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Concept map: synthesis of teaching-learning in Botany applied to the Environment

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A B S T R A C T

A concept map is a visual tool, a graphic summary, that brings together ideas related to a main topic. Using a metaphor, the concept "tree" was created collaboratively with graduate students in the Special Topics in Applied Botany course, offered in 2025. The course was developed to reflect on the importance of plants and botany applied to the environment, especially in light of current challenges. The concept "tree" presents the topics covered in the course in an interactive teacher-student format, both through lectures and seminars chosen and presented by the students, as well as the conclusions discussed on the course's final day. The illustrated botany-related themes address the beauty of landscapes, conservation of green areas, sustainable crops, and the problems of ecosystem suppression, increased air pollution, and climate change.

Keywords: Concept map, Botany, Graduate education, Environment.

Mapa conceitual: síntese do ensino-aprendizagem em Botânica aplicada ao Meio ambiente

R E S U M O

O mapa conceitual é uma ferramenta visual, um resumo gráfico, que reúne ideias relacionadas a um tópico principal. Usando uma metáfora, a "árvore" conceitual foi feita de forma colaborativa com os alunos de pós-graduação da disciplina Tópicos Especiais em Botânica Aplicada, oferecida em 2025 a pós-graduação. A disciplina foi desenvolvida na perspectiva de pensar a importância das plantas e da botânica aplicada ao meio ambiente principalmente diante dos desafios dos tempos presentes. A "árvore" conceitual apresenta os temas abordados na disciplina de modo interativo professor-alunos, tanto através das aulas dadas quanto dos seminários escolhidos e apresentados pelos alunos, bem como as conclusões discutidas no dia de finalização da disciplina. Os temas ilustrados e relacionados a botânica abordam a beleza das paisagens, conservação de áreas verdes, cultivos sustentáveis e problemáticas de supressão dos ecossistemas, aumento da poluição atmosférica e alterações climáticas.

Palavras-Chaves: Mapa conceitual, Botânica, Ensino pós-graduação, Meio ambiente.

1. Introduction

Concept maps are graphical tools for organizing and representing knowledge, allowing the visualization of hierarchical relationships between concepts. They facilitate meaningful learning by integrating new theoretical and practical knowledge with pre-existing cognitive structures (Novak & Cañas, 2010; Novak, 2010; Machado & Carvalho, 2020). Within the teaching–learning process, concept maps play a fundamental

role in fostering the active construction of knowledge. They facilitate the logical organization of knowledge, the development of critical and reflective thinking, and the identification of relationships among concepts, thereby contributing to the internalization of knowledge (Novak & Gowin, 1999; Moreira, 2010; Izci & Akkoc, 2024).

Concept maps are grounded in central themes from which related ideas branch out. This hierarchical structure, extending from central to peripheral concepts, reflects the natural process of cognitive acquisition and how knowledge is organized in the human mind (Ausubel, 2000; Tavares, 2007). According to Tavares (2007), concept maps function as facilitators of meta-learning, elucidating connections within the teaching–learning process and contributing to critical and reflective thinking.

In fields such as Biology, concept maps have been employed as effective teaching tools to facilitate understanding of complex content, strengthen the articulation between theory and practice, and support knowledge organization. Their use contributes to students' intellectual autonomy and analytical skills (Lenski, Mustafa, & Großschedl, 2024; Pinto et al., 2025). Kaiser (2010) applied concept maps as a pedagogical strategy to organize theoretical and practical knowledge in a Microbiology course within an undergraduate Biological Sciences program. The study elicited positive feedback from students, who reported that using concept maps facilitated the review of assessment content, offered an integrated perspective on knowledge and its interrelationships, and highlighted the collaborative experience of collectively developing the material. It is also noteworthy that several digital tools are currently available for constructing concept maps, such as CmapTools, Lucidchart, Venngage, and EdrawMind, some of which even provide thematic templates tailored to specific areas of Biology. In the Botany area, concept maps facilitate cognitive processes involved in understanding, memorizing, and reasoning about topics such as photosynthesis (Uno, 2009).

This article describes the dynamics of constructing a concept map within the teaching–learning course structured around two interrelated central axes: Botany and Environment. This approach underscores concept maps as an effective pedagogical strategy for acquiring and consolidating scientific concepts (Júnior, 2013).

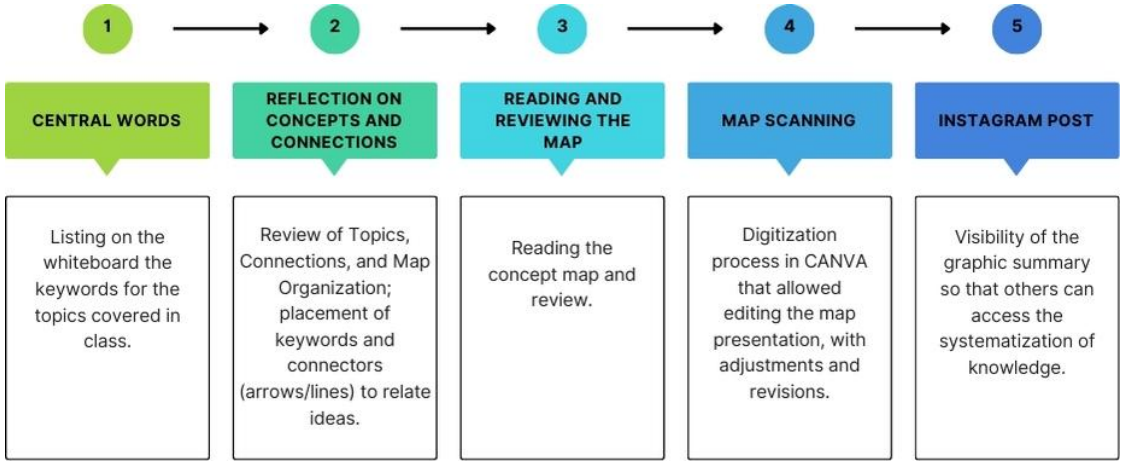
2. Material e Methods

The study was conducted with 20 students enrolled in two graduate degree programs at the Rio de Janeiro State University (UERJ, Brazil): Environmental Science and Technology and Plant Biology, during the first semester of 2025. The course was delivered over two months at the UERJ West Zone Campus in Campo Grande. This article constitutes a qualitative experience report associated with a graduate-level course, focusing on academic and professional development. According to Souza et al. (2018), an experience report involves a reflective, analytical, contextualized, and systematic description. It represents the written expression of individuals' practical experiences, aimed at sharing knowledge acquired across different topics (Mussi et al., 2021).

The report discusses the collaborative construction of a concept map designed to synthesize the content learned throughout the course "Special Topics in Botany Applied to the Environment," targeting both master's and doctoral students. In constructing the concept map, the central themes were ‘Botany’ and ‘Environment,’ reflecting content addressed in the classroom through lectures by the teacher and students, alongside the reading and discussion of scientific articles. The concept map was termed a ‘concept tree,’ as its central theme was Botany.

Initial guidance was provided to facilitate students’ structuring of the concept map and comprehension of the visual tool. On the final day of the two-month course, students collaboratively developed the concept map in a traditional classroom, based on a survey of key ideas and concepts. "Botany" and "Environment" were placed at the center of the concept map. A whiteboard and markers were utilized as resources, and the teaching sequence is illustrated in Figure 1.

Figure 1. Teaching sequence for constructing a concept map.
Figura 1. Sequência didática da construção do mapa conceitual.



Source: Author, CANVA platform.
Fonte: Autor, plataforma CANVA.

The concept map was structured around the central words, with subsequent breakdowns developed to relate them to the topics covered in the course in an orderly and logical sequence. The map was created, reviewed, and digitized using CANVA for later dissemination on Instagram. The organization of ideas and concepts resulting from the teaching–learning process was then shared for scientific communication.

During the digitization and editing, branches were color-coded, and symbols were added to facilitate the visualization of relationships. This article analyzes the collaborative strategy employed in constructing the concept map and the content reviewed and acquired through the course.

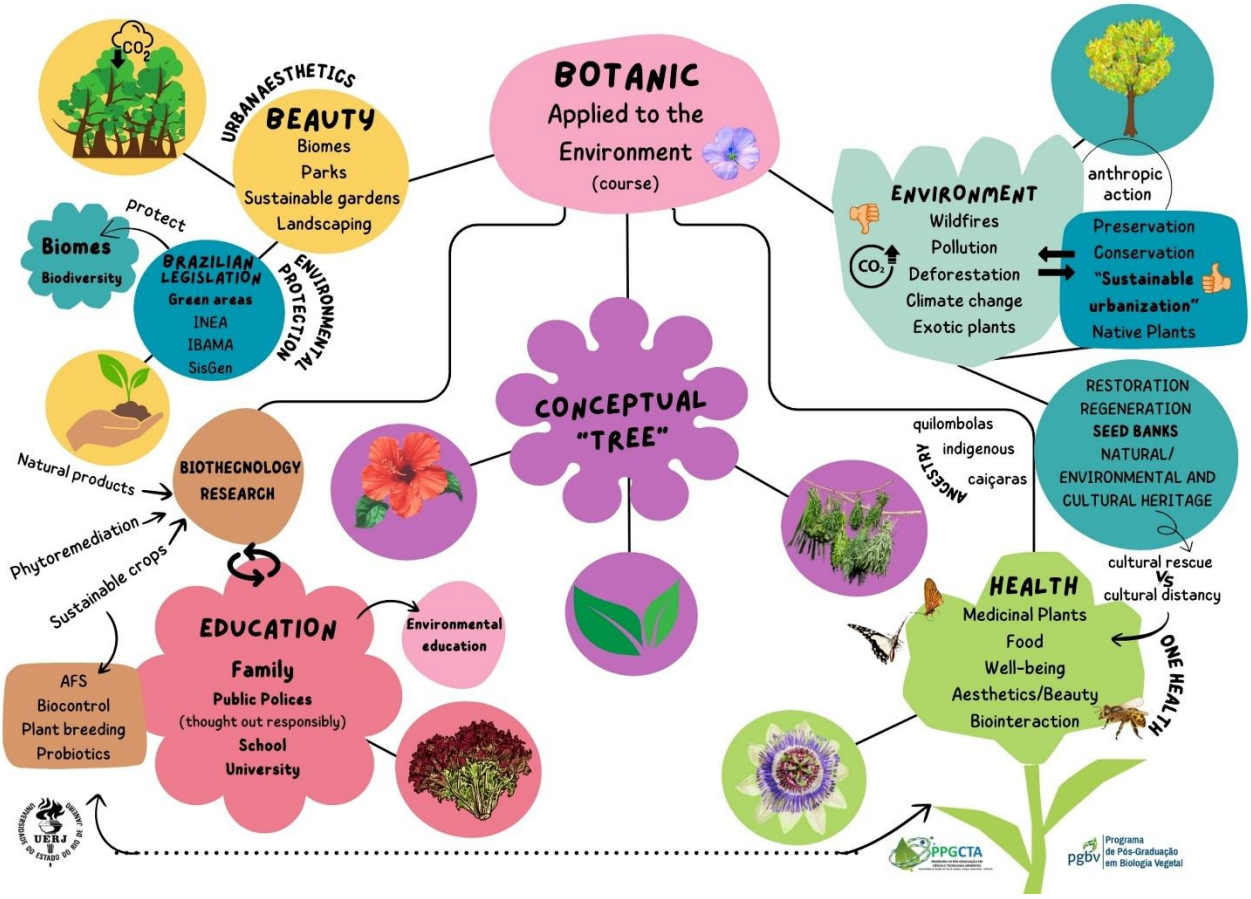
3. Results and Discussion

The teacher acted as a mediator, encouraging a review of previously discussed topics and organizing a concept map around the thematic axis Botany (applied to the environment). Student participation occurred through oral and written contributions, with markers provided for recording ideas on the whiteboard. With the introduction of each new concept, collaborative reflection on the established connections occurred, including arrows and linking words—essential elements for the logical structuring and cohesion of the represented ideas.

The construction of the concept map facilitates qualitative dialogues (Júnior, 2013). In the course evaluation, combined with teaching practice and active participation by graduate students, the collaborative production of the conceptaul map yielded positive feedback on the teaching–learning process for both teachers and students. Concept maps also promote self-assessment and stimulate interaction between teachers and students (Xu et al., 2024). No resistance or passivity was observed among the graduate students during the elaboration of the map, although previous studies report difficulties in applying this strategy in the academic environment (Machado & Carvalho, 2020; Izci & Akkoc, 2024).

The concept map was structured in a spider diagram (Gomes et al., 2011) (Figure 2), a format that emphasizes the relationships extending from a central theme, with peripheral concepts distributed radially. The map integrated various themes from the course and featured cross-links between concepts at different hierarchical levels. Nonetheless, due to its visual and creative qualities, it sometimes displayed characteristics similar to a mind map.

Figure 2 - Concept "tree" of the spider web type, with the central theme "Botany" and "Environment", referring to the graduate course.
Figura 2 – "Árvore" conceitual do tipo teia de aranha, como tema central "Botânica" e "Meio Ambiente", referente a disciplina de pós-graduação.



Source: Author, CANVA platform. Published in Portuguese: (bit.ly/4fFTn1m)
Fonte: Autor, plataforma CANVA. Publicado em português: (bit.ly/4fFTn1m)

Connections between elements were established logically, employing words and/or expressions that support concept correlations and textual interpretation. This configuration facilitates the visualization of multiple linkages and integrates cross-cutting themes, strategically incorporated to expand and reinforce the represented concept network. Regarding the map's central and cross-cutting themes, numerous connections highlight interactions between plants and the environment, emphasizing the significance of Botany in addressing contemporary environmental challenges.

Botany and the environment constitute central axes that permeate all the connections represented. The concept map can be analyzed structurally by sections, although alternative arrangements are equally possible, as the connections are not mutually exclusive. For instance, the cross-cutting theme of health connects with the traditional knowledge of local communities and the medicinal use of plants, aspects related to aesthetics and well-being, including mental health.

In addition to the health section, other sections include aesthetics/beauty; environment (anthropogenic actions), which addresses both positive and negative human impacts; and education, from the family environment to formal educational institutions that foster environmental citizenship. Education also

encompasses specific learning linked to biotechnology research, contributing to green technologies such as phytoremediation, biocontrol, probiotics, and sustainable crops that provide healthy food, ultimately linking back to human, animal, and environmental health.

The construction of a concept map is influenced by the subject, including their perceptions, opinions, and prior knowledge. Another key aspect is the integration of understanding during collaborative concept map development. In the final synthesis activity, additional perspectives were incorporated, highlighting the subjective dimension inherent in concept maps. The concept map reflects a technical and comprehensive perspective, addressing the general and specific aspects of the topic under analysis. Some students emphasized aspects drawing on their professional experiences, such as scientific projects or companies, connecting prior knowledge with course content to build a deeper and more lasting understanding. The application of concept maps is a pedagogical strategy that enhances meaningful learning by enabling students to establish hierarchical relationships and interconnections between concepts, integrating new knowledge into previously consolidated cognitive structures (Ausubel, 2000).

At this stage of reviewing and summarizing the content covered in the course, aspects that position Botany among the most relevant topics in the current context were considered, given its close relationship with environmental issues and their societal implications.

The selection of terms in the concept tree and the definition of connections represented by arrows were clarified through collaboration between the teacher and students. Some topics were emphasized more due to their relevance to individual research projects or students' previous experiences. Although the concept map did not encompass all the content covered throughout the course, it synthesized most topics, enabling the integration and organization of key themes discussed.

One of the themes revisits the importance of aesthetics, encompassing the beauty of landscapes and their association with health. Natural ecosystems are visually pleasing, enjoyable, and beneficial for mental health (Bratman et al., 2019). Sensory well-being, experienced when immersed in green spaces, contributes to overall health, which involves plants in various contexts. This includes the ancestral knowledge of traditional communities that utilize plants, for example, to treat illnesses and maintain a diverse and healthy diet (Silva et al., 2022). The use of medicinal plants by *caiçara*, *quilombola*, and indigenous peoples was discussed, recalling two seminars: one on the *caiçara* communities of São Paulo and another on a *Quilombo* in Rio de Janeiro.

Safe food production, promoted through sustainable cropping systems such as agroforestry systems (AFSs) without destruction of native vegetation or chemical contamination, was another theme emphasized on the map. Environmental health reflects the well-being of the biota. In line with this perspective, health systems have adopted the One Health approach, which emphasizes the interdependence of human, animal, and environmental health, promoting collaborative, intersectoral actions that enable more effective and sustainable responses to contemporary health challenges (Brazil, 2025)

Sustainability-related themes emerged throughout the development of the concept map, highlighting their relevance as an integrative axis for organizing and representing content. There is a growing emphasis on sustainable urbanization that engages with environmental conservation and the expansion of urban greening through the development of sustainable gardens, parks, urban AFSs, mini-forests, green roofs, and sustainable landscaping that prioritizes the use of native plants. Additionally, there is an urgent need to conserve natural green areas and germplasm, which can be ensured through legal protection, *herbaria*, and initiatives such as reforestation, ecological restoration, seed banks, and the rescue or multiplication of creole seeds (Pereira & Soglio, 2020; Engles & Ebert, 2021; Egerer & Suda, 2023).

Conversely, numerous anthropogenic actions contribute to environmental degradation, including increased greenhouse gas (GHG) emissions such as CO_2, deforestation, biodiversity loss, the introduction of exotic species, and climate change (Ellwanger et al., 2025). These issues involve plants both as targets of degradation and as solutions for mitigation, for instance, through CO_2 absorption. This is illustrated in another

concept map, centered on photosynthesis, which demonstrates—through arrows and linking words—that plants remove CO_2 from the atmosphere during this process (Uno, 2009).

During the class discussion, a question arose regarding the distinction between preservation and conservation, with the latter clarified by a student experienced in reforestation. Given the ongoing anthropogenic impacts on ecosystems, the term conservation is more appropriate to describe strategies for mitigating environmental damage. In this context, reconciliation between society and nature can be promoted through the adoption of sustainable cultivation practices for food production, such as hydroponics, aquaponics, organic gardens, and agroforestry systems (AFSs) (Silva & Victório, 2023; Pereira et al., 2024). In the field of plant biotechnology (applied Botany), recent scientific advances encompass innovations and technologies for biocontrole insect, the use of probiotics to enhance plant productivity, the selection of plants for pollutant remediation (phytoremediation), and the application of plant metabolites as alternatives to pesticides, all within an ecologically informed framework (Wani et al., 2023; Pereira et al., 2024).

The comprehensive reflection on central themes during the development of the concept map underscores the relevance of this strategy as a pedagogical approach for teaching and learning. Research shows that concept maps promote inductive reasoning in collaborative settings, enhancing collective understanding and improving individual learning. (Fischer et al., 2019).

Concept maps also activate visual memory; thus, although constructed as part of the teaching–learning process, they support long-term retention of the topic, encourage deeper exploration of specific aspects, and make scientific information more accessible to individuals not involved in their development. Increased content retention is one of the key benefits of using visual resources such as concept maps (Ramos et al., 2024).

4. Conclusion

This article presents a "concept tree" of ideas developed within the teaching–learning process of the course "Special Topics in Botany Applied to the Environment," offered in graduate degree programs. The application of concept maps in the classroom represents an active methodology integrated with theoretical instruction.

The course was developed to reflect on the importance of plants and the application of Botany to environmental contexts, particularly in contemporary challenges. Botany applied to the environment integrates diverse approaches, positioning plants as key elements in critical issues such as climate change, sustainable food production, and biodiversity conservation. As fundamental components of ecosystem functioning, plants sustain biotic interactions and constitute the foundation of food chains, making them indispensable for the maintenance of life. In the context of global challenges—such as rising atmospheric carbon dioxide concentrations, increasing average temperatures, and consequent climate change—the importance of plants becomes even more pronounced, underscoring the need for integrated research, management, and conservation strategies.

Graphic summaries organize ideas, guide study, and facilitate the dissemination of scientific knowledge. The concept map facilitated the integration of course content and acted as an assessment tool. Its creation and subsequent digitization enabled its sharing through social media, thus constituting an outreach activity of the graduate degree programs.

The collaborative development of the "concept tree" integrated technical knowledge into a dynamic and dialogical pedagogical practice, promoting meaningful learning, which involves incorporating new knowledge into existing cognitive structures in an integrated and lasting manner.

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