphibians). Each student group will be assigned responsibility for one animal group. Make cards showing images of each selected pair, with one card for the male and one for the female (see Figure 2.

Choose 5 animal pairs from each group, with 4 pairs exhibiting apparent sexual dimorphism and 1 pair showing non-apparent sexual dimorphism, despite potentially possessing them, which may not be observable solely through images or physically. In total, there will be 10 cards for each animal group. Additionally, prepare individual cards detailing characteristics of sexual dimorphism present in the chosen animals, such as size, coloration, courtship behavior, and ornamentation. Optionally, cover the cards with contact paper for increased durability, as they may become fragile when only glued to cardboard; **Dynamic**: Divide students into groups according to the number of animal groups chosen. For example, if 5 animal groups were selected and there are 20 students, divide them into 5 groups of 4 students, each representing one animal group. Conduct a draw to assign each student group an animal group (e.g., group of birds, group of mammals).

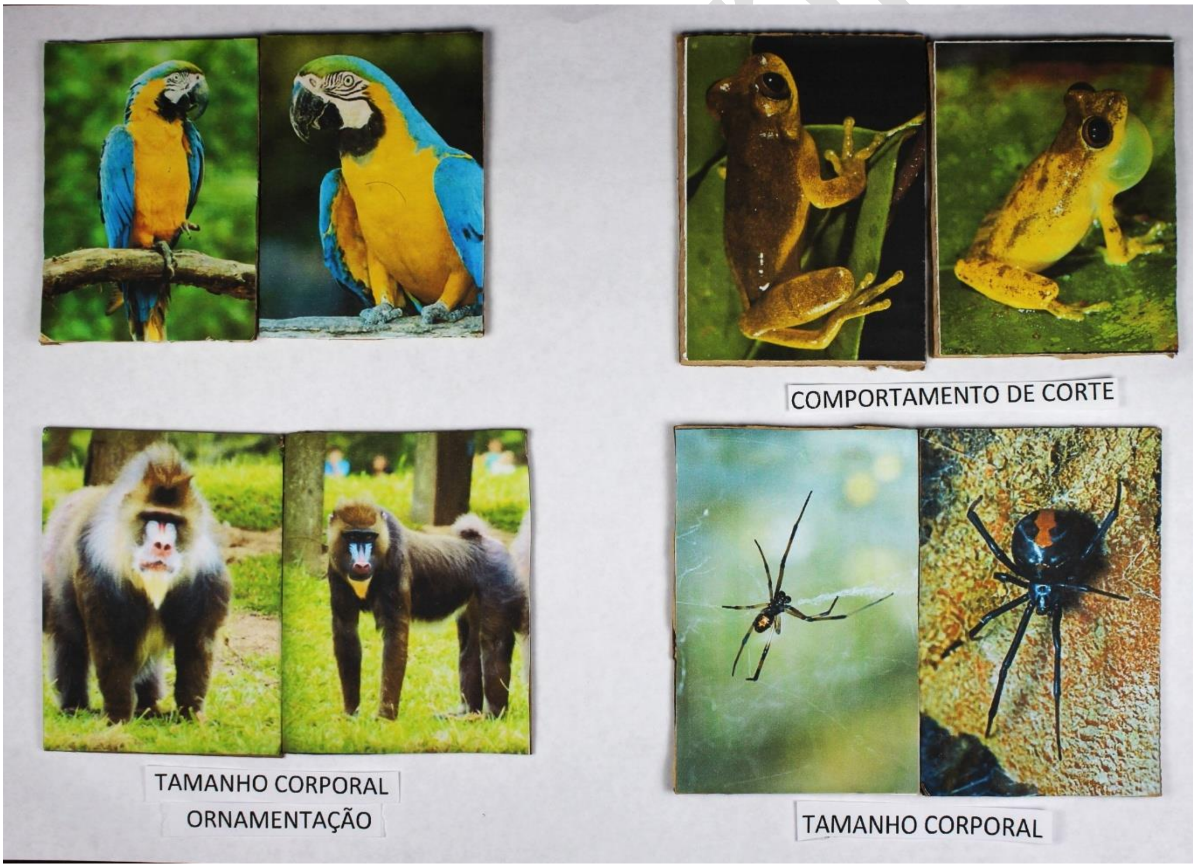

Figure 2. – Cards with pairs of animal species indicating absence (in the case of the Macaw - *Ara ararauna* - top left corner) or presence of sexual dimorphism, as well as type of sexual dimorphism present (behavior, size, ornamentation). Elaborated by the authors, 2023.

Next, shuffle the cards of all animal pairs and distribute 10 random cards with animal images to each student group. Place the cards detailing sexual dimorphism characteristics in a box at the center of the room. Students should then match the correct pairs within their animal group, as the cards will be distributed randomly. Groups must interact to exchange materials that are missing in both groups.

After forming the pairs, students retrieve sexual dimorphism characteristic cards from the box and match them with the corresponding pairs. They should discuss among themselves the factors that differentiate the male from the female, even if these differences weren't initially associated with sexual dimorphism. This practice helps develop skills and recognize characteristics that weren't previously linked to sexual dimorphism**.**

Biomes Battle

Biomes are large units of the terrestrial landscape that share distinct climatic, geographic and ecological characteristics (Whittaker 1975). Each biome is home to a unique community of plants, animals and microorganisms adapted to the specific environmental conditions that prevail in that region (Golley 1994).

The approach consists of a card game where characteristics of each biome were used to prepare the topics to be scored (Figure 3). 5 characteristics of biomes were listed: Territorial extension, Vegetation, Fauna, Soil and Climate. Values assigned to each topic receive a score depending on the nature of the description. For example: "Extension": the greater the extent of the biome, the greater the value attributed to this characteristic; "Vegetation" and "Fauna": the more diverse and threatened, the higher the score; "Soil": the richer it is in nutrients, the higher the score and "Climate": the more adverse for most species, the lower the score. The choice of biome characteristics that can be part of the scoring items can be adapted, as well as the scoring criteria adopted. It's worth highlighting that it's not a game to classify biomes as "best" or "worst", but rather to evaluate different characteristics.

The card beats the others in the deck depending on the value of its characteristics.

Playing with the Game: Each player will receive the same number of cards, and it is prohibited to see other players' cards. Whoever starts the game chooses one of the five characteristics of the card, and then everyone reveals this information on the card. Whoever has the highest score for that characteristic win. In case of a tie, another characteristic of the same card must be chosen. The winner adds the cards to their hand, and whoever has the most cards in their hand wins the game. The premise of "Biome Battle" is to provide an engaging and interactive learning experience centered on the characteristics of different biomes.

Figure 3. – Biome cards with their respective scores for each of the listed items. Developed by the authors, 2023.

Who am I? Ecological Interactions Quest

The game "Who Am I? Ecological Interactions" is an adaptable educational activity designed to explore various theoretical concepts, particularly those related to ecological interactions. Key concepts covered include ecological interactions, such as predation, competition, mutualism, parasitism, and commensalism. This game facilitates learning about these concepts in a fun and interactive manner using readily available materials like paper, scissors, and tape.

Necessary materials: A4 paper format; cardboard; scissors (blunt for children); pens or pencils/prints of figures and text; wide transparent adhesive tape or contact paper; glue; **Making the Cards**: Participants research the topic of ecological interactions. They separate the name, definition, and a representative image of each ecological interaction. Print this information on A4 paper and stick it on cardboard for greater stability. They cut the letters individually and cover them with contact paper or adhesive tape for greater durability (Figure 4); **Playing with the Game**: Participants are divided into pairs, with an even number of players. Each player is randomly given a card, without looking at its contents. Participants have a set amount of time to meet their partner, comparing the definitions of their cards and their images. After the stipulated time, the pairs meet to check if they found their pairs correctly. If necessary, the round can be repeated to allow those who did not find their matches a second chance. Finally, the pairs are corrected, and the definitions of each pair are named; **Game rules**: Any means of consultation during the game is prohibited. Participants have a limited time to find their matches. Once the pair is formed, exchange is not permitted. The class is divided according to the number of participants. Failure to comply with the rules may result in the participant's disqualification.

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Figure 4. – Illustration of cards with images and respective descriptions of each of the ecological interactions described for association between players. Developed by the authors, 2023.

Construction of the Trophic Web Quest

The construction of the food web is a visual representation of the feeding relationships between different organisms in an ecosystem (Paine 1980). It illustrates how energy and nutrients flow through trophic levels, starting with producers, through primary, secondary, and tertiary consumers, to decomposers (Begon & Townsend 2021). Understanding the construction of the food web is fundamental to understanding ecological interactions and ecosystem dynamics. Main Concepts to be Covered: Producers (Autotrophs); Primary Consumers (Herbivores); Secondary Consumers (Carnivores); Tertiary and Quaternary Consumers; and Decomposers (Figure 5).

Figure 5. Example of the boards to be used by players with respective elements of food chains/webs, including primary producers and primary, secondary, and tertiary consumers. Developed by the authors, 2023.

The main objective of the game "Construction of the Trophic Web" is to provide students with a deeper understanding of the relationship between living beings and the dependence between different trophic levels within food chains and webs. Through a dynamic and interactive activity, students will be involved in the construction of food chains and webs, allowing them to understand how human action, especially anthropogenic action, compromises, and imbalances this natural harmony.

Necessary materials: 1 - Cardboard; 2 - Twine (one roll); 3 - Scissors; 4 - Awl; 5 - Printed images of the organisms that will make up food chains; 6 - A black trash bag or something like simulate pollution. **Plate preparation**: Cut the cardboard into rectangles approximately 20 cm long by 12 cm wide. Make two holes along the length of the rectangle, close to the edge, so that, when passed through by the string, they form a strap that can be hung around the student's neck, leaving the plate exposed on their chest. **Preparation of organisms**: Print images of the different organisms that will be part of food chains. These organisms may include producers (plants), primary consumers (herbivores), secondary consumers (carnivores), among others, depending on the desired level of complexity. **Organization of dynamics**: Arrange the students in a circle, with the teacher in the center, holding a roll of string. Each student will receive a plaque with a photo of an organism. The teacher will begin the activity by asking students what the first trophic level is in a food chain and what are the characteristics of this living being that allow it to be self-sufficient.

Construction of food chains: Students will identify the producers (autotrophs) and select a student to represent them, holding the end of the string. Through consensus and teacher guidance, students will connect the different trophic levels until they form a complete food chain. After each chain is formed, the string is cut and another chain can begin, following the same procedure.

External factor introduction: After the formation of several food chains, the teacher can introduce an external factor into the dynamics, such as soil and water pollution or the use of insecticides. Students involved in the affected chains release the string, demonstrating how the compromise of one link in the chain can affect several trophic levels.

How the game works: The game consists of a practical and interactive activity in which students build food chains using plates with images of organisms and string to represent the connections between them. Students are encouraged to discuss and negotiate trophic relationships, building knowledge collectively. The introduction of an external factor into the dynamics allows students to visualize the impacts of human action on ecosystems, promoting environmental awareness and critical thinking. The game encourages collaboration between students, consolidates theoretical understanding about food chains and promotes environmental awareness in relation to the challenges faced by biodiversity.

Composting as a Teaching Tool in Ecosystem Ecology

Composting is a natural process of decomposition of organic matter by aerobic microorganisms, such as bacteria, fungi and insects, under controlled conditions of humidity, temperature and aeration. This process transforms organic waste, such as food scraps, garden clippings and leaves, into a nutrient-rich organic compound, known as compost or humus, which can be used as a fertilizer for agricultural soils and gardening. Main concepts to be covered including: Decomposition of organic matter into simpler compounds, such as water, carbon dioxide and nutrients, releasing energy in the process; Microbiology of Composting: Each group plays a specific role in the decomposition of different organic components; Composting Control Factors: Several factors influence the efficiency and speed of composting, including the carbon:nitrogen (C:N) ratio of organic materials, humidity, temperature, aeration, and the proportion of green and dry materials in the pile of composting; Benefits of Composting: In addition to reducing the amount of waste sent to landfills, composting produces a high-quality organic fertilizer that improves soil structure, increases water and nutrient retention, and promotes plant health (Figure 6).

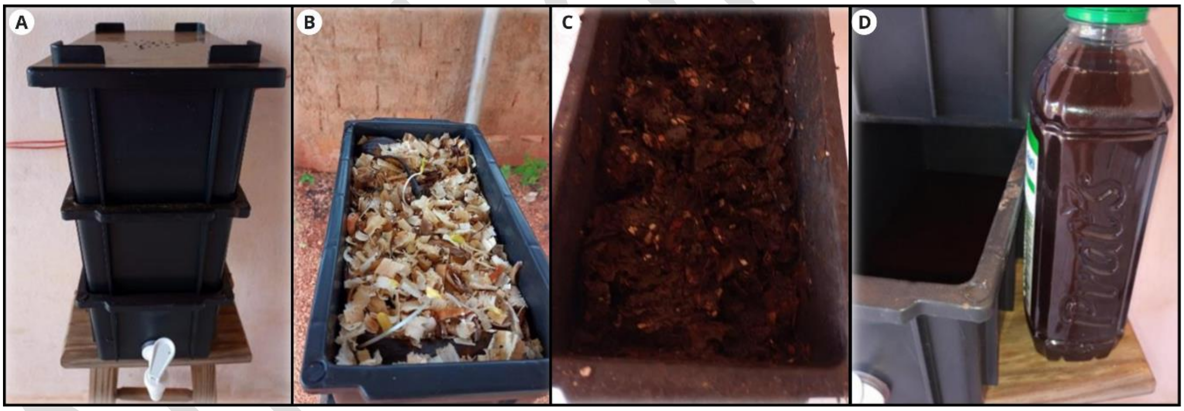

Figure 6. (A) Assembling the compost bin with three compartments, the upper one for placing organic matter, the second for the soil with worms and the third for storing excess water that creates liquid fertilizer (slurry) (B) Filling the compost bin and (C) result after the decomposition process. (D) Surplus liquid fertilizer produced. Prepared by the authors, 2023.

The activity proposes the use of a compost bin as a teaching tool to explore concepts related to the flow of matter, energy, and biogeochemical cycles in ecosystems. Throughout the creation and monitoring of the compost bin, students will be encouraged to observe and understand the processes of decomposition of organic matter, the cycling of nutrients and the transfer of energy between the different components of the system.

Compost bin: The compost bin is a system made up of layers of organic materials, such as food waste, leaves, sawdust, among others, which are decomposed by microorganisms in a controlled environment. The final product of this process is organic compost, a natural fertilizer rich in essential nutrients for the soil and plants.

Assembling the Compost Bin: Students will be guided in assembling the compost bin, following specific instructions to create an environment conducive to the decomposition of organic waste. Alternating layers of green materials (rich in nitrogen, such as fruit and vegetable waste) and dry materials (rich in carbon, such as dry leaves and shredded cardboard) will be used, promoting aeration and the balance necessary for the composting process.

Monitoring and Observation: Students will be responsible for monitoring and recording the changes that occur in the compost bin over time. They will observe the emergence of microorganisms, the temperature and humidity of the system, the decomposition of organic materials and the formation of the organic compound. The temperature of the compost bin must be observed and monitored with the help of a thermometer. Temperature variation information can be discussed relating to aerobic and anaerobic decomposition processes.

Association to Ecology Themes: During the process of creating and monitoring the compost bin, students will be guided to make connections with the concepts of matter flow, energy and biogeochemical cycles. They will discuss how decomposer organisms transform organic matter into nutrients available to plants, how energy is transferred along the food chain, and how nutrient cycles affect ecosystem dynamics.

Educational Advantages:

By integrating educational practices related to ecology, such as the study of ecological niches, sexual dimorphism, biome battles, ecological interactions, food webs, and composting, we can identify several educational advantages:

Adaptability and Flexibility: The game's customizable nature allows for adaptation to educational goals and player preferences. Educators can adjust scoring criteria to emphasize specific concepts or tailor the game to different age groups and learning levels.

Development of Social Skills: Collaborative activities, such as biome battles, promote teamwork, effective communication, and conflict resolution, preparing students to collaborate on future projects and tackle complex challenges as a team. Through discussions and sharing of discoveries, they engage in debate, exchanging ideas, and learning from one another, enhancing the overall educational experience.

Environmental Awareness: By investigating the effects of human interactions on ecosystems, students develop a deeper understanding of the environmental impacts of human actions and become more informed and active advocates for the environment.

Hands-on Experience: Practical activities, such as building food webs or observing ecological interactions in the field, offer students a tangible and applied experience of theoretical knowledge, making learning more meaningful.

Interdisciplinarity: The integrated approach to these topics allows for connections between disciplines such as biology, geography, chemistry, and even mathematics, providing a broader and more holistic understanding of ecological systems. By associating theoretical concepts with images and definitions, participants have a better understanding and fixation of the content covered.

Low Cost and Easy to Make: The necessary materials are accessible, and the cards can be easily made, allowing the activity to be carried out in different educational contexts.

Practical and Visual Experience: The use of simple materials, such as cardboard, string and printed images of organisms, allows students to participate in a practical and visually stimulating experience. This facilitates the understanding of the concepts covered, making them more tangible and concrete for students.

Stimulates Critical Thinking: By exploring different aspects of ecology, students are challenged to think critically about the complexities of natural systems, analyze data, and make informed decisions based on the evidence presented.

Student Engagement: Hands-on and interactive activities spark student interest and engagement, making the learning process more immersive and motivating.

DISCUSSION

Gamification adds a sense of thrill to ecology lessons, enabling students to participate as environmental researchers tackling authentic problems. This method improves critical thinking, problem-solving, and collaboration abilities within an interactive educational setting. With problems like climate change, habitat loss, and biodiversity decline at hand, it is more important than ever to have trained individuals ready to address these issues (Novacek 2008, Cooke *et al.* 2021). Upon consideration of these factors, it is evident that educational programs and training methods need to adapt in order to promote the development of a fresh cohort of equipped for environmental engagement and ethical decision-making.

At the core of this initiative is the creation of multidisciplinary curricula that go beyond the usual boundaries of individual disciplines. Ecological issues are complex, needing comprehensive solutions that incorporate information from various disciplines like biology, environmental sciences, politics, economics, and social sciences (Palmer *et al*. 2005, Jerneck *et al.* 2011). Hence, educational programs should highlight the interdependence between ecological systems, human communities, and economies, encouraging a holistic comprehension of the intricate interactions involved. This is evident when we teach "Ecosystem Ecology", focusing on the interconnections between organisms and the recycling of nutrients through composting. By managing the organic waste they produce, individuals gain insight into their consumption habits, the transformation of waste into fertilizer, and the connections between material and energy transfer.

In addition, it is important for teaching methods to focus on hands-on, experiential learning experiences that enable students to interact directly with ecological systems. Visualizing abstract concepts aids in the teaching and learning process by helping students retain the covered content. Encouraging teamwork across disciplines is crucial in shaping the next generation of citizens (Songer & Breitkreuz 2014, Scott 2015). Environmental issues go beyond country borders and academic fields, requiring teamwork that involves a variety of viewpoints and expertise. Hence, educational programs should include joint and interdisciplinary tasks that inspire students to cooperate towards common objectives, fostering communication abilities, teamwork, and interdisciplinary comprehension, irrespective of their future fields of work. Training programs can enable students to support environmental justice and create positive change in their communities and beyond by including conversations about ethics, equity, and social responsibility.

The practices presented are crucial for training biology teachers who specialize in ecology due to multiple reasons. First and foremost, they provide real-life instances of putting theoretical ideas from ecology into practice, allowing upcoming educators to understand ecosystem dynamics directly. This hands-on learning improves their skill in communicating ecological information, making the educational experience more interesting and impactful for students. Moreover, promoting interdisciplinary collaboration encourages future biology educators to incorporate knowledge from fields like environmental sciences, politics, economics, and social sciences into their ecological teachings. This interdisciplinary method is essential because environmental problems frequently demand solutions that transcend conventional scientific limits, forcing educators to tackle them in a thorough and holistic manner.

In conclusion, advancing ecology education is crucial in addressing today's complex environmental challenges. Through interdisciplinary approaches and hands-on learning, we can nurture a generation of environmentally literate individuals ready to confront these pressing issues. Collaboration between educational institutions and environmental organizations is essential to develop curricula integrating knowledge from diverse fields and emphasizing the interconnectedness of ecological systems with human societies and economies. Encouraging a culture of collaboration and interdisciplinary teamwork prepares future citizens to address ecological challenges effectively. By engaging in collaborative projects and discussions on ethics, equity, and social responsibility, we empower students to advocate for environmental justice and drive positive change in their communities and beyond.

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