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RESEARCH ARTICLE

Mind maps for eliciting and assessing plant awareness: A preliminary study on pre-service teachers

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Societal Impact Statement

Teachers play an indispensable role in promoting citizens' plant awareness. To this end, they need adequate plant knowledge –including classification–, experience in out-of-classroom settings, and enthusiasm for plants. With the aim of improving pre-service teachers' plant awareness, we designed and implemented a didactic sequence including several drawing exercises, prominently botanical illustration, which ran in parallel with a gardening program that provided an outdoor learning experience. Assessment was performed through mind maps and revealed improvements related to knowledge of plants, including morphological knowledge and appreciation of plants' beauty, which may positively influence their teaching practice in the future.

Summary

- Promoting plant awareness is considered a main goal of biological education. Plant awareness is particularly relevant in teachers, who oversee the botanical education of future generations. The literature highlights the need to develop plant knowledge, experience in outdoor education, and enthusiasm for plants in pre-service teachers.
- We designed a didactic sequence contextualized at an organic garden, constituted by both artistic and scientific activities. The artistic perspective consisted of drawing based on observation (prominently, botanical illustration), with the aim of constructing knowledge on plant morphology, and promoting emotional engagement through appreciation of plants' beauty.
- Several instruments were used to collect information on initial ideas and the process of learning, outstandingly mind maps, a type of multimodal diagram used to represent ideas on a topic by means of drawings and text. A qualitative procedure was developed to analyze them, encompassing three perspectives: information structure, artistic performance (e.g., graphic richness), and scientific performance (plant knowledge, per content categories). Obtained data were subsequently analyzed through statistical tests.
- This preliminary study shows that knowledge of plant morphology was developed through botanical illustration, incorporated by pre-service teachers, and used in final mind maps. Significant improvements were observed in certain dimensions of

plant awareness, related to plant knowledge and the aesthetic appreciation of their biological characteristics.

KEYWORDS
art-based education, botanical illustration, mind maps, organic garden, plant awareness, pre-service teachers

1 | INTRODUCTION

1.1 | Plant awareness

The term plant awareness refers to the capacity to acknowledge and value the presence, significance, and unique attributes of plants within the environment. It encompasses understanding their ecological roles, appreciating their importance in sustaining life and societies, and recognizing their diverse biological features (Pany et al., 2022; Parsley, 2020; Wandersee & Schussler, 2001). Thus, fostering plant awareness is a condition to achieve sustainability (Amprazis & Papadopoulou, 2020; Thomas et al., 2022). The lack of plant awareness, previously termed plant blindness (Wandersee & Schussler, 1999) and plant awareness disparity (Parsley, 2020) arises from four main factors (Parsley, 2020):

1. Most people pay little attention to plants or even overlook them. This can be attributed to perceptual, memory-related (Balas & Momsen, 2014; Wandersee & Schussler, 2001), and cultural constraints (Schussler & Olzak, 2008; Stagg & Dillon, 2022).
2. People tend to be more interested in animals than in plants, which is related to the degree of behavioral and physical resemblance between animal species and humans (Lubbe & Castillo Alfonzo, 2024) and has historically led to a zoocentric bias in education.
3. Negative attitudes toward plants limit plant awareness, and formal education plays a key role in improving them. Teachers' enthusiasm for, and knowledge of, plants (Strgar, 2007), along with methodological approaches such as outdoor education (Fančovičová & Prokop, 2011) can contribute to foster plant awareness.
4. The lack of specific knowledge about the importance of plants for the biosphere hinders the understanding of their role in sustaining life and societies (Howard, 2003; Wandersee & Schussler, 2001).

Moreover, the literature highlights that enhancing knowledge improves attitudes, interest, and attention toward plants, and vice versa (Kubiatko et al., 2021; Pany et al., 2019).

1.2 | Why use a garden to promote plant awareness?

Gardens are out-of-classroom teaching contexts that are considered to improve science learning for several reasons, including that they involve authentic, practical work and promote positive attitudes to science (Braund & Reiss, 2006). This stands true for the case of biology; in fact, outdoor learning is considered the most effective and popular approach for improving knowledge and attitudes toward biodiversity (Eugenio-Gozalbo & Ortega-Cubero, 2022; Fančovičová & Prokop, 2011). Regarding botanical education, it has been shown that outdoor education can enhance plant identification knowledge (Borsos et al., 2021; Buck et al., 2019). In the case of initial teacher training, outdoor learning programs act as a model for future teachers, providing them with experience and training, and making them more likely to use out-of-classroom settings in their future professional practice (Lindemann-Matthies, 2006).

Gardens have some strengths, particularly their closeness to classrooms, so that: (1) they save money and teaching time, and avoid complications (Borsos et al., 2018; Lindemann-Matthies, 2006), and (2) they provide opportunities for sustained contact with an outdoor environment, which favors place attachment and development of environmentally responsible behaviors (Vaske & Kobrin, 2001). From a scientific point of view, gardens are agroecosystems, i.e., functional systems of complementary relationships between living organisms and their environment, which appear to maintain a stable state of equilibrium, but at the same time are dynamic; managed by humans for the purpose of agricultural production, being modified in structure and function and in emerging qualities (Altieri, 1995). Thus, gardens are valuable for science teaching, since they facilitate approaching the study of their components and processes from a scientific point of view and reflecting on environmental issues that are linked to management practices (e.g. deciding if use or not pesticides, how to care for soils, if composting or buying fertilizers, how to irrigate to save water, etc.) (Eugenio-Gozalbo et al., 2021).

In the case of botanical education, gardening involves direct contact with live plants through their cultivation, which is known to develop emotional engagement (Krosnick et al., 2018). A recent review on plant awareness has highlighted that increasing people's interactions with plant-rich environments and introducing them to useful and edible plants could be an effective approach for enhancing it (Pany et al., 2019; Stagg & Dillon, 2022), a recommendation that perfectly fits with using gardens for such purposes in formal education.

1.3 | Why choose an art-based approach?

Art allows us to contemplate reality from different perspectives, and certain artistic approaches can bring to the surface everyday things that otherwise remain unnoticed. Art also allows us to discover and appreciate the beauty of the natural world, even when the observed elements seem irrelevant, unattractive, or even ugly (Attenborough et al., 2017; Eugenio-Gozalbo & Ortega-Cubero, 2022). Additionally, there is an emerging body of work at the interface between art and plant sciences (Sanders, 2019, 2022), which supports the benefits of introducing artistic or cultural dimensions into other disciplines (O'Farrell, 2010). Lastly, art can add interest to formal curricula, facilitating students' engagement and fostering perceptive refinement, which has often long-term positive effects (Eisner, 2017).

In educational contexts, drawing can be used for different purposes (Ainsworth et al., 2011), including: (1) as a pleasant activity for observation and personal study (Stagg & Verde, 2019), (2) as a way to elicit students' ideas about specific topics (Bartoszek & Tunnicliffe, 2017; Giordan & De Vecchi, 1988), and (3) as an instrument to assess the effectiveness of certain activities or programs (Eugenio-Gozalbo et al., 2020; Stears & Dempster, 2017). A theoretical line is a consideration of drawing as a strategy to build scientific knowledge (Anderson, 2019; Chang, 2017; Gómez-Llombart & Gavidia, 2015; Sanders, 2007; Tishman, 2018; Tytler et al., 2020). Although promising evidence exists (Bovek & Tversky, 2016; Fiorella & Zhang, 2018; Schmidgall et al., 2019), learning relies on the final quality of drawing, which in turn is linked with the art teacher, who plays a fundamental role in success (Dempsey & Betz, 2009; Van Meter & Garner, 2005).

2 | MATERIALS AND METHODS

2.1 | Characterization of the didactic intervention

A didactic sequence was designed to promote plant awareness in pre-service teachers (PSTs). It comprised artistic and scientific activities, both theoretical and practical (Table 1), and was contextualized in an organic garden. The artistic perspective consisted in drawing based on observation (outstandingly, through botanical illustration), to construct knowledge on plant morphology, thus laying the foundation for effective learning of basic plant classification in families. Mind maps (MMs) were used as a visual thinking strategy to collect information before and after the didactic intervention, to test its usefulness for eliciting and assessing plant awareness. A garden was used as a real context where learning science, as a source of inspiration for drawing, and to

TABLE 1 List of activities that constituted the didactic sequence to promote plant awareness in pre-service teachers, characterized at a basic level.

Objective	Activities	Timing
Motivation	Short introduction video: "I am a plant lover … and you?" (self-production in which the teacher introduces the topic and tries to motivate students)	10'
Initial ideas' eliciting	Realization of **initial mind maps** (after an introduction on what is a mental map by the art teacher)	30′ (15′)
	Visit to the garden + selection of 13 plant species to draw and classify them following common criteria + sharing	55′
Knowledge construction	Reading (the chapter "Constructing the model of a living being" by Pujol (2004)) + summarizing + sharing	Homework
	Theoretical science class: Evolution and main groups of plants	55'
	Theoretical science class: Morphological and functional characteristics of plants	55'
	Theoretical art class: How to draw botanical sketches in nature	20'
	Garden art session: Drawing botanical sketches (freely chosen plant at the garden)	35'
	Practical science class at the "laboratory of art and science for children": To observe and take pictures of plant structures (samples obtained from the garden) under magnifying glasses + observing non-fiction picture books	55'
	Practical art class: **Botanical illustration** (freely chosen plant)	2 sessions of 55′ + 1 voluntary session of 55'
	Naming all plant parts in the botanical illustration + sharing	Homework
	Practical science class: Recalling of garden plants + intuitive classification based on morphological similarities + informed classification into botanical families	55′ + homework
Summary of ideas	Theoretical science class: Recapitulating all that has been explained about plants (morphology, anatomy, physiology, taxonomy, ecology, plant uses). Reasons to become a plant lover	55'
Final assessment	Realization of **final mind maps**	30'

Note: Note that the initial activities were aimed at motivating students and eliciting their ideas; that those were followed by a knowledge construction phase consisting of theoretical and practical science and art activities, contextualized in the garden; and that the final activities were aimed at recapitulating and summarizing ideas. This sequence ran in parallel with a gardening program at the organic garden.

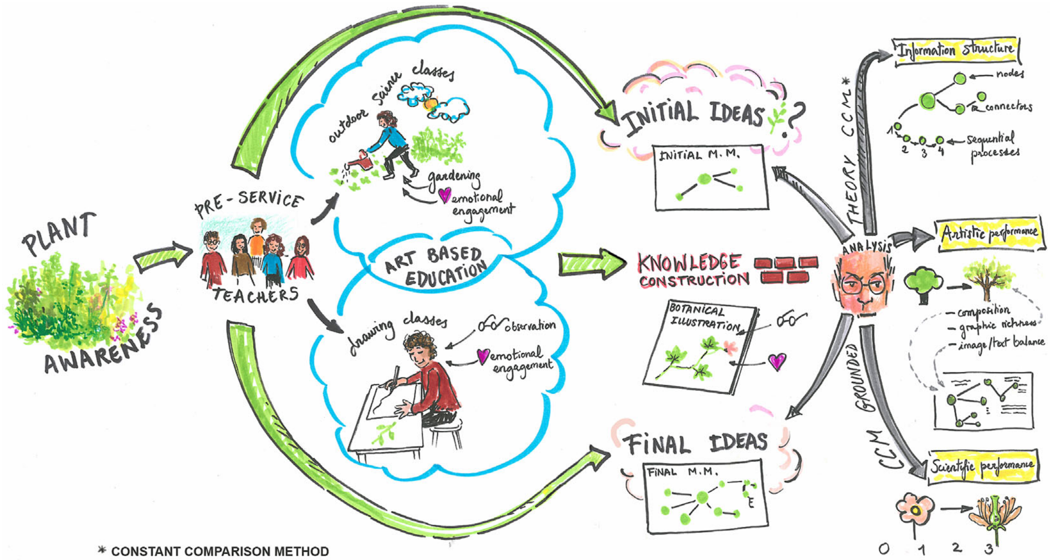

FIGURE 1 Mind map (MM) on the didactic intervention and analysis of students' MMs. CCM: constant comparison method. Author: Inés Ortega-Cubero.

promote direct contact and emotional engagement with alive plants (Figure 1). The sequence ran in parallel with an organic gardening course held in the framework of the compulsory course "Natural sciences" (degree in Pre-School Teacher, Faculty of Education of Soria, University of Valladolid, Spain).

2.2 | Ethical considerations

All participants were of legal age (18) at the time of the study. They were informed of the aims of the study and were asked to give their explicit written consent for the use of the anonymized data for research purposes.

2.3 | Assessment through mind maps: definition and analysis procedure

MMs are a visual thinking modality used to express the fundamental ideas on a certain topic through drawings, connectors, key terms, and colors; in a hierarchical and organized manner, and on a single sheet of paper (Sibbet, 2010). As multimodal productions including image and text, they can be considered semiotic units "structured, not linguistically, but by the principles of visual composition" (Kress & Leeuwen, 2003, p. 185). A MM should be meaningful for its author, for which quick, simple, and easy-to-remember personal drawings are employed. MMs can be used for personal study or as an instrument to communicate content to an audience (Dimeo, 2016; Larralde, 2022; Roam, 2010; Rohde, 2019); we have previously proposed their use to assess students' learning (Ortega-Cubero & Coca-Jiménez, 2021). Most MMs present a radial structure and connectors (normally arrows) that link drawings, showing conceptual relations; however, other organizations are also possible. Typically, MMs are clearly informative, since they can show a great amount of content in a synthetic way. Interestingly, they also reveal knowledge gaps and mistakes, as well as the right or wrong relations that are established between nodes of information, so its elaboration involves a problem-solving dimension (Sibbet, 2010).

In this work, PSTs were asked twice to draw an MM to express their knowledge about plants: at the beginning and at the end of the sequence, an activity that lasted one hour each time (Table 1). A total of 43 paired maps were obtained after discarding unmatched ones and eccentric cases. They were qualitatively analyzed by two researchers based on the Grounded Theory to provide a deep visual reading of MMs as conceptual instruments by applying the constant comparison method, i.e., systematically and recurrently analyzing them for the theory to emerge from the dataset. Thus, after descriptive and coding work, researchers established a series of content categories and subcategories, which were gradually refined and saturated. A certain degree of subjectivity is admitted since the method considers the expert judgment of researchers as necessary to develop the sensitivity that will allow theory to be obtained from data (Corbin & Strauss, 2015). MMs were analyzed regarding (see Figure 1):

a. **information structure:** parameters such as the number of nodes of information, the number of connectors, and the number of sequential processes (stages linked to each other by secondary arrows) were considered (Figure 2).
b. **artistic performance**: issues such as the main compositional structure (radial-centered, radial-top, left to right reading, eccentric configuration), the level of graphic richness (low, medium, high), and the level of text-image balance (balanced, text-dominated, image-dominated) were determined.

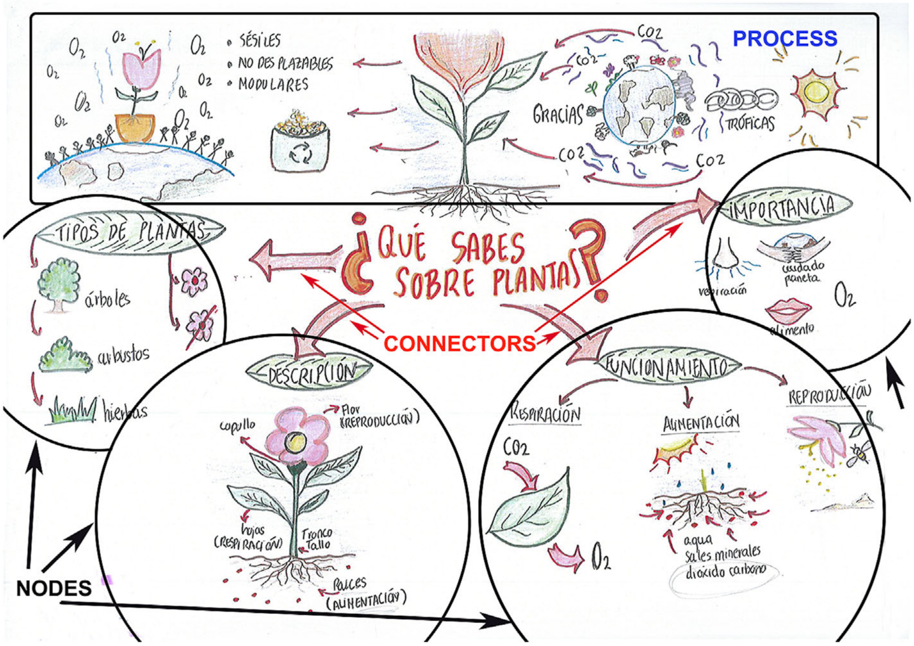

FIGURE 2 Example of analysis of (a) information structure: radial-centered structure, 4 connectors, 5 nodes (one corresponding to a process not linked with the rest of contents); and (b) artistic performance: high graphic richness, image-dominated. O_2: oxygen; CO_2: carbon dioxide.

TABLE 2 Results of statistical analysis of changes in contents of mind maps (post-pre).

Category / *Subcategory*	Observations	Observed change[a] Z value (p-value)	Effect size (Cohen's r[b])
Morphology			
Plant habit	General form of a plant (e.g. tree, shrub, herb, etc.).	= -0.203 (.028)	0.031
Plants as modular organisms	Body organization in modules[c]	= -0.460 (.646)	0.070
Plant organs (general)		= -1.122 (.262)	0.173
Flowers (in detail)		↑ -4.873 (<.001)	0.743
Leaves (in detail)		↑ -2.266 (.023)	0.346
Seeds (in detail)		↑ -3.275 (.001)	0.499
Plant classification			
Based on leaf abscission	Distinguishing between deciduous and evergreen plants.	↓ 2.828 (.005)	0.431
Based on wide evolutionary groups	Such as bryophytes, gymnosperms or angiosperms.	↑ -4.475 (<.001)	0.682
Main families of garden plants	Such as *Poaceae*, *Solanaceae* or *Fabaceae*.	↑ -4.778 (<.001)	0.729
A variety of commonly used criteria	For example: Wild, cultivated edible, poisonous, aromatic, etc.	= -1.911 (.056)	0.291
Physiology			
Photosynthesis		↑ -2.062 (.039)	0.314
Nutrient uptake		= -1.268 (.205)	0.193
Respiration		= -1.370 (.171)	0.209
Reproduction		= -1.872 (.061)	0.285
Germination		= -1.841 (.066)	0.281
Interaction	Plants are not immobile; they exhibit nastyas and tropisms.	↑ -2.200 (.028)	0.335
Ecology			
Primary producers	Includes mentions to plants as basis of food chains.	= -1.687 (.092)	0.260
Pollination		= 1.186 (.236)	0.181
Other interspecific interactions		↑ -2.266 (.023)	0.346

[a] ↑ denotes an increase after the learning sequence, while ↓ represents a decrease; = indicates no change.
[b] According to Cohen (1988), effect size may be interpreted as small when r > 0.1, medium when r > 0.3, and large when r > 0.5.
[c] From an evolutionary perspective, plants' body organization is modular, with a photosynthetic module (leave), a reproductive module (flower), and a module for nutrients' search and absorption (root), which are repeated a number of times, and produced depending on particular environmental factors.

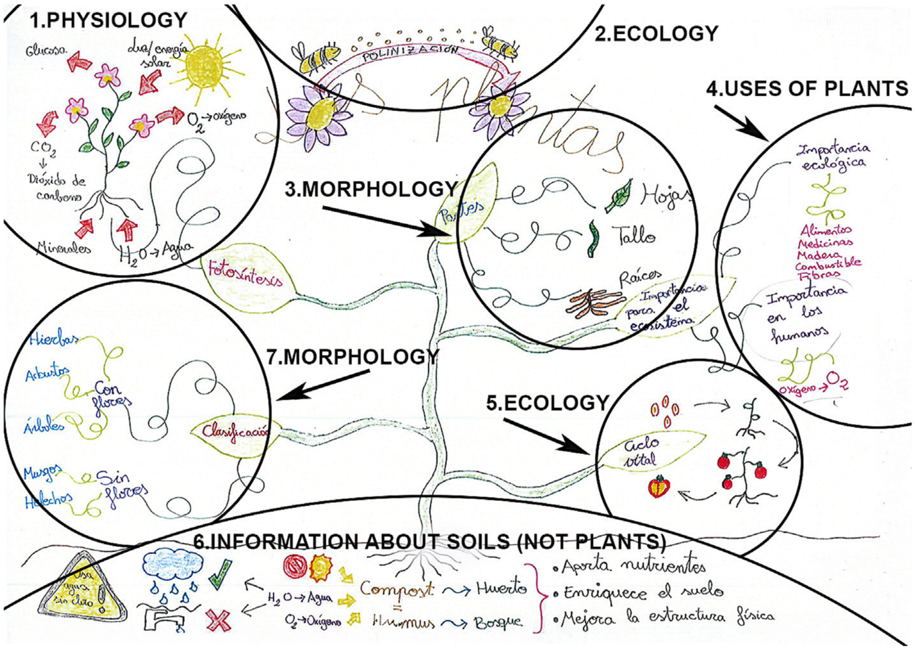

FIGURE 3 Example of analysis of (c) scientific performance in an initial mind map (MM); labels in capital letters indicate content categories. Note that a single information node can include more than one category or subcategory (e.g., node 7), or it may not provide content about plants (e.g., node 6). Node 1 provides information on physiology / photosynthesis. Node 2 on ecology/ pollination. Node 3 on morphology/plant organs (general). Node 4 on uses of plants. Node 5 on ecology/life cycle. Node 6 does not provide information on plants, but on soils. Node 7 provides information on both morphology/plant habit and plant classification/based on wide evolutionary groups. All contents in this initial MM were considered of quality level 1 (low). O_2: oxygen; CO_2: carbon dioxide; H_2O: water.

c. **scientific performance**: system of emerging content categories and subcategories is shown in Table 2. The quality of the content was assessed at three levels: low, medium, or high (1 to 3, with 0 indicating absence), by considering both written and drawn information. For the categories role in ecosystems" and uses of plants, only the presence of subcategories was considered, since students gave exclusively key terms and not explanations (Figure 3).

The post-pre variation in all such variables was statistically assessed using McNemar-Bowkes tests (for nominal variables, e.g. compositional structure and text-image balance), McNemar tests (for presence-absence variables, e.g., role in ecosystems and uses of plants), and Wilcoxon signed-rank tests for the remaining, scaled, variables. Effect sizes were calculated according to Fritz et al. (2012) and interpreted according to Cohen (1988).

2.4 | Knowledge construction through botanical illustration: justification and analysis procedure

Botanical illustration is a traditional modality of drawing that connects the interests of science and art. It derives from scientific drawing, but artists can arrange composition and choose materials and techniques according to their aesthetic criteria and personal style (Birch, 2020). Scientific illustration, being guided by the ideals of verisimilitude and representativeness, seeks both to transmit knowledge in an accessible way to a non-specialized audience and to awaken sensitivity to the natural world. To illustrate a botanical specimen, it is necessary to observe it carefully and distinguish its structural traits; the main drawing goals are capturing it in a correct line drawing and achieving appropriate finishing in terms of color and texture.

A seminar was held on botanical illustration with the aim of promoting the construction of knowledge on plant morphology, with PSTs divided into two groups (Table 1). It was conducted by an art teacher and involved two compulsory sessions of 2 hours each, plus one voluntary session (in each group). Students were encouraged to freely choose a plant specimen –to foster individual interests (Pany et al., 2019)– and were provided with magnifying glasses and dissection materials. Main concepts explained by the teacher included: composition (distribution of the visual masses of the drawing on the paper sheet), structure (external organization of the model), proportion (size relation between the different parts, and between parts and the whole), and inclusion of minor details were.

As a learning strategy, drawing is a process that must be unveiled. Consequently, an example of the process of drawing a botanical illustration with the same available technical means and materials was given by the teacher, step by step. Furthermore, the progress of each student was individually monitored by the art teacher during the seminar. PSTs were encouraged to obtain a drawing, as accurate as possible, and consisting of precise, clear, and simple lines at the end of the two compulsory sessions; and to add color and texture to achieve a more realistic finish in the additional, voluntary session.

A total of 43 botanical illustrations were obtained and assessed by means of a purposely designed rubric, originally constructed by the art teacher, and refined and validated by an external researcher. Such rubric focused on structural aspects and considered general structure, proportion, the morphology of the leaves (shape, veins, margin), flowers (petals, stamen, pistil, sepals, receptacle, flower buds), and other structures (fruits, seeds, roots), at different levels of performance (from 1 to 4, fanciful to realistic). It also considered the consistency of structures that are similar (e.g., leaves) and two artistic items: color and texture.

3 | RESULTS

3.1 | Botanical illustrations

Botanical illustrations reflected an accurate observation of plants and showed a good artistic level (Figure 4). Most drawings captured general structure (45.2% and 40.5%) and proportions between elements at an adequate or high level (33.3% and 54.8%, respectively). PSTs paid particular attention to leaves and their traits: shape, veins, or leaf margin, among others (73.8% and 14.3%, respectively). Flowers appeared in 32 out of 43 illustrations, and their structures (petals, stamens, pistils, etc.) were represented at an adequate or high level (83.9% altogether). Roots were scarcely drawn (only in 7 out of 43 illustrations). Main identified limitations were primarily related to the appropriate selection of the viewpoint allowing structures to be clearly shown; sometimes students chose an excessively close viewpoint, so it was difficult to include the whole plant structure, or they simply focused on their favorite parts (particularly flowers, e.g., Figure 5).

Finally, PSTs sought to obtain realistic colors by mixing watercolors, which was an interesting strategy since it caused a sense of naturalism, although the hues of green were not completely accurate, partly due to the school-type quality of art materials. Texture was the most difficult aspect: the variety of existing textures (leaves with a velvety finish, with a waxy shine, or a wet appearance, among others) involves that a standard painting technique cannot be used, and capturing all such surface nuances would have involved more time investment.

3.2 | Mind maps

From the perspective of information structure, the complexity of MMs significantly increased after the didactic sequence regarding the three considered parameters: number of nodes ($Z = -5.559$; $p < .001$), connectors ($Z = -3.081$; $p = .002$), and processes represented ($Z = -2.063$; $p = .039$) (Figures 5 and 6). Following Cohen (1988), the effect sizes were large (Cohen's $r = 0.848$) for the number of nodes and medium for the other two variables ($r = 0.470$ and $r = 0.315$, respectively).

From the perspective of artistic performance, statistical analyses revealed significant increases in graphic richness ($Z = -4.185$; $p < .001$), and a tendency to incorporate more text ($\chi 2 = 10.455$; $p = .015$) after the implementation (Figure 4), while no significant changes were observed in the compositional structure ($\chi 2 = 7{,}133$; $p = .309$), which was prominently radial-centered both before and after the implementation (Figure 5). Following Cohen (1988), effect sizes were large for graphic richness ($r = 0.662$), small for text incorporation ($r = 0.029$), and medium for compositional structure ($r = 0.348$).

Table 2 shows statistical results for scientific performance. Significant improvements were observed in relation to morphological features (particularly flowers (in detail), followed by seeds (in detail) and

FIGURE 4 Examples of three botanical illustrations produced by different students.

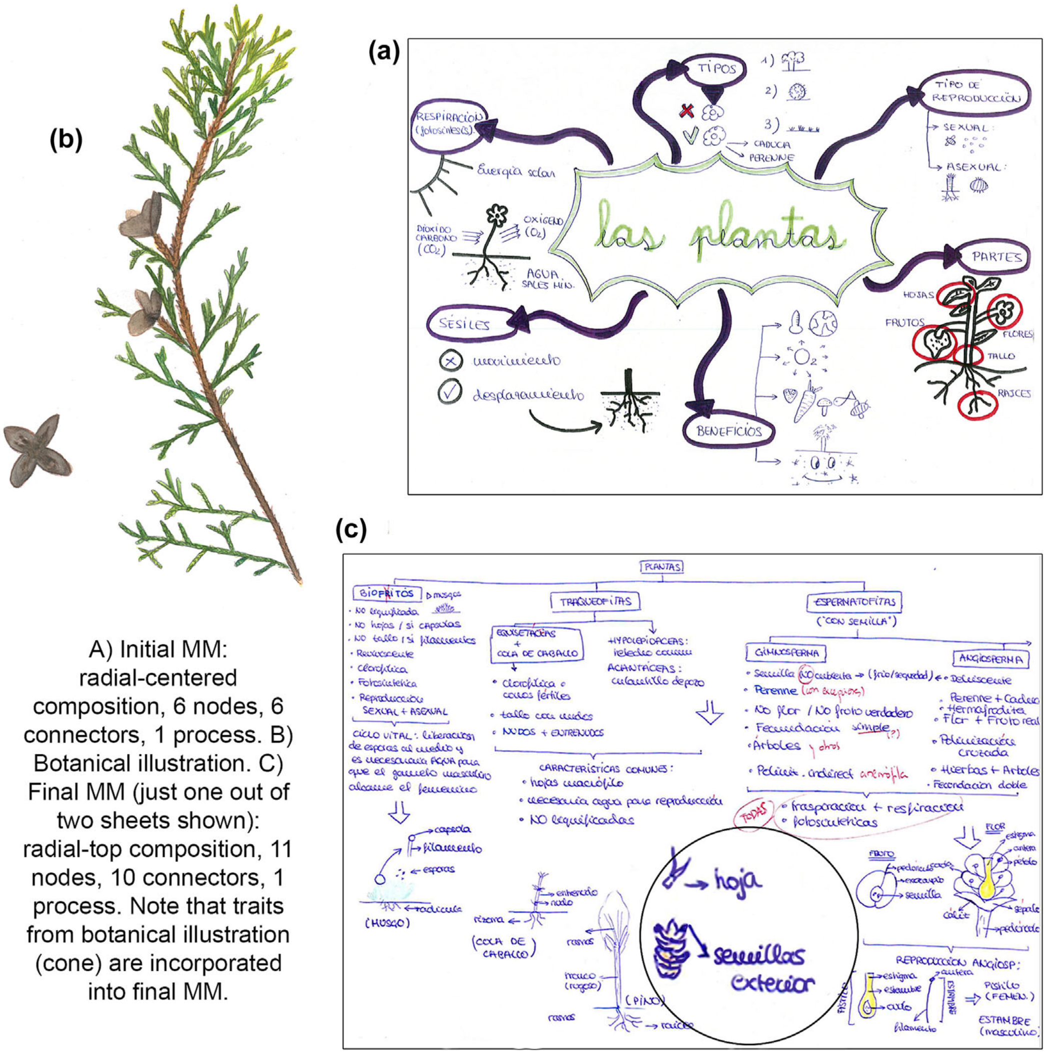

FIGURE 5 Example of drawing sequence (a–c), from the initial to the final mind map through botanical illustration (and other science and art theoretical and practical activities).

leaves (in detail)), and plant classification (based on wide evolutionary groups and main families of garden plants, to the detriment of simpler classifications, such as based on leaf abscission).

Knowledge improvements were not observed regarding physiological and ecological aspects, except for the subcategories photosynthesis and other interactions between species, respectively. Regarding the categories role in ecosystems and uses of plants, changes were not observed, except for decreases in mentions to oxygen production ($p < .001$) and human food ($p < .001$), respectively. Effect sizes were low for both (Cramer's $V = .017$ and Cramer's $V = .179$, respectively).

Importantly, the analysis of initial MMs also revealed some widespread misconceptions regarding plants, such as (1) flowers being considered a plant habit at the same level as trees, shrubs, and grasses, or drawn with roots (resembling a tree structure), (2) on respiration and photosynthesis; e.g., respiration involves taking in CO_2, photosynthesis involves taking in O_2, photosynthesis occurs only during the day, respiration occurs only during the night. In this study, misconceptions were not quantified.

3.3 | Qualitative relations between data from botanical illustrations and mind maps

In the final MMs, the structural features of plants were described through drawings that were more precise and detailed than in the initial MMs. Furthermore, in some cases, the specimen chosen for botanical illustration conditioned which details were included in final MMs (Figure 5). Graphic stereotypes also appeared, used as quickly drawn and merely communicative symbols (e.g., in Figure 6, main families of garden plants).

4 | DISCUSSION

4.1 | Case study in PSTs

This preliminary study on Spanish PSTs has evidenced knowledge construction both in the fields of art and science after the implementation

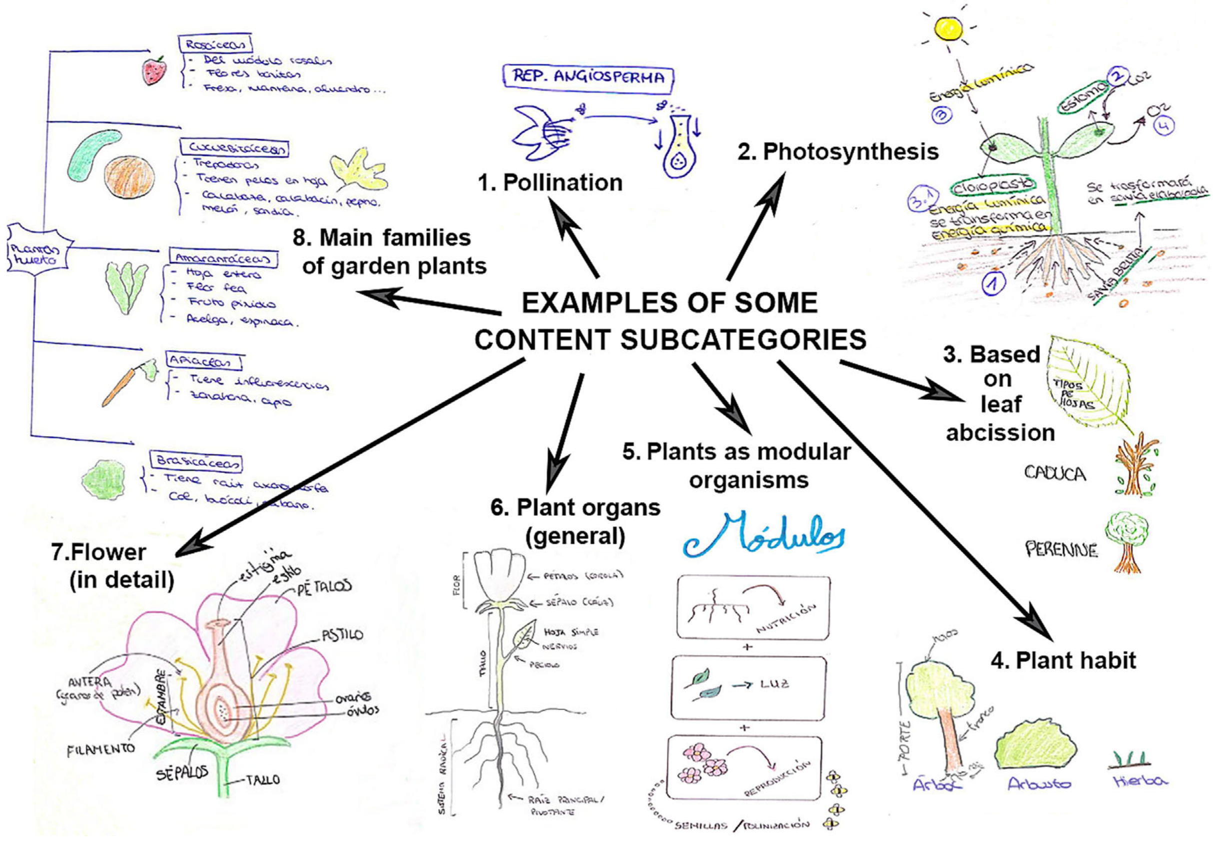

FIGURE 6 Some graphic examples and their classification by the two researchers into content categories and subcategories. Image 1 shows an example of ecology/pollination. Image 2 shows an example of physiology/photosynthesis. Image 3 shows an example of plant classification /based on leaf abscission. Image 4 is an example of plant classification / plant habit. Image 5 of morphology/plants as modular organisms. Image 6 is an example of morphology/plant organs (general). Image 7 shows an example of morphology/flowers (in detail). Image 8 shows an example of plant classification/Main families of garden plants. O_2: oxygen; CO_2: carbon dioxide.

of the didactic sequence; the analysis of final MMs revealed a greater richness in graphic expression and the inclusion of more abundant and better-structured information on plants. Since the Spanish curriculum for pre-school education (Royal Decree 95/2022) includes both the Discovery and Exploration of the Environment (which raises, among others, issues such as knowledge of natural elements and living beings and their needs, and their observation and care) and the Communication and Representation of Reality (which refers to the use of different languages and forms of expression), it is valuable that PSTs also learned useful strategies to adequately approach these contents and skills with children, such as close observation and drawing, gardening, or outdoor instruction.

Significant improvements of plant knowledge were observed in the areas of Morphology, and Plant classification, which received more attention and time investment during instruction. These positive results support the utility of the two main selected teaching strategies: art and contextualization in an outdoor setting (Borsos et al., 2021; Fančovičová & Prokop, 2011; Lindemann-Matthies, 2006; Nyberg & Sanders, 2014; Sanders, 2007; Stagg & Verde, 2019). Another important choice that contributed to success was teaching about useful plants of interest for PSTs (Pany et al., 2019; Stagg & Dillon, 2022), which they grew and cared for regularly, thus developing emotional engagement with them (Krosnick et al., 2018). More limited knowledge construction was evidenced in other areas that were not specifically treated during instruction.

Whether achieved plant knowledge is sufficient for PSTs could be a matter of discussion. In fact, plant awareness is defined operationally, enabling a broad understanding of the problems arising from the lack of such awareness. Attempts exist to measure plant awareness disparity (Pany et al., 2022; Pedrera et al., 2023) and to establish a general framework for botanical literacy (Uno, 2009), but consensus on a standardized plant curriculum has not been reached. In this work, we identified several emerging, key content categories and subcategories, although other relevant ones exist. Note that the choice of categories and subcategories may depend on the objectives and scope of the educational intervention. Therefore, it may be advisable to select certain categories and/or subcategories of particular interest for assessing specific learning outcomes.

Importantly, plant knowledge is just one of the domains postulated for "plant awareness", along with visual perception, categorizing plants as living organisms, and attitudes toward plants (Pany et al., 2022). Increasing knowledge can improve attitudes and interest toward plants (Kubiatko et al., 2021; Pany et al., 2019), and we presume that such was the case for our PSTs. Moreover, the use of an art-based approach likely had positive impacts on another important question: recognizing and appreciating plants' aesthetic and unique biological features (Parsley, 2020; Wandersee & Schussler, 2001).

4.2 | MMs for eliciting and assessing plant awareness

MMs appear as a valuable tool for eliciting students' initial ideas and for assessing learning on plants, given their integrated, multimodal (images and text) approach to knowledge and their sensitivity toward structural and spatial features, which is absent in other instruments (Van Meter & Garner, 2005). This visual thinking modality fits well with an art-based learning strategy since it fosters attention and engagement with the topic (Eisner, 2017). Another advantage is that MMs promote the personal construction of a clear conceptual structure regarding any subject, mainly through visual composition and the use of connectors (Dimeo, 2016; Larralde, 2022; Roam, 2010; Rohde, 2019). They also involve a problem-solving dimension that makes students conscious of their mistakes and knowledge gaps (Sibbet, 2010). Finally, they are less intimidating than other types of drawing, because they use quick and simple personal drawings (Rohde, 2019), so they constitute a good introductory drawing activity that can subsequently be complemented with more demanding ones, such as botanical illustration, which is clearly oriented toward careful observation and representation.

In our preliminary study on PSTs, most students accurately perceived the structural details of plants through botanical illustration, and later incorporated them into MMs. This evidence supports the idea that drawing is a useful strategy to construct knowledge (Anderson, 2019; Chang, 2017; Sanders, 2007) and challenges the notion that graphic expression is a time-consuming activity yielding vague results, otherwise suggesting that drawing skills should be cultivated within curricula (Dempsey & Betz, 2009; Stagg & Verde, 2019). Since the quality of drawings that students can produce constitutes a determinant factor for learning, the role of a drawing-specialist art teacher is key to success (Fiorella & Zhang, 2018; Van Meter & Garner, 2005).

5 | CONCLUSIONS

This preliminary work on the usefulness of MMs as a tool for eliciting and assessing plant awareness, that was elaborated by PSTs before and after an art-based didactic sequence contextualized in an organic garden, has relevant implications in terms of educational practice at initial teacher training, since (1) it further supports the value of teaching outdoors in science education, by evidencing the positive outcomes of using an organic garden to improve botanical literacy; (2) it further supports the usefulness of genuinely integrating art into science didactic proposals, deepening in its use for a range of purposes, remarkably promoting careful and systematic observation, appreciation of beauty, construction of structural (morphological) knowledge on living beings, and communication of knowledge.

MMs appear as a tool with a strong potential, and particularly aligned with didactic proposals that genuinely integrate art and science. Our current research uses MMs to assess mainly knowledge and is focused on: (1) developing other instruments to evaluate visual perception and attitudes toward plants, so that an overview of progress in plant awareness can be reached by integrating such measurements and (2) further improving didactic proposals aimed at enhancing plant awareness.

AUTHOR CONTRIBUTIONS

ME-G and IO-C planned and designed the research, implemented the didactic sequence during academic year 22–23, and collected and qualitatively analyzed data; RS-L conducted statistical analyses; MEG, IOC, and RS-L worked together on the manuscript. Most figures were produced by IO-C.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

RESEARCH ETHICS

Ethical review and approval were not required in accordance with the local legislation and institutional requirements. The participants, who were students over 18 years old, provided their written informed consent both to participate in this study and for the images of their productions to be published or disseminated.

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