http://doi.org/10.14393/ER-v32e2025-40

Concept Maps in Composting Education: a proposal for Environmental Scientific Literacy Based on the SDGs[1]

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ABSTRACT
This article presents a pedagogical activity proposal for high school education focused on the construction of concept maps related to the composting process and the different types of organic matter involved. The activity aims to foster scientific literacy and environmental education, aligning with the Sustainable Development Goals (SDGs) through participatory and inquiry-based methodologies. Composting is addressed as a sustainable practice that reduces environmental impacts and promotes critical reflection on solid waste management. The use of digital tools and conceptual organization is expected to help students develop cognitive, environmental, and civic competencies. This proposal was developed as part of the requirements of the Professional Master's Program in Biology Teaching (PROFBIO/UFMG).
KEYWORDS: Composting; Biology Teaching; Concept Map; C/N Ratio; Sustainability.

Mapas Conceituais no Ensino de Compostagem: uma proposta de Educação Científica Ambiental com Base nos ODS

RESUMO
Este artigo apresenta uma proposta de atividade pedagógica para o Ensino Médio, centrada na construção de mapas conceituais sobre o

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processo de compostagem e os diferentes tipos de matéria orgânica envolvidos. A atividade visa promover a alfabetização científica e a educação ambiental, alinhando-se aos Objetivos de Desenvolvimento Sustentável (ODS) por meio de metodologias participativas e investigativas. A compostagem é abordada como uma prática sustentável, capaz de reduzir impactos ambientais e estimular a reflexão crítica sobre o destino dos resíduos sólidos. Espera-se que, por meio da organização conceitual e do uso de ferramentas digitais, os estudantes desenvolvam competências cognitivas, socioambientais e cidadãs. A proposta foi elaborada como parte das exigências do Mestrado Profissional em Ensino de Biologia (PROFBIO/UFMG).

PALAVRAS-CHAVE: Compostagem; Ensino de Biologia; Mapa Conceitual; Relação C/N; Sustentabilidade.

Mapas conceptuales en la enseñanza de la compostaje: una propuesta de Alfabetización Científica Ambiental Basada en los ODS

RESUMEN

Este artículo presenta una propuesta de actividad pedagógica para la Educación Secundaria, centrada en la construcción de mapas conceptuales sobre el proceso de compostaje y los diferentes tipos de materia orgánica implicados. La actividad tiene como objetivo fomentar la alfabetización científica y la educación ambiental, en consonancia con los Objetivos de Desarrollo Sostenible (ODS), mediante metodologías participativas y basadas en la indagación. El compostaje se aborda como una práctica sostenible que reduce los impactos ambientales y estimula la reflexión crítica sobre la gestión de los residuos sólidos. Se espera que, mediante la organización conceptual y el uso de herramientas digitales, los estudiantes desarrollen competencias cognitivas, socioambientales y ciudadanas. Esta propuesta fue elaborada como parte de los requisitos del Programa de Maestría Profesional en Enseñanza de la Biología (PROFBIO/UFMG).

PALABRAS CLAVE: Compostaje; Enseñanza de la Biología; Mapa conceptual; Relación C/N; Sostenibilidad.

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Introduction

The proper management of solid waste represents one of the major socio-environmental challenges of contemporary society, demanding solutions that combine the technical handling of discarded materials with the development of critical and environmentally conscious citizens. The environmental impacts resulting from the improper disposal of urban, industrial, and agricultural waste are diverse and often intensify processes of environmental degradation. Conversely, sustainable practices such as composting allow organic waste to be reintegrated into the natural cycle of matter, contributing to the reduction of negative impacts and the reuse of nutrients (Budziak, 2004).

Composting is a biological process that transforms organic waste into a stable, nutrient-rich compound, representing a sustainable practice for the reuse of organic matter.

In the educational context, composting represents a relevant theme for science teaching, as it allows the exploration of interdisciplinary content involving biochemistry, ecology, microbiology, and sustainability. Addressing this topic through participatory methodologies fosters the development of environmental scientific literacy, stimulating inquiry, problem solving, and the critical construction of knowledge.

A teaching resource that enhances this approach is the use of concept maps, grounded in the Theory of Meaningful Learning, which foster the organization and articulation of scientific concepts. Recent research reinforces the relevance of this tool in science education. Ramos and Bagio (2020) emphasize that concept maps promote meaningful learning by enabling students to establish relationships between concepts based on pre-existing cognitive structures, thus contributing to the consolidation of knowledge in an active and visually organized manner. In Inquiry-Based Science Education, these tools support the articulation between observation, hypothesis formulation, and data analysis (Pedaste et al., 2015).

In this context, the following guiding question emerges: How can the use of concept maps promote the organization of thought and the construction of scientific knowledge within the school context? This question guides the present didactic proposal, which aims to explore the potential of concept maps as instruments for fostering scientific literacy.

Furthermore, the topic of composting aligns with the Sustainable Development Goals (SDGs) by promoting reflections on responsible consumption, the mitigation of environmental impacts, and sustainability within the school context.

In light of this scenario, this article presents a pedagogical activity designed for high school students, centered on the construction of concept maps about the composting process. Grounded in established theoretical and methodological foundations, the proposal seeks to integrate scientific and environmental content, promoting critical scientific literacy and the development of socio-environmental competencies. Furthermore, it aligns with sustainable practices that can be incorporated both within the school environment and in students' daily lives, contributing to a more contextualized and civic-oriented education.

Theoretical Framework

Concept Maps in Science Education

Concept maps are hierarchical graphic representations that organize and relate concepts through propositions connected by linking words. They are based on Ausubel's (2003) Theory of Meaningful Learning, according to which learning becomes more effective when new knowledge is integrated into previously existing cognitive structures.

This approach is particularly effective in science education, as it stimulates logical reasoning, the construction of conceptual relationships, and intellectual autonomy (Novak; Gowin, 1996).

Recent studies reinforce the pedagogical value of this tool in high school education. Alves and Gasparini (2025) analyzed more than 300 concept maps created by students, identifying structural patterns and assessing the depth of propositions. The authors demonstrated that concept maps facilitate learning assessment by revealing different levels of conceptual understanding. Almeida (2022) also highlights that, when used in interdisciplinary contexts, concept maps expand students' ability to connect school knowledge to real-world situations, fostering meaningful learning.

Despite their contributions, the use of concept maps also presents challenges. Students may struggle to hierarchize concepts, select appropriate linking words, or graphically structure the content (campelo; piconez, 2018). These obstacles can be overcome through active teacher mediation and the use of accessible digital tools, such as XMind, which provide visual and organizational support for the construction of maps.

In the context of Inquiry-Based Science Education, as proposed by Pedaste et al. (2015), concept maps strengthen the connection between problematization, hypothesis formulation, data analysis, and synthesis of conclusions, positioning the student as an active subject in the learning process.

Composting and the SDGs

Composting is an aerobic biological process that transforms organic waste into a stable, nutrient-rich compound, promoting the reuse of organic matter and contributing to the reduction of environmental impacts. In the educational context, its application in high school enables the integration of content from biochemistry, ecology, microbiology, and environmental education in a practical and interdisciplinary manner.

http://doi.org/10.14393/ER-v32e2025-40

According to Santos, Fellipetto, and Araújo (2021), proposals such as this are aligned with the integration of the SDGs into the school curriculum, promoting a critical, engaged, and contextualized education. UNESCO (2017) also emphasizes the importance of participatory methodologies connected to students' real-life experiences for developing competencies related to sustainability. From this perspective, composting becomes not only a scientific topic but also a pedagogical opportunity to address contemporary socio-environmental issues with transformative potential.

In addition to scientific content, the study of composting allows for the exploration of the SDGs, particularly:

SDG 12 – Responsible Consumption and Production, by encouraging the reduction and reuse of waste;

SDG 13 – Climate Action, by addressing the reduction of methane emissions through composting;

SDG 15 – Life on Land, by promoting the sustainable use of soil and organic fertilization.

According to Soares (2019), the incorporation of the SDGs into the high school curriculum can be enriched through interdisciplinary and contextualized approaches that bring global issues closer to students' everyday experiences. UNESCO (2017) also emphasizes that education for the SDGs should include participatory, project-based methodologies that foster the development of competencies for global citizenship. Santos, Fellipetto, and Araújo (2021), when analyzing teachers' perceptions of the SDGs, highlight the importance of teacher training to ensure that these goals are effectively integrated into pedagogical planning.

Sociocultural Barriers to the Adoption of Composting

Despite the recognized environmental and pedagogical benefits of composting, its adoption still faces significant obstacles, particularly in urban contexts. The scarcity of space, the lack of technical knowledge about proper management, and cultural prejudices—such as the mistaken association of composting with unpleasant odors and unsanitary conditions—continue to limit its implementation in school and domestic environments. As noted by Zanta (2013), these barriers are often reinforced by the lack of qualified information and the absence of educational practices that promote a safe and accessible understanding of the process. According to Santos, Fellipetto, and Araújo (2021), overcoming these resistances requires strengthening interdisciplinary proposals for environmental education that connect scientific knowledge to students' social and cultural realities, fostering sustainable attitudes through meaningful experiences. In this context, the school plays a strategic role in overcoming these barriers by promoting a scientifically grounded and socially contextualized understanding of the process. Activities that integrate inquiry, conceptual organization, and community dialogue—such as the construction of concept maps—contribute to demystifying composting and encouraging sustainable practices. By positioning students as active agents in the learning process, such proposals foster the development of critical and transformative attitudes.

General Objective

To develop an investigative pedagogical activity based on the construction of concept maps that promotes the understanding of the biochemical processes involved in composting and demonstrates how different proportions of organic matter affect the dynamics of decomposition and the quality of the final compost.

Specific Objectives

- To understand composting as a biochemical process essential for the reuse of organic matter and environmental sustainability.

- To relate biochemical knowledge to the factors that influence the decomposition of organic matter, such as the carbon-to-nitrogen (C/N) ratio.
- To explore the Sustainable Development Goals (SDGs), particularly those related to waste management, climate change, and soil conservation.
- To value students' prior knowledge, promoting meaningful and contextualized learning.
- To use computational tools, such as the XMind software, for the development of concept maps as a resource for organizing, synthesizing, and sharing knowledge.
- To encourage responsible attitudes toward waste disposal and reuse, promoting the practice of composting in domestic environments.

Methodology

The proposal was designed for implementation with high school students, preferably in school contexts that promote interdisciplinary activities focused on environmental education and sustainability. The activity can be carried out either in person or remotely; however, this version was planned for in-person implementation, using the school's computer laboratory as the primary space for its execution.

The activity is organized into two distinct stages, distributed over two 50-minute class sessions:

1st Stage – Theoretical Introduction and Construction of the Concept Map

In the first class, the proposal suggests that the teacher introduce the concept of composting, emphasizing its socio-environmental relevance, the main factors involved in the process (with an emphasis on the carbon-to-nitrogen (C/N) ratio), and its connections with the SDGs. This initial contextualization aims to raise students' awareness of the importance of reusing organic waste as a sustainable practice.

http://doi.org/10.14393/ER-v32e2025-40

Next, the concept of a concept map will be introduced to the students, accompanied by visual examples that guide its hierarchical and relational construction, in accordance with the approach proposed by Novak and Gowin (1996).

For the construction of the maps, the digital tool XMind will be used—a free mind-mapping software that offers an intuitive interface, various visual templates, and features such as file export and presentation mode ("Pitch Mode").

The activity will be guided by the sequence for constructing concept maps described by Almeida (2022), which recommends the following steps:

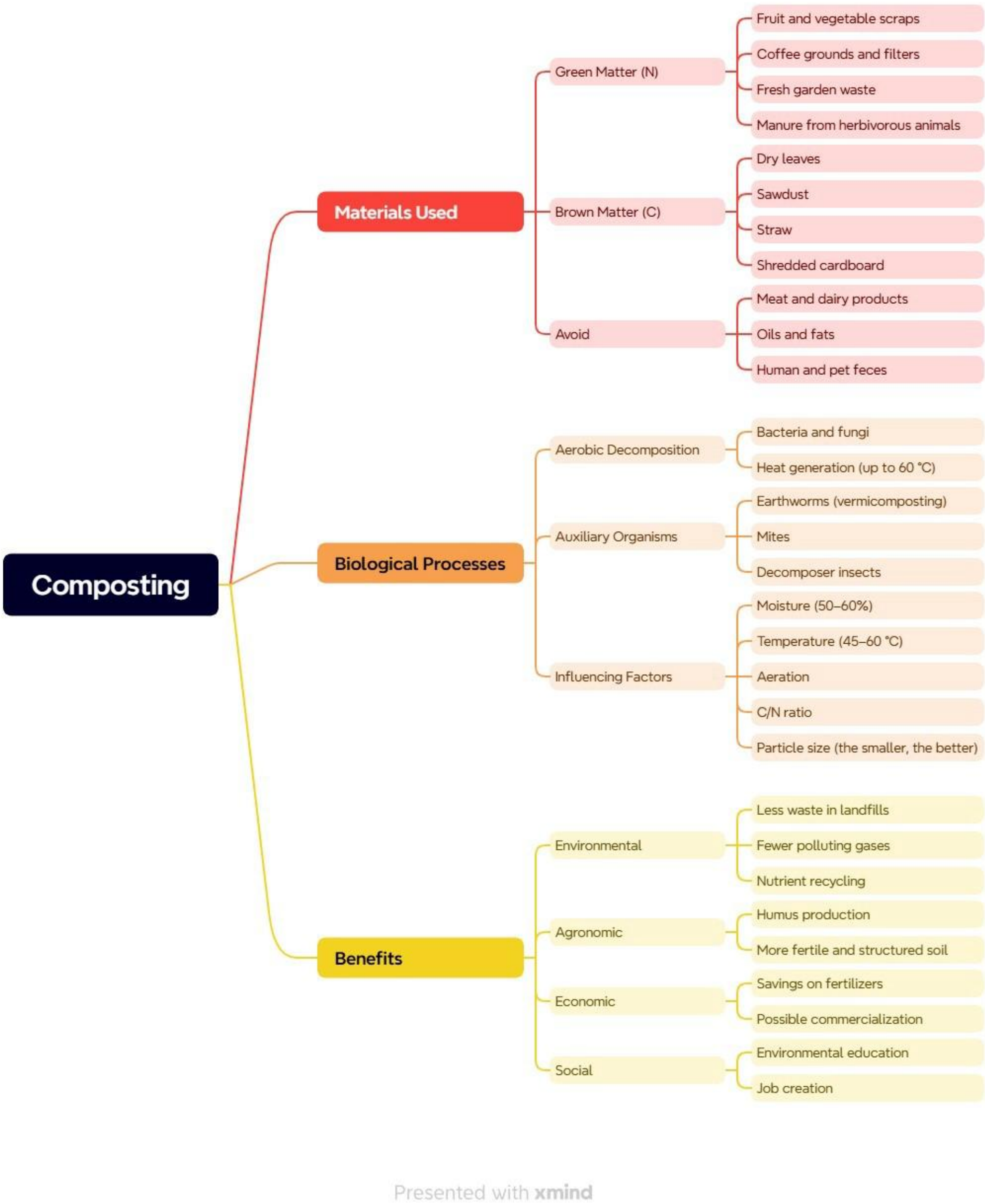
- Prepare in advance a list of concepts related to the topic;
- Organize the concepts hierarchically, from the most general to the most specific;
- Establish connections between concepts using lines or arrows accompanied by linking words that express the type of relationship;
- Use examples, usually placed near the related concepts or at the base of the concept map.

2nd Stage – Development, Guided Reading, and Conceptual Deepening

In the second class, students will begin the activity in the computer laboratory, working on their concept maps with the assistance of the XMind software, a free mind-mapping and brainstorming tool. XMind offers an intuitive interface, various visual organization templates, and allows users to export maps in formats such as PDF and image. The "Pitch Mode" feature can also be used for students to present their work, promoting the sharing and discussion of the knowledge they have constructed.

The proposed task consists of creating concept maps that articulate the main concepts introduced in the first stage of the activity, using appropriate hierarchical connections and linking words. Figure 1 presents an example of a concept map created with this tool.

Figure 1 – Concept Map on the Composting Process



Source: Prepared by the author using the XMind software (XMIND, 2025).

Subsequently, students will engage in a guided reading of the technical material presented in Appendix A, which was developed based on publications by Embrapa, such as that of Lopes and Matos (2013), focused on the domestic management of organic composting. The purpose of this reading is to deepen students' understanding of the main factors that influence the composting process, including the type and proportion of organic materials used, particle size, moisture, temperature, aeration, the C/N ratio, pH, and the presence of undesirable agents such as pathogens and heavy metals.

The activity will be conducted under teacher mediation, encouraging note-taking, the formulation of questions, and the establishment of connections between the concepts discussed in the text and the concept maps under development. At the end of the collective discussion, students should review and expand their maps, incorporating the newly learned concepts and refining the relationships among the represented elements.

This stage aims to consolidate learning through cognitive restructuring, deepening the understanding of the biochemical and environmental processes involved in composting, and strengthening the articulation between scientific knowledge, social practice, and sustainability. The entire activity was designed as a structured didactic plan, based on established theoretical frameworks, with a view to future implementation in school contexts committed to scientific and environmental education.

Activity Assessment

The evaluation of the proposal will be qualitative and formative, considering both student participation and the final product (the concept map). The main assessment criteria will be as follows:

- Conceptual accuracy: the concepts presented must be scientifically correct;
- Clarity of relationships: the connections between concepts must be coherent and understandable;

- Quantity and relevance of information: the map is expected to include the main elements discussed (such as the C/N ratio, types of waste, microorganisms, and physical factors);
- Autonomy and organization: the student should demonstrate the ability to structure the content logically and in a visually organized manner.

In addition, a self-assessment form (Appendix B) will be administered at the end of the activity as a means of encouraging students to reflect on their own learning process and level of engagement.

Expected Results

The pedagogical proposal presented here aims to promote the learning of the biochemical processes involved in composting while contributing to the scientific, environmental, and civic education of students. The activity was designed based on established theoretical foundations and structured to foster the articulation between scientific knowledge, social practice, and sustainability.

It is expected that, by organizing concepts through concept maps, students will develop cognitive and investigative skills as well as strategies for structured scientific thinking. In this sense, the central question is revisited: how can the use of concept maps promote the organization of thought and the construction of scientific knowledge within the school context?

- Among the main expected products of the activity, the following stand out;
- The creation of digital concept maps that clearly and coherently represent the main concepts related to composting, highlighting the hierarchy and logical connections among the studied elements;
- The completion of a guided technical reading, with the identification and incorporation of new concepts into the constructed maps;
- Participation in moments of knowledge sharing, including the presentation of maps and oral argumentation in the classroom;
- The autonomous use of the XMind tool as a resource for organizing, synthesizing, and communicating ideas within the school context.

Among the expected formative outcomes for students, the following stand out:

- The development of cognitive skills and investigative competencies, such as critical analysis, hypothesis formulation, and the articulation of concepts from biochemistry, ecology, and sustainability;
- A critical understanding of the composting process as an environmentally relevant and scientifically grounded practice;
- The internalization of sustainable practices, such as domestic composting and waste reduction, recognizing their positive impacts on the environment;
- The enhancement of awareness regarding the SDGs, especially those related to waste management, soil conservation, and climate change mitigation;
- The re-signification of prior knowledge about waste and decomposition, fostering interdisciplinary and contextualized learning connected to students' realities.

These results aim at conceptual development and at fostering the formation of individuals capable of acting with socio-environmental awareness, reflecting on their choices, and contributing to sustainable practices in their daily lives.

Despite the formative potential of the proposal, its implementation may face practical limitations, especially in school contexts with limited technological infrastructure. The use of the XMind software, for instance, requires access to computers and the internet, which can pose a challenge in some public institutions. In such cases, teachers can resort to viable alternatives, such as the manual construction of concept maps or the use of free mobile applications. Furthermore, teacher training focused on the pedagogical use of technology is a determining factor for ensuring that activities of this nature achieve effective results in meaningful learning.

http://doi.org/10.14393/ER-v32e2025-40

Final Considerations

The pedagogical activity proposed in this article demonstrates the potential of concept maps as a didactic resource for promoting meaningful learning in science education, especially when associated with environmentally relevant topics such as composting. By fostering the organization of ideas and the articulation of scientific concepts, concept maps become strategic tools for stimulating logical reasoning, autonomy, and the integration of knowledge.

More than addressing specific content from biochemistry and ecology, the proposal seeks to foster critical reflection on sustainable practices, connecting students' daily lives to environmental issues of global scope. In this context, the approach to composting proves to be a fertile ground for developing conscious attitudes and for understanding the interdependence among science, society, and the environment.

By linking composting to the Sustainable Development Goals (SDGs), the proposal reinforces the importance of connecting local educational practices to global challenges, promoting a form of scientific education that is both critical and committed to sustainability.

The use of digital tools such as XMind also represents an opportunity for methodological innovation, by incorporating technological resources that enhance conceptual synthesis, creativity, and student communication. The possibility of applying the activity in both in-person and remote settings makes the proposal flexible and accessible to different school realities.

By organizing concepts, establishing relationships, and constructing visual representations of knowledge, students are encouraged to systematize scientific thinking in an active and meaningful way—precisely the kind of experience sought when questioning how conceptual tools can foster knowledge construction within the school context.

As a further development, this experience is expected to be adapted and expanded into other educational fronts, such as teacher training programs, interdisciplinary school projects, or community-based environmental education initiatives. Efforts of this kind can contribute to consolidating a culture of sustainability within the school environment, fostering a form of learning that transcends the boundaries of the classroom.

Finally, it is believed that investigative and interdisciplinary pedagogical practices such as this one can inspire educators and students to rethink their relationship with scientific knowledge and the environmental challenges of the present, acting as agents of social transformation.

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http://doi.org/10.14393/ER-v32e2025-40

Appendix A – Technical Text to Support the Construction of the Concept Map

The following text was prepared as guided reading material to assist students in constructing their concept maps on composting. It brings together the fundamental concepts of the process, using accessible language and a didactic organization, and is based, among other sources, on contributions adapted from the dissertation by Antunes (2022), which investigated the pedagogical application of composting and home gardening with high school students.

Composting: Fundamentals and Essential Factors

Composting is an aerobic biological process in which microorganisms (such as bacteria and fungi) transform organic waste into a stable, nutrient-rich material known as compost. This natural fertilizer can be used in gardens, vegetable plots, and pots, enhancing soil fertility and reducing the amount of organic waste discarded.

Process Phases

The composting process goes through two main stages:

- **Thermophilic phase** – characterized by intense microbial activity and a temperature increase that can reach up to 60 °C. This stage eliminates pathogenic agents and accelerates the initial decomposition.
- **Maturation phase** – with a lower temperature, this is the stage of stabilization and humus formation.

Materials Used

For proper functioning, it is necessary to balance two types of waste:

- **Carbon-rich materials (dry materials):** dry leaves, shredded paper, straw, small branches, sawdust.

- **Nitrogen-rich materials (wet materials):** fruit and vegetable scraps, coffee grounds, eggshells, animal manure.

The ideal C/N ratio is around 30:1. An imbalance in this ratio can cause unpleasant odors or slow down the composting process.

Factors Influencing Composting

- **Aeration:** essential for the aerobic process. Turning the pile ensures proper oxygenation and prevents bad odors.
- **Moisture:** should remain between 50% and 60%. Excess or lack of moisture harms microbial activity.
- **Temperature:** the natural rise in temperature indicates intense biological activity.
- **pH:** varies between 6.5 and 8.0 throughout the process. Values outside this range hinder the action of microorganisms.
- **Particle size:** materials should be fragmented but not too finely, to prevent compaction.

What to Avoid

- Meat, fats, milk, and dairy products;
- Processed or industrialized waste;
- Pet feces;
- Plastics, metals, glass, or any type of non-biodegradable waste.

Benefits of Composting

- Reduction of household waste volume;
- Decrease in greenhouse gas emissions;
- Improvement of soil quality;
- Promotion of environmental responsibility;
- Practical application of knowledge from biology, chemistry, and ecology.

Appendix B – Student Self-Assessment Form

Dear student, this form aims to evaluate your participation, learning, and perception of the activity developed. The information collected will be used to improve future pedagogical proposals and to understand the impacts of the educational practice. Please answer sincerely.

1) Do you consider that your participation in this activity contributed to your learning in Science?

( ) Yes, significantly

( ) Yes, partially

( ) It did not contribute

( ) I'm not sure

2) Before this activity, what was your level of familiarity with the topic of composting?

( ) I was already well acquainted with the topic

( ) I had superficial knowledge

( ) I did not know about it

( ) I don't remember

3) Did the activity help you better understand the chemical and biological processes related to the decomposition of organic matter?

( ) Yes, clearly

( ) Partially

( ) It did not help

( ) I can't assess

4) Do you consider composting an important practice for the environment?

( ) Yes, very importante

( ) Yes, to some extent

( ) I don't see its importance

( ) I still have doubts

5) If it were possible to set up a composter at home, would your family be willing to collaborate?

( ) Yes, completely

( ) Yes, partially

( ) Probably not

( ) I don't know

6) Do you believe that the compost produced through composting can benefit plant cultivation?

( ) Yes, definitely

( ) Yes, but I have some doubts

( ) I don't believe it is effective

( ) I don't know

7) Was the teacher's support important for your understanding of the activity?

( ) Yes, it was essential

( ) It was reasonable

( ) I didn't have sufficient support

( ) I can't assess

8) Would you recommend this activity to other high school classes?

( ) Yes, definitely

( ) Maybe

( ) I wouldn't recommend it

( ) I have no opinion

9) After completing the activity, what is the likelihood that you would set up a composter at home on your own initiative?

( ) 100% likelihood

( ) High likelihood

( ) Low likelihood

( ) 0% likelihood

10) Did you feel that the activity helped you develop your ability to organize ideas and relate scientific concepts?

( ) Yes, very much

( ) Partially

( ) I didn’t notice that

( ) I don’t know how to answer

11) Did you feel motivated when using digital tools such as XMind to build concept maps?

( ) Yes, it was an engaging experience

( ) Partly, it was interesting

( ) I didn’t enjoy using it

( ) I didn’t use the tool

12) Overall, how do you evaluate the activity as a learning resource?

( ) Excellent

( ) Good

( ) Fair

( ) Poor

Received in May 2025.

Approved in November 2025.