JOURNAL OF BIOLOGICAL EDUCATION
https://doi.org/10.1080/00219266.2023.2255197

Routledge
Taylor & Francis Group

Check for updates

Overcoming plant blindness: are the future teachers ready?

Javier Bobo-Pinilla [a,b], Javier Marcos-Walias [c], Jaime Delgado Iglesias [a] and Roberto Reinoso Tapia [a]

[a]Didáctica de las Ciencias Experimentales, Sociales y de la Matemática, Universidad de Valladolid, Valladolid, Spain; [b]Didáctica de las Matemáticas y de las Ciencias Experimentales, Universidad de Salamanca, Salamanca, Spain; [c]Dpto. de Botánica y Fisiología Vegetal, Universidad de Salamanca, Salamanca, Spain

ABSTRACT

Plant blindness refers to the tendency of people to overlook and undervalue plants in their environment, which can have negative consequences for both the environment and human well-being. As pre-service teachers play a key role in shaping the environmental attitudes and knowledge of future generations, it is important to assess their level of plant blindness and identify ways to overcome it. To assess the plant blindness effect among pre-service teachers several tests have been used, including an endangered animals and plants test, an identification test, a memory test, and a blink test. All of the tests indicate that the plant blindness effect is strong among pre-service teachers. This article proposes five different topics that can be integrated into teacher education programs to help future teachers overcome plant blindness, including plant identification skills, the ecological and cultural importance of plants, the use of plants in teaching science and environmental concepts, and the connection between plant knowledge and sustainable behaviours. By incorporating these topics into teacher education programs, they can help future teachers develop a greater appreciation and understanding of plants, which can in turn benefit the environment and human well-being.

ARTICLE HISTORY
Received 28 April 2023
Accepted 28 August 2023

KEYWORDS
Plant blindness; teacher training; sustainability; biodiversity; botany education

Introduction

Plants and society

Despite what human beings may think, the importance of plants for the planet, and for humans themselves, is above the rest of living beings in several aspects; plants are the main factor of environmental sustainability (Cardinale et al. 2012; Thorogood 2020), they accumulate 80% of the planet's biomass (Bar-On, Phillips, and Milo 2018) and play an essential role in mitigating the effects of climate change, among other things, by regulating the concentration of carbon dioxide (Ziska, Epstein, and Schlesinger 2009). This fact directly collides with the growing needs of society in terms of resources and space, needs that are causing most of the environmental problems (Balding and Williams 2016), mainly the degradation of the plant communities of the planet.

The disconnection between society and nature has been linked to the trend of increasing urbanisation (Amprazis and Papadopoulou 2018; Fletcher 2017), as well as the general lack of interest in plants at all levels of society (Tunnicliffe and Ueckert 2007). This lack of appreciation has also been observed in students, who often view plants as a mere backdrop to animal life (Amprazis, Papadopoulou, and Malandrakis 2021). Neglecting plants poses a significant obstacle

CONTACT Javier Bobo-Pinilla javier.bpinilla@uva.es

This article has been republished with minor changes. These changes do not impact the academic content of the article.
Supplemental data for this article can be accessed online at https://doi.org/10.1080/00219266.2023.2255197

to achieving the 17 Sustainable Development Goals (SDGs) (Sharrock and Jackson 2017), as they play a vital role in many of these goals (Thomas, Ougham, and Sanders 2022). In particular, plant conservation, which is a focus of the SDGs, is undervalued by society (Balding and Williams 2016). But not only that, many of the SDGs have targets directly related to plants and plant diversity, plants as resources, or plants as an essential part of efficiency in consumption (see Sharrock and Jackson 2017 for the full list of plant related targets of each SDG). Conservation efforts tend to favour mammals and birds over plants (Havens, Kramer, and Guerrant 2014; Martín-López et al. 2011), even though plants are the taxonomic group most at risk of extinction (Mammola et al. 2020). This is also reflected in the results of internet searches about endangered species listings; currently, the results only return animal species (e.g. https://www.google.com/). Even the IUCN red list only includes 2 plant groups (conifers and cycads) in its headline statistics of nine species threatened with extinction (https://www.iucnredlist.org/). This bias may be due in part to societal attitudes towards plants (Balding and Williams 2016). There is evidence that human perceptions of species and ecosystems have a direct impact on conservation efforts (Bozniak 1994; Uno 1994; Wandersee and Schussler 2001). However, education and information alone are often insufficient to promote conservation behaviour (McKenzie-Mohr 2011). This lack of awareness also leads to inadequate government funding to address the issue (Cires et al. 2013). Improving understanding of biodiversity, including among science teachers who are expected to have high levels of scientific literacy (Köklükaya, Demirhan, and Beşoluk 2014), may be necessary to address this issue.

This lack of appreciation for plants has been referred to as 'plant blindness' (Wandersee and Schussler 2001), which is defined as the inability to recognise the importance of plants in the biosphere and in human affairs, a failure to appreciate the aesthetic and unique biological features of plant life, and a misguided hierarchy that values animals over plants, leading to the erroneous belief that they are unworthy of consideration (Wandersee and Schussler 2001). While the term 'plant blindness' has been criticised as disenfranchising, exclusionary, and ableist (McDonough MacKenzie et al. 2019; Zani and Low 2022), and alternative terms such as 'plant awareness disparity' (Parsley 2020) and 'biodiversity naivety' (Niemiller, Davis, and Niemiller 2021) have been proposed, all of these terms describe a similar phenomenon: humans have a relatively limited awareness of plants (Amprazis and Papadopoulou 2020). This may be due in part to the general colouration of plants and to the fact that their movement is much slower, much faster or just different than that of most animals (Sanders 2019), which for some people suggests that they are inanimate beings, perceiving plants as boring or less interesting than animals (Lindemann-Matthies 2005; Schussler and Olzak 2008). Research has also indicated that the evolutionary history of predator-prey relationships in ancient environments may have influenced humans to have a greater response to animals as opposed to plants (New, Cosmides, and Tooby 2007).

Plant blindness and education

Alternative perceptions about plants develop at an early age and are difficult to change (Opfer and Siegler 2004; Wynn et al. 2017). Although education should provide solutions to the problem of 'plant blindness', it seems that in most cases, education itself is the main obstacle in mitigating this effect (Thomas, Ougham, and Sanders 2022). Early educational experiences that provide equal exposure to both plant and animal groups are crucial in countering the plant blindness effect and encouraging future generations to pursue careers in science, particularly botany (Jose, Wu, and Kamoun 2019). The complexity and relevance of plants to the environment and society are often underestimated in STEM subjects (Science, Technology, Engineering, and Mathematics; Colon et al. 2020). In addition, on certain occasions a disconnection between teachers and students is detected in the teaching experiences of experimental sciences, even between the students and the educational experience itself (Uno 2009). Education, both in the formal and informal context, can play an important role in this matter (Pedrera et al. 2021; Sanders 2007).

In general, biology classes and biology teachers have been defined as 'zoochauvinistic' (Bozniak 1994; Hershey 2005; Uno 1994). If teachers receive little botanical training, the inevitable result is that they end up not teaching botany to their own students (Gatt et al. 2007). It has been detected that the presence of a mentor in the field of botany, such as a teacher or tutor who teaches observing, planting, cultivating, and generally caring for plants, is the main factor reducing the effect of plant blindness and improving awareness in relation to conservation and sustainability (Gatt et al. 2007; Wandersee, Clary, and Guzman 2006).

Despite the fact that teachers plan their teaching individually, they must still adhere to the given conditions in the curriculum. This means that the curriculum must include the basic content to be worked on, and a deficient curriculum will inevitably affect the development of students (Ellis 2004). Regarding the issue of plant blindness, ignoring plants when designing a curriculum means overlooking the group of living beings that can most influence the sustainability of the planet. Several studies have confirmed that teachers face serious problems when trying to give more weight to plants due to the curriculum's lack of representation and coverage (Amprazis and Papadopoulou 2018); some authors also indicate that in general plants are often portrayed and treated less appealingly compared to animals (Sanders and Jenkins 2018), and although in other cases the curriculum appears to be balanced in this topic, as in the case of the Spanish educational system, in which the treatment of animals and plants appears to be equitable in all curricula at all educational levels [see Marcos-Walias et al. (2023) for a full list of the Spanish curriculum content on this topic], this does not solve the underlying problem.

The use of digital resources is growing in use among the teachers of all levels, but textbooks remain the most commonly used tool for science teachers (Fukkink 2010). Textbooks reflect the perception that animals are more important than plants, and therefore, that it is more important to know subjects related to animals than subjects related to plants (Bozniak 1994; Hershey 1996, 2002). In general, elementary school science textbooks include more images of, and diversity about, animals than plants; in the amount of text and examples dedicated to each group textbooks are discriminatory against plants (Link-Pérez et al. 2010; Schussler et al. 2010). This has not only been detected in the number of photographs dedicated to each group, but animal photographs in textbooks were also labelled three times more than plant photographs (Link-Pérez et al. 2010). If animal species receive more attention than plant species in a resource as widely used as textbooks, it is inevitable that it will facilitate the concept of 'plant blindness' (Uno 2009).

Detecting plant blindness

Several studies have shown that humans prefer, detect, and remember animals better than plants (Balding and Williams 2016; Díez et al. 2018; Marcos-Walias et al. 2023; Patrick and Tunnicliffe 2011; among others) with few exceptions (e.g. Nyberg, Brkovic, and Sanders 2021). As examples of different studies, Baird et al., (1984) and Wandersee (1986) conducted surveys among secondary school students in the United States and found a clear preference for zoology over botany; Kinchin (1999) tested the preferences of UK students for plant and animal specimens in the classroom and found a strong preference for animals over plants; In a memory task (Zani and Low 2022), university students were shown a sequence of images showing either a plant or an animal, after a period of time, the participants remembered the images of plants less well than the images of animals, even when all elements were familiar; Balas et al. (2014) detected that people were better at detecting animals than plants through the use of rapid succession of images (attentional blink); Schussler and Olzak (2008) conducted a study on the ability to recall images of animals and plants among psychology and botany students at a university in the United States, the participants rating the images according to their affinity towards them; recall was tested after a distraction task, showing that, regardless of the students' major, animal images were significantly better recalled than plant images. In general, the authors concluded that the tendency to overlook plants may be deeply ingrained in the subconscious such that the general human being does not recognise plants as living beings that deserve attention, even when they are visually predominant in the displayed image.

Regarding the importance of teachers to overcoming the Plant Blindness effect in society, the main objective of this research is to evaluate the plant blindness effect over pre-service teachers of the three levels of teacher education in the Spanish university system.

Material and methods

Study design

In order to address the different facets that can influence the Plant Blindness effect, four different tests were designed. First, to evaluate the basic knowledge of the participants regarding endangered animal and plant species (endangered species test), participants were asked to make a list of all the animals and plants considered under some protection figure (UICN 2012) that they knew, both common names and scientific names were accepted. Second, to assess the ability to recognise nearby species (recognition test) and following the method of previous research (Hooykaas et al. 2019; Kaasinen 2019; Wolff and Skarstein 2020), participants were shown 15 photographs of animals and 15 of plants and they were asked to write down their names. The selection of the animals and plants to be shown followed the criteria of Marcos-Walias et al. (2023) and Marcos-Walias et al. (2020) with slight variations, the species chosen were the following: crow (*Corvus corax*), Iberian wolf (*Canis lupus signatus*), seal (*Monachus monachus*), owl (*Tyto alba*), Iberian lynx (*Lynx pardinus*), western capercaillie (*Tetrao urogallus*), lizard (*Podarcis hispanicus*), ant (*Lasius niger*), salamander (*Salamandra salamandra*), bear (*Ursus arctos*), bearded vulture (*Gypaetus barbatus*), scolopendra (*Scolopendra cingulata*), stork (*Ciconia ciconia*), bat (*Pipistrellus pipistrellus*) and sperm whale (*Physeter macrocephalus*) as animals, and pine (*Pinus pinea*), holly (*Ilex aquifolium*), oak (*Quercus pyrenaica*), wild rose (*Rosa canina*), holm oak (*Quercus ilex* subsp. *ballota*), canary dragon tree (*Dracaena drago*), orchid (*Ophrys tenthredinifera*), moss (Briophyta), juniper (*Juniperus oxycedrus*), blackberry (*Rubus ulmifolius*), thistle (*Silybum marianum*), poplar (*Populus alba*), fern (*Pteridium aquilinum*), yew (*Taxus baccata*) and fir (*Abies alba*) as plants. This list was designed following the criteria of general difficulty and closeness to the participants (Iberian Peninsula and the Canary Islands). The pictures showed the main characteristics of the species and were presented randomly to avoid order bias (see example images in Supplementary Figure S1). Third, a memory test was performed, at the end of the second test all the species were named in order to make sure that all the participants knew them, the participants then had a 15 min break, after which they were asked to list the 15 animals and the 15 plants showed in the second test. Last, an attentional blink was designed following Zani and Low (2022); 10 pictures of animals and plants in the same frame were showed to the participants for 0.5 seconds each, the time lapse between photo and photo was 30 seconds, during this time the participants were asked to briefly describe what they saw. The images showed an animal and a plant in the same plane, both clearly visible, and placed randomly left and right.

Participants

The study was conducted over a total of 182 participants at the universities of Salamanca and Valladolid (Spain), to cover the different levels of teacher education. Five different groups from the last year of each degree were selected, 2 groups of students from the Early Childhood education (ECE) degree, one from the University of Salamanca (36 participants) and another from the University of Valladolid (39 participants), two groups of students from the degree of Primary Education (PE), also one from the university of Salamanca (45 participants) and another from the university of Valladolid (46 participants) and one group of students from the Master degree of Secondary Education (SE; 16 participants from the University of Valladolid). All the participants were informed about the research and data collection was agreed with all of them. The test was performed anonymously without distorting the scholarly meaning and written consent to use their answers in this study was also solicited.

Data analysis

The data were analysed using the software SPSS v.26 (IBM Corp., 2019). Descriptive values were obtained for all the tests (Table 1); values for the full dataset and for the different university grades were calculated. Values for the tests 2, 3 and 4 were expressed as a percentage to make the results easy to interpret; for test 2 (Image identification) the value indicates the percentage of correctly identified images, regarding test 3 (Memory test), the values indicate the percentage of animals and plants they remembered; for the last test (Attentional blink), the values indicate the percentage of animals and plants mentioned in the description of the images. The normality of the data was checked using the one-sample Kolmogorov-Smirnov test or the Shapiro –Wilk test (when $n < 50$), applied to the full dataset and to the different university grades.

In order to detect significant differences between the results obtained for animals and plants, an independent samples t-test was performed when data followed a normal distribution. In the cases that the data follows a non-normal distribution, the Mann-Whitney U test for independent samples was applied. P-value <0.05 was consider as significant. In our case, the null hypothesis would indicate a low probability that the distribution/mean of the results of the tests related to animals and plants were different. The analyses were applied for the complete sample group, for the different university grades and for the different groups.

Table 1. Descriptive values of the dataset. ECE (Early Education pre-service teachers); PE: (Primary education pre-service teachers); SE (Secondary education pre-service teachers).

				Degrees		
Descriptive values			Total	ECE	PE	SE
Test 1 (Endngered species test)	1.1 Animals	Average	3.7	2.9	3.8	6.5
		Standard deviation	2.1	1.6	1.8	2.9
		Minimum	0	0	0	2
		Maximum	12	7	12	12
	1.2 Plants	Average	0.3	0.1	0.3	1.3
		Standard deviation	0.6	0.4	0.6	1.1
		Minimum	0	0	0	0
		Maximum	4	2	2	4
Test 2 (Recognition test)	2.1 Animals	Average	9.8 (65%)	9.6 (64.2%)	9.6 (63.9%)	11.4 (76%)
		Standard deviation	1.9	1.8	2.0	1.2
		Minimum	4	4	4	8
		Maximum	14	14	14	13
	2.2 Plants	Average	4 (26.8%)	3 (20.3%)	4.3 (28.9%)	6.9 (45.8%)
		Standard deviation	2.5	2.2	2.2	2.9
		Minimum	0	0	0	3
		Maximum	12	11	11	12
Test 3 (Memory test)	3.1 Animals	Average	10 (66.8%)	9.9 (66.1%)	10.1 (67.5%)	9.9 (66.2%)
		Standard deviation	2.5	2.0	2.9	1.5
		Minimum	3	4	3	8
		Maximum	15	14	15	13
	3.2 Plants	Average	6.9 (46.2%)	6.7 (44.8%)	7.2 (48.2%)	6.2 (41.3%)
		Standard deviation	2.4	2.5	2.5	1.5
		Minimum	0	0	2	3
		Maximum	13	12	13	9
Test 4 (Attentional blink)	4.1 Animals	Average	8.4 (83.8%)	8.4 (84%)	8.2 (82.2%)	9.2 (92%)
		Standard deviation	1.5	1.3	1.6	1.4
		Minimum	4	5	4	5
		Maximum	13	10	13	10
	4.2 Plants	Average	4.3 (43.1%)	5.9 (58.9%)	2.8 (28.1%)	5.5 (55.3%)
		Standard deviation	3.2	2.5	3.0	3.0
		Minimum	0	0	0	0
		Maximum	10	10	10	9

Results

Regarding the endangered species test, the participants mentioned an average of 3.7 animal species and an average of 0.3 plant species, giving the different grades, the average number of animal species the participants mentioned was 2.9 in ECE, 3.8 in PE and 6.5 in SE, and of plant species the values were, 0.1 for ECE, 0.3 for PE and 1.3 for SE. Considering the full set, the endangered plants most mentioned were moss (4.4%), carnivorous plant (3.8%), holly (2.2%), orchid (2.2%) and water lily (1.6%); moreover, another seventeen plant species were mentioned. Regarding animals, the most mentioned were Iberian lynx (71.4%), panda bear (40.1%) and polar bear (35.2%), with other animals as koala, tiger, rhinoceros, wolf, whale and elephant also being mentioned by more than 10% of the participants; in total, 56 different animals were mentioned (please see Tables S2 and S3 for the full list of animals and plants mentioned in the endangered species test).

The recognition test for the full dataset provided an average value of 9.8 of 15 (65%) animals and 4.0 of 15 (26.8%) plants correctly identified; average values of 9.6, 9.6 and 11.4 of animals correctly identified were obtained for ECE, PE and SE respectively. Regarding plant identification, average values of 3.0, 4.3 and 6.9 were obtained. For the full dataset, the ten most recognised species were Iberian wolf (96.2%), bear (94.5%), bat (94.5%), Iberian lynx (89.6%), ant (86.3%), stork (85.7%), seal (85.7%), crow (79.7%), lizard (75.8) and pine (72.0%); some species were recognised by under the 5% of the participants, yew (2.7%), wild rose (2.2%), canary dragon tree (1.1) and juniper (0.0%). See Table S4 for the full results for the identification test.

The memory test provided an average value of 10 (66.8%) remembered animals and 6.9 (46.2%) remembered plants; by degrees, values were very similar - between 9.9 and 10.1 for animals, and between 6.2 and 7.2 for plants. The ten most remembered species were Iberian lynx (87.0%), pine (84.7%), bear (84.7%), Iberian wolf (84.2%), lizard (78.5%), seal (75.1%), salamander (71.2%), crow (64.4%), fir (62.1%) and sperm whale (61.6%); nine of the ten least remembered species were plants (full list with the memory test results can be checked in the Table S5).

The attentional blink test also returned similar results for animal-recall among the different degrees (values between 8.2 and 9.2 animals detected), but not for plant-recall (values between 2.8 and 5.9); the average value for the full group was 8.4 (83.8%) for animal recalland 4.3 (43.1%) for plant recall. Similar values were obtained for the different groups within childhood and primary education for all tests (Table 1).

The results for the normality test showed non normal distribution in all cases except for test 3 in the Secondary Education teachers' dataset (Table 2). Giving this, the Mann-Whitney U test for independent samples showed significant differences between the responses given for animals and plants for all degrees and all tests (Table 3). This result was also obtained for the students t test performed for the Secondary Education teachers' level in the Test 3.

Table 2. Results of the normality test. ECE (Early Education pre-service teachers); PE: (Primary education pre-service teachers); SE (Secondary education pre-service teachers).

	(Total) Kolmogorov-Smirnov			(ECE) Kolmogorov-Smirnov			(PE) Kolmogorov-Smirnov			(SE) Shapiro-Wilk		
	Value	gl	sig.	Value	gl	sig.	Value	gl	sig.	Value	gl	sig.
Test 1.1	0.182	177	0.000	0.153	73	0.000	0.185	89	0.000	0.949	15	0.511
Test 1.2	0.456	177	0.000	0.516	73	0.000	0.472	89	0.000	0.866	15	0.029
Test 2.1	0.154	177	0.000	0.171	73	0.000	0.143	89	0.000	0.845	15	0.015
Test 2.2	0.124	177	0.000	0.177	73	0.000	0.146	89	0.000	0.923	15	0.217
Test 3.1	0.129	177	0.000	0.174	73	0.000	0.113	89	0.007	0.923	15	0.210
Test 3.2	0.104	177	0.000	0.147	73	0.000	0.107	89	0.013	0.932	15	0.293
Test 4.1	0.193	177	0.000	0.228	73	0.000	0.164	89	0.000	0.629	15	0.000
Test 4.2	0.132	177	0.000	0.122	73	0.009	0.242	89	0.000	0.905	15	0.113

Table 3. Results of the hypotheses testing. ECE (Early Education pre-service teachers); PE: (Primary education pre-service teachers); SE (Secondary education pre-service teachers).

	Test	Null hypothesis	Test	Sig.	Result
Full dataset	Test 1	The distribution of values/mean for the test about animals is the same between categories of values for the test about plants	Mann-Whitney U test for independent samples	0.000	Reject the null hypothesis.
	Test 2			0.000	Reject the null hypothesis.
	Test 3			0.000	Reject the null hypothesis.
	Test 4			0.000	Reject the null hypothesis.
ECE	Test 1	The distribution of values for the question about animals is the same between categories of values for the question about plants	Mann-Whitney U test for independent samples	0.000	Reject the null hypothesis.
	Test 2			0.000	Reject the null hypothesis.
	Test 3			0.000	Reject the null hypothesis.
	Test 4			0.000	Reject the null hypothesis.
PE	Test 1	The distribution of values for the question about animals is the same between categories of values for the question about plants	Mann-Whitney U test for independent samples	0.000	Reject the null hypothesis.
	Test 2			0.000	Reject the null hypothesis.
	Test 3			0.000	Reject the null hypothesis.
	Test 4			0.000	Reject the null hypothesis.
SE	Test 1	The distribution of values for the question about animals is the same between categories of values for the question about plants	Mann-Whitney U test for independent samples	0.000	Reject the null hypothesis.
	Test 2			0.000	Reject the null hypothesis.
	Test 3		T-test for independent samples	0.000	Reject the null hypothesis.
	Test 4		Mann-Whitney U test for independent samples	0.000	Reject the null hypothesis.

Discussion

Pre-service teachers and plant blindness

All the tests performed resulted in the conclusion that pre-service teachers that participated in this survey are influenced by the plant blindness effect. In terms of recall of endangered animal and plant species (Table 1), the number of endangered plant species which participants mentioned was very low, a finding which was signficant considering the number of endangered animal species. Among the endangered animals mentioned, only three of the ten most mentioned were native from the country of the participants (wolf, Iberian lynx and stork), sixteen if we consider the full list of endangered animals; as already detected (Ballouard et al. 2011; Lindemann-Matthies 2005; Nates, Campos, and Lindemann-Matthies 2010), students tend to remember animal species either because they are close to them in the environment or because they are considered 'lovable'., but regarding the endangered animals mentioned in this study this seems to be different; despite being able to consider some of the animals mentioned as 'lovable' (panda bear or koala), others can hardly fit into that category, such as rhinoceros, tiger or Komodo dragon. In most of the cases it seems probable that the publicity that is being given in the media to the flagship species of the different countries may be playing an essential role. Only few participants were able to mention endangered plants - the species most mentioned can also be considered flag or charismatic species (e.g. moss, carnivorous plant, holly and orchid;

see full list in Table S3); moreover, Kaasinen (2019) suggests that usually people don't mention endangered or rare plants which could explain such a low number of plants being mentioned. The most mentioned endangered plants have characteristics that make them somewhat charismatic; for example moss is commonly used to decorate nativity scenes and 'carnivorous' plants attract attention for equating their way of getting nutrients with animals. In the case of flagship species, most are only mentioned by a single participant, which indicates that they are not generally known or are not known to be endangered.

Pre-service teachers were also unable to recognise as many plants as animals when photographs were shown (Table 1). These results corroborate previous investigations in this area. Studies conducted under comparable circumstances have consistently demonstrated that plants are mentioned or identified to a significantly lesser extent (Díez et al. 2018; Marcos-Walias et al. 2023; Patrick and Tunnicliffe 2011; Pedrera et al. 2021; Skarstein and Skarstein, 2020). This pattern is also evident in research involving plants and animals from the participants' surrounding environment (Balas, Momsen, and Holt 2014; Dallimer et al., 2012; Muratet et al., 2015; Palliwoda et al., 2017; Schussler and Olzak 2008; Shwartz et al., 2014; Voigt & Wurster, 2015), even when the participants showed interest in ecology and biodiversity.

This is probably due not only to a lack of knowledge but also to a lack of interest (Kubiatko, Fančovičová, and Prokop 2021; Otto and Pensini 2017). This is reinforced by the fact that the participants also remembered fewer plants than animals in Test 3, results strengthened by the attentional blink; again, fewer plants were mentioned in Test 4 than animals. In this case, given the limitations of what we can attend to regarding all the things we see, we ignore apparently useless information (Wandersee, Clary, and Guzman 2006), and in this context, useless information usually correspond with plants and 'inferior' animals, with our focus attributed to animals with forward facing eyes (Smith et al. 2012). Despite the apparent equality in the treatment of animals and plants in the curriculum of the different levels of the Spanish educational system (Marcos-Walias et al. 2023), the fact that teachers tend to teach what they feel closer to, could result in the inability of the future teachers to teach equally in relation to animals and plants, spending a great deal of curricular time teaching the animal kingdom (Uno 1994), not closing the gap between animals and plants, nor improving the learning of future students regarding biodiversity (Pedrera et al. 2021). Indeed, Uno (1994, 2009) suggested that the most important cause of plant blindness is education.

Awareness and knowledge are the two first goals of the five goals of Environmental Education included in the Tbilisi Declaration (UNESCO 1977); these should establish the basis of environmental education and teachers must act as necessary entities in the achievement of these goals (Frisch, Unwin, and Saunders 2010). Also, as already mentioned, neglecting plants poses a significant obstacle to achieving many of the specific targets of the 17 Sustainable Development Goals (SDGs) (Sharrock and Jackson 2017), as they play a vital role in many of these goals (Thomas, Ougham, and Sanders 2022); in particular but not only, plant conservation, which is a focus of the SDGs, and is undervalued by society (Balding and Williams 2016).

Surprisingly, similar levels of plant blindness were detected in all levels from childhood education to biology baccalaureate level; this is worrying as some of the participants had considerable biological training. This pattern was already found in the biological community in which experts in biomedical fields showed a surprisingly limited knowledge of plant biology (Savary et al. 2019); the lack of enthusiasm of the teachers for the plant kingdom results in students' tendency to be less interested in plants (Sjøberg et al. 2010; Strgar 2007). Among other considerations already mentioned, this results in the perpetuation of plant blindness.

What to teach the pre-service teachers?

All the results make it possible to clearly affirm that the effect of plant blindness is still widely present among pre-service teachers and as a result some authors have detected that this will limit their ability to teach botany themselves (Frisch, Unwin, and Saunders 2010). This is especially important as research shows that the interest of students in plants was started by inspirational teachers (Jose, Wu, and Kamoun 2019). If teachers are not able to teach about botany, learners won't overcome plant blindness (Nyberg and Sanders 2014; Uno 2009).

Given this, and considering as discussed, that there are multiple reasons for the plant blindness effect, we should ask ourselves, 'How can we overcome the plant blindness effect in future teachers so they can help to overcome the effect in society?'

Authors have proposed different answers to this question. They can be summarised in five general points:

(1) The importance of plants in the ecosystem and their role in supporting life on Earth. Education about the crucial role of plants in our ecosystem can help raise awareness about their significance. This can include lessons on how plants produce oxygen, provide food and habitat for animals, and how they play a role in regulating the Earth's climate. Some proposals mention the benefits of the school yard as an effective and cheap resource for ecology lessons (Brewer 2002), some authors also mention the importance of non-formal education in this topic (Colli-Silva et al. 2019). The disconnection between plant and humans, also between educators and plants (Thomas, Ougham, and Sanders 2022), remains one of the main threats to global sustainability; as some authors emphasise 'Every living thing, from the small insects (and we must add through plants) to the largest mammals, contributes to Earth's sustainability' (Amprazis and Papadopoulou 2018, 239) and we should make sure to convey that idea to both future teachers and students, making them feel they are part of the ecosystems and responsible for its well-being (Brewer 2002). Linked to this, it is inevitable that plant blindness emerges as a major problem of understanding the importance of plants for the biosphere (Uno 2009).

(2) The diversity of plant species and their unique characteristics. Teaching about the diversity of plants can help individuals appreciate the vast array of shapes, sizes, colours, and adaptations that exist within the plant kingdom. This can include lessons on different plant families, unique adaptations, and the fascinating ways that plants have evolved to survive in different environments. It should be easy, given the possibilities, to banish the idea that plants are boring (Thorogood 2020). The process of comparing and contrasting plant structures is a higher-level skill that allows students to form schema and connections between schema, enhancing their understanding of both scientific concepts and the natural world (Anderson et al. 2001). Some cross-disciplinary initiatives can exploit this variety of shapes, sizes, and colours in order to raise awareness about plants (Snæbjörnsdóttir, Wilson, and Sanders 2020); for example, some initiatives focus on artistic work in class, such as the use of drawing as a means of raising awareness about the plant world (Comeau et al. 2019). Also, some proposals use games as a potential tool to exploit this topic too (Borsos 2019).

(3) The economic, cultural, and medicinal significance of plants. Emphasising the cultural and historical significance of plants can increase appreciation and understanding of their value. This can include lessons on the traditional uses of plants in different cultures, such as for food, medicine, and spiritual rituals. There are many plants with useful qualities that can be used to create engaging and interesting learning contexts for botanical content (Batke, Dallimore, and Bostock 2020; Pany et al. 2014; Sjøberg & Schreiner, 2010). Mayer and Horn (1993) were among the first to suggest that plants with practical uses for humans could be of particular interest to students. This idea was supported by the findings of Krüger and Burmester (2005), who found that the 'usefulness of plants' was the most prominent category students used to classify plants, followed by the 'beauty of plants' (Tunnicliffe and Reiss 2000). Lindemann-Matthies (2005) also supports the idea that plants with human uses are more valued by most people. Hammann (2011) found that students were particularly interested in medicinal plants. These findings suggest that medicinal plants and stimulant herbal drugs could be effective subjects for botany lessons, as they tend to

maintain high levels of student interest across age groups (Elster 2007), unlike ornamental plants, which tend to have lower levels of student interest overall but are of high interest to a smaller group of students.

(4) The methods of identifying and classifying plants. Promoting hands-on experiences with different plants can help individuals develop a deeper connection and appreciation for these organisms. Collect, identify and classify plants from nearby environments, using smart phone apps or field guides are some of the usual proposals in order to connect students and plants (Frisch, Unwin, and Saunders 2010; Hershey 2005; Kissi and Dreesmann 2017; Lindemann-Matthies 2005; Randler 2008; Wandersee, Clary, and Guzman 2006), also generating simple biodiversity guides or determination keys of the nearby environment (Brewer 2002). Furthermore, as some authors have pointed out, teaching students about the names of local plants while also educating them about the plants themselves and their environment is highly effective in overcoming 'plant blindness'. This could serve as a starting point for building lessons and placing local biodiversity in a wider context (Frisch, Unwin, and Saunders 2010).

(5) The threats to plant biodiversity and conservation efforts to protect them. Encouraging critical thinking about the impact of human activities on plant populations can help individuals understand the importance of conservation efforts (Margulies et al. 2019). This can include lessons on the effects of deforestation, climate change, and other human-driven changes on plant populations and ecosystems. Some hands-on interaction with plants already mentioned in the previous points can also help to develop in the students' conservation behaviours (Beery and Jørgensen 2018; Krishnan et al. 2019; Krosnick, Baker, and Moore 2018; Soga et al. 2016). It is crucial for the students to understand that biodiversity loss is much more important than an exotic animal (Amprazis and Papadopoulou 2018). The extent of the conservation bias against plants is highlighted by some authors; there is a big difference between the money invested in plant conservation compared to the number of plants in danger (Havens, Kramer, and Guerrant 2014; Laycock et al. 2011; Margulies et al. 2019; Martín-López et al. 2011). Even artificial intelligence applications exhibit this bias towards endangered animals; when asked to name 50 endangered species, none of the listed species were plants [Bengal Tiger, African Lion, Asian Elephant, White Rhinoceros, Mountain Gorilla, Bornean Orangutan, Polar Bear, Snow Leopard, California Condor, Goodfellow's Tree Kangaroo, Blue Whale, Vaquita (Marine Porpoise), Leatherback Turtle, Ring-tailed Lemur, Chinese Pangolin, Giant Panda, Bachman's Sparrow, Amazon River Dolphin (Pink Dolphin), Saiga Antelope, Iberian Lynx, Philippine Eagle, Andean Condor, Sumatran Orangutan, Kakapo (Night Parrot), Black Rhinoceros, Eurasian Lynx, Spix's Macaw, Chimpanzee, Javan Rhinoceros, Angonoka Tortoise (Ploughshare Tortoise), African Elephant, Malayan Pangolin, White-bellied Heron, Malayan Sun Bear, Harpy Eagle, Laysan Albatross, Irrawaddy Dolphin, Black Crested Gibbon, Canadian Lynx (Red Lynx), Zanzibar Red Colobus, Koala, Puma (Mountain Lion or Cougar), Sea Otter, Quetzal, Hyacinth Macaw, Steller Sea Lion, Celebes Tarsier, North Atlantic Right Whale, Maui Dolphin, Kakihona (Hawaiian Hawk); https://chat.openai.com/]; this bias also happens in more traditional internet search engines and must be corrected in order to avoid artificial intelligence perpetuating the problem.

Conclusions

In conclusion, our study found that pre-service teachers are influenced by the plant blindness effect, which can have negative consequences for the environment and human well-being. As future educators, it is crucial that pre-service teachers develop a greater appreciation and understanding of plants so that they can effectively teach their students about the importance of biodiversity and environmental sustainability. Our proposed topics for overcoming plant blindness in teacher education programs offer a starting point for incorporating this important content into pre-service teacher training. However, more work is needed in this area, and we recommend that the content and resources used for training pre-service teachers in these topics be reconsidered and improved upon. Additionally, the creation of standardised tools for detecting plant blindness would be beneficial in order to unify research efforts and evaluate the effectiveness of different interventions. By taking these steps, we can better equip future teachers with the knowledge and skills necessary to address plant blindness and promote a more sustainable future.

Acknowledgments

We would like to extend our gratitude to the Teaching Innovation Projects "Design thinking como recurso didáctico para la enseñanza/aprendizaje de los objetivos de desarrollo sostenible (ID2021/162; University of Salamanca)", "El huerto escolar como herramienta para poner en marcha una iniciativa de aprendizaje-servicio en centros escolares de la ciudad de Ávila (ID2021/190; University of Salamanca)")" and "ConCienciaDos (University of Valladolid)" for their support in this study. Additionally, we would like to thank the following students who assisted with data gathering: Almudena Costas, Alejandro Álvarez, Roberto Diago y Nerea González. Their dedication and hard work were essential to the success of this project. Finally, we would like to thank all of the pre-service teachers who participated in this study for their time and willingness to contribute to our research.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This study has been developed within the framework of the research project TED2021-130300B-C21 funded by the Ministry of Science and Innovation.

ORCID

Javier Bobo-Pinilla http://orcid.org/0000-0001-9600-2657
Javier Marcos-Walias http://orcid.org/0000-0002-3111-4348
Jaime Delgado Iglesias http://orcid.org/0000-0001-8726-6976
Roberto Reinoso Tapia http://orcid.org/0000-0003-0476-4975

Declarations and ethics statements

Authors declared that the study did not require formal ethics approval since the data was completely anonymous, with no personal information collected. Informed consents were obtained from the research participants. Vulnerable or dependent groups were not included in the study.

References

Amprazis, A., and P. Papadopoulou. 2018. "Primary School Curriculum Contributing to Plant Blindness: Assessment Through the Biodiversity Perspective." *Advances in Ecological and Environmental Research* 3 (11): 238–256.

Amprazis, A., & P. Papadopoulou. 2020. "Plant Blindness: A Faddish Research Interest or a Substantive Impediment to Achieve Sustainable Development Goals?" *Environmental Education Research* 26 (8): 1065–1087. https://doi.org/10.1080/13504622.2020.1768225.

Amprazis, A., P. Papadopoulou, and G. Malandrakis. 2021. "Plant Blindness and Children's Recognition of Plants as Living Things: A Research in the Primary Schools Context." *Journal of Biological Education* 55 (2): 139–154. https://doi.org/10.1080/00219266.2019.1667406.

Anderson, L. W., D. R. Krathwohl, P. Airasian, K. A. Cruikshank, and R. Mayer. 2001. *A Taxonomy for Learning, Teaching, and Assessing — a Revision of Bloom's Taxonomy of Educational Objectives*. Pintrich, P. R. Eds. Addison Wesle.

Baird, J., R. Lazarowitz, and V. Allman. 1984. "Science Choices and Preferences of Middle and Secondary School Students in Utah." *Journal of Research in Science Teaching* 21 (1): 47–54. https://doi.org/10.1002/tea.3660210106 .
Balas, B., J. L. Momsen, and E. A. Holt. 2014. "Attention "Blinks" Differently for Plants and Animals." *CBE Life Sciences Education* 13 (3): 437–443. https://doi.org/10.1187/cbe.14-05-0080.
Balding, M., and K. J. H. H. Williams. 2016. "Plant Blindness and the Implications for Plant Conservation." *Conservation Biology* 30 (6): 1192–1199. https://doi.org/10.1111/cobi.12738.
Ballouard, J.-M., F. Brischoux, X. Bonnet, and M. Somers. 2011. "Children Prioritize Virtual Exotic Biodiversity Over Local Biodiversity." *PLoS ONE* 6 (8): e23152. https://doi.org/10.1371/journal.pone.0023152.
Bar-On, Y. M., R. Phillips, and R. Milo. 2018. "The Biomass Distribution on Earth." *Proceedings of the National Academy of Sciences* 115 (25): 6506–6511. https://doi.org/10.1073/pnas.1711842115.
Batke, S. P., T. Dallimore, and J. Bostock. 2020. "Understanding Plant Blindness – Students' Inherent Interest of Plants in Higher Education." *Journal of Plant Sciences* 8 (4): 98. https://doi.org/10.11648/j.jps.20200804.14.
Beery, T., and K. A. Jørgensen. 2018. "Children in Nature: Sensory Engagement and the Experience of Biodiversity." *Environmental Education Research* 24 (1): 13–25. https://doi.org/10.1080/13504622.2016.1250149.
Borsos, E. 2019. "The Gamification of Elementary School Biology: A Case Study on Increasing Understanding of Plants." *Journal of Biological Education* 53 (5): 492–505. https://doi.org/10.1080/00219266.2018.1501407.
Bozniak, E. C. 1994. "Challenges Facing Plant Biology Teaching Programs." *Plant Science Bulletin* 40:42–46.
Brewer, C. 2002. "Conservation Education Partnerships in Schoolyard Laboratories: A Call Back to Action." *Conservation Biology* 16 (3): 577–579. https://doi.org/10.1046/j.1523-1739.2002.01633.x.
Cardinale, B. J., J. E. Duffy, A. Gonzalez, D. U. Hooper, C. Perrings, P. Venail, A. Narwani, et al. 2012. "Biodiversity Loss and Its Impact on Humanity." *Nature* 486 (7401): 59–67. https://doi.org/10.1038/nature11148.
Cires, E., Y. De Smet, C. Cuesta, P. Goetghebeur, S. Sharrock, D. Gibbs, S. Oldfield, A. Kramer, and M.-S. Samain. 2013. "Gap Analyses to Support ex situ Conservation of Genetic Diversity in Magnolia, a Flagship Group." *Biodiversity and Conservation* 22 (3): 567–590. https://doi.org/10.1007/s10531-013-0450-3.
Colli-Silva, M., A. C. S. Corsi, J. D. J. Florentino, L. A. Teixeira, and S. Ursi. 2019. "Evidences of Plant Blindness in a Brazilian Urban Green Space with Plaqued Trees." *Paisagem e Ambiente* 30 (43): e151370. https://doi.org/10.11606/issn.2359-5361.paam.2019.151370.
Colon, J., N. Tiernan, S. Oliphant, A. Shirajee, J. Flickinger, H. Liu, J. Francisco-Ortega, and M. McCartney. 2020. "Bringing Botany into Focus: Addressing Plant Blindness in Undergraduates Through an Immersive Botanical Experience." *BioScience* 70 (10): 887–900. https://doi.org/10.1093/biosci/biaa089.
Comeau, P., C. L. M. Hargiss, J. E. Norland, A. Wallace, and A. Bormann. 2019. "Analysis of Children's Drawings to Gain Insight into Plant Blindness." *Natural Sciences Education* 48 (1): 190009. https://doi.org/10.4195/nse2019.05.0009.
Dallimer, M., K. N. Irvine, A. M. Skinner, Z. G. Davies, J. R. Rouquette, L. L. Maltby, P. H. Warren, P. R. Armsworth, and K. J. Gaston. 2012. "Biodiversity and the Feel-Good Factor: Understanding Associations Between Self-Reported Human Well-Being and Species Richness." *BioScience* 62 (1): 47–55.
Díez, J. R., A. Meñika, I. Sanz-Azkue, and A. Ortuzar. 2018. "Urban and Rural Children's Knowledge on Biodiversity in Bizkaia: Tree Identification Skills and Animal and Plant Listing." *International Journal of Humanities & Social Sciences* 12 (3): 396–400.
Ellis, R. A. 2004. "University Student Approaches to Learning Science Through Writing." *International Journal of Science Education* 26 (15): 1835–1853. https://doi.org/10.1080/0950069042000243772.
Elster, D. 2007. "Student Interests — the German and Austrian ROSE Survey." *Journal of Biological Education* 42 (1): 5–10. https://doi.org/10.1080/00219266.2007.9656100.
Fletcher, R. 2017. "Connection with Nature is an Oxymoron: A Political Ecology of "Nature-Deficit disorder"." *The Journal of Environmental Education* 48 (4): 226–233. https://doi.org/10.1080/00958964.2016.1139534.
Frisch, J. K., M. M. Unwin, and G. W. Saunders. 2010. "Name That Plant! Overcoming Plant Blindness and Developing a Sense of Place Using Science and Environmental Education." In *The Inclusion of Environmental Education in Science Teacher Education*, edited by A. Bodzin, B. S. Klein, and S. Weaver, 143–157. Springer Netherlands. https://doi.org/10.1007/978-90-481-9222-9_10.
Fukkink, R. G. 2010. "Missing Pages? A Study of Textbooks for Dutch Early Childhood Teacher Education." *Teaching and Teacher Education* 26 (3): 371–376. https://doi.org/10.1016/j.tate.2009.01.015.
Gatt, S., S. D. Tunnicliffe, K. Borg, and K. Lautier. 2007. "Young Maltese Children's Ideas About Plants." *Journal of Biological Education* 41 (3): 117–122. https://doi.org/10.1080/00219266.2007.9656080.
Hammann, M. 2011. "Wie groß ist das Interesse von Schülern an Heilpflanzen?" *Zeitschrift Für Phytotherapie* 32 (1): 15–19. https://doi.org/10.1055/s-0031-1271317.
Havens, K., A. T. Kramer, and E. O. Guerrant. 2014. "Getting Plant Conservation Right (Or Not): The Case of the United States." *International Journal of Plant Sciences* 175 (1): 3–10. https://doi.org/10.1086/674103.
Hershey, D. R. 1996. "A Historical Perspective on Problems in Botany Teaching." *The American Biology Teacher* 58 (6): 340–347. https://doi.org/10.2307/4450174.
Hershey, D. R. 2002. "Plant Blindness: "We Have Met the Enemy and He is Us." *Plant Science Bulletin* 48 (2): 78–84.

Hershey, D. R. 2005. *Plant Content in the National Science Education Standards*. http://www.actionbioscience.org/education/hershey2.html?print.

Hooykaas, M. J. D., M. Schilthuizen, C. Aten, E. M. Hemelaar, C. J. Albers, and I. Smeets. 2019. "Identification Skills in Biodiversity Professionals and Laypeople: A Gap in Species Literacy." *Biological Conservation* 238:108202. https://doi.org/10.1016/j.biocon.2019.108202.

IBM Corp. Released. 2019. *IBM SPSS Statistics for Windows, Version 26.0*. Armonk, NY: IBM Corp.

Jose, S. B., C. H. Wu, and S. Kamoun. 2019. "Overcoming Plant Blindness in Science, Education and Society." *Plants, People, Planet* 1 (3): 169–172. https://doi.org/10.1002/ppp3.51.

Kaasinen, A. 2019. "Plant Species Recognition Skills in Finnish Students and Teachers." *Education Sciences* 9 (2): 85. https://doi.org/10.3390/educsci9020085.

Kinchin, I. M. 1999. "Investigating Secondary-School Girls' Preferences for Animals or Plants: A Simple 'Head-To-head' Comparison Using Two Unfamiliar Organisms." *Journal of Biological Education* 33 (2): 95–99.

Kissi, L., and D. Dreesmann. 2017. "Plant Visibility Through Mobile Learning? Implementation and Evaluation of an Interactive Flower Hunt in a Botanic Garden." *Journal of Biological Education* 52 (4): 1–20. https://doi.org/10.1080/00219266.2017.1385506.

Köklükaya, A. N., E. Demirhan, and Ş. Beşoluk. 2014. "The Prospective Science Teachers' Perceptions of Biodiversity." *Procedia - Social & Behavioral Sciences* 116:1562–1567. https://doi.org/10.1016/j.sbspro.2014.01.435.

Krishnan, S., T. Moreau, J. Kuehny, A. Novy, S. L. Greene, and C. K. Khoury. 2019. "Resetting the Table for People and Plants: Botanic Gardens and Research Organizations Collaborate to Address Food and Agricultural Plant Blindness." *Plants, People, Planet* 1 (3): 157–163. https://doi.org/10.1002/ppp3.34.

Krosnick, S. E., J. C. Baker, and K. R. Moore. 2018. "The Pet Plant Project: Treating Plant Blindness by Making Plants Personal." *The American Biology Teacher* 80 (5): 339–345. https://doi.org/10.1525/abt.2018.80.5.339 .

Krüger, D., and A. Burmester. 2005. "Wie Schüler Pflanzen ordnen." *Zeitschrift Für Didaktik Der Naturwissenschaften* 11:85–102.

Kubiatko, M., J. Fančovičová, and P. Prokop. 2021. "Factual Knowledge of Students About Plants is Associated with Attitudes and Interest in Botany." *International Journal of Science Education* 43 (9): 1426–1440. https://doi.org/10.1080/09500693.2021.1917790.

Laycock, H. F., D. Moran, J. C. R. Smart, D. G. Raffaelli, and P. C. L. White. 2011. "Evaluating the Effectiveness and Efficiency of Biodiversity Conservation Spending." *Ecological Economics* 70 (10): 1789–1796. https://doi.org/10.1016/j.ecolecon.2011.05.002.

Lindemann-Matthies, P. 2005. "'Loveable' Mammals and 'Lifeless' Plants: How Children's Interest in Common Local Organisms Can Be Enhanced Through Observation of Nature." *International Journal of Science Education* 27 (6): 655–677. https://doi.org/10.1080/09500690500038116.

Link-Pérez, M. A., V. H. Dollo, K. M. Weber, and E. E. Schussler. 2010. "What's in a Name: Differential Labelling of Plant and Animal Photographs in Two Nationally Syndicated Elementary Science Textbook Series." *International Journal of Science Education* 32 (9): 1227–1242. https://doi.org/10.1080/09500690903002818.

Mammola, S., N. Riccardi, V. Prié, R. Correia, P. Cardoso, M. Lopes-Lima, and R. Sousa. 2020. "Towards a Taxonomically Unbiased European Union Biodiversity Strategy for 2030." *Proceedings of the Royal Society B: Biological Sciences* 287 (1940): 20202166. https://doi.org/10.1098/rspb.2020.2166.

Marcos-Walias, J., and J. Bobo-Pinilla. 2020. "Análisis del conocimiento sobre plantas y animales en Educación Secundaria Obligatoria." In *Desempeño docente y formación en competencia digital en la era SARS COV-2*, edited by I. Aznar Díaz, J. A. López Núñez, M. P. Cáceres Reche, C. De Barros Camargo, and F. J. Hinojo Lucen, 1346–1355. Madrid: Dykinson, S. L.

Marcos-Walias, J., J. Bobo-Pinilla, J. Delgado Iglesias, and R. Reinoso Tapia. 2023. "Plant Awareness Disparity Among Students of Different Educational Levels in Spain." *European Journal of Science and Mathematics Education* 11 (2): 234–248. https://doi.org/10.30935/scimath/12570.

Margulies, J. D., L. Bullough, A. Hinsley, D. J. Ingram, C. Cowell, B. Goettsch, B. B. Klitgård, A. Lavorgna, P. Sinovas, and J. Phelps. 2019. "Illegal Wildlife Trade and the Persistence of "Plant blindness"." *Plants, People, Planet* 1 (3): 173–182. https://doi.org/10.1002/ppp3.10053.

Martín-López, B., M. García-Llorente, I. Palomo, and C. Montes. 2011. "The Conservation Against Development Paradigm in Protected Areas: Valuation of Ecosystem Services in the Doñana Social–Ecological System (Southwestern Spain)." *Ecological Economics* 70 (8): 1481–1491. https://doi.org/10.1016/j.ecolecon.2011.03.009.

Mayer, J., and F. Horn. 1993. "Knowledge About Plants Forms and Taxonomy – What For?" *Unterricht Biologie* 189 (17): 4–13.

McDonough MacKenzie, C., S. Kuebbing, R. S. Barak, M. Bletz, J. Dudney, B. M. McGill, M. A. Nocco, T. Young, and R. K. Tonietto. 2019. "We Do Not Want to "Cure Plant blindness" We Want to Grow Plant Love." *Plants, People, Planet* 1 (3): 139–141. https://doi.org/10.1002/ppp3.10062.

McKenzie-Mohr, D. 2011. *Fostering Sustainable Behavior*. 3rd ed. Gabriola Island, Canada: New Society Publishers.

Muratet, A., P. Pellegrini, A. B. Dufour, T. Arrif, and F. Chiron. 2015. "Perception and Knowledge of Plant Diversity Among Urban Park Users." *Landscape and Urban Planning* 137:95–106.

Nates, J., C. Campos, and P. Lindemann-Matthies. 2010. “Students’ Perception of Plant and Animal Species: A Case Study from Rural Argentina.” *Applied Environmental Education and Communication* 9 (2): 131–141. https://doi.org/10.1080/1533015X.2010.482495.

New, J., L. Cosmides, and J. Tooby. 2007. “Category-Specific Attention for Animals Reflects Ancestral Priorities, Not Expertise.” *Proceedings of the National Academy of Sciences* 104 (42): 16598–16603. https://doi.org/10.1073/pnas.0703913104.

Niemiller, K. D. K., M. A. Davis, and M. L. Niemiller. 2021. “Addressing ‘Biodiversity naivety’ Through Project-Based Learning Using iNaturalist.” *Journal for Nature Conservation* 64:126070. https://doi.org/10.1016/j.jnc.2021.126070.

Nyberg, E., I. Brkovic, and D. Sanders. 2021. “Beauty, Memories and Symbolic Meaning: Swedish Student teachers´ Views of Their Favourite Plant and Animal.” *Journal of Biological Education* 55 (1): 31–44. https://doi.org/10.1080/00219266.2019.1643761.

Nyberg, E., and D. Sanders. 2014. “Drawing Attention to the ‘Green Side of life’.” *Journal of Biological Education* 48 (3): 142–153. https://doi.org/10.1080/00219266.2013.849282.

Opfer, J. E., and R. S. Siegler. 2004. “Revisiting preschoolers’ Living Things Concept: A Microgenetic Analysis of Conceptual Change in Basic Biology.” *Cognitive Psychology* 49 (4): 301–332. https://doi.org/10.1016/j.cogpsych.2004.01.002.

Otto, S., and P. Pensini. 2017. “Nature-Based Environmental Education of Children: Environmental Knowledge and Connectedness to Nature, Together, are Related to Ecological Behaviour.” *Global Environmental Change* 47:88–94. https://doi.org/10.1016/j.gloenvcha.2017.09.009.

Palliwoda, J., I. Kowarik, and M. von der Lippe. 2017. “Human-Biodiversity Interactions in Urban Parks: The Species Level Matters.” *Landscape and Urban Planning* 157:394–406.

Pany, P., C. Thorogood, G. M. A. Bermudez, S. Díaz, A. L. De Longhi, M. Balding, K. J. H. Williams, et al. 2014. “Students’ Interest in Useful Plants: A Potential Key to Counteract Plant Blindness.” *Plant Science Bulletin* 60 (1): 18–27. https://doi.org/10.3732/psb.1300006.

Parsley, K. M. 2020. “Plant Awareness Disparity: A Case for Renaming Plant Blindness.” *Plants, People, Planet* 2 (6): 598–601. https://doi.org/10.1002/ppp3.10153.

Patrick, P., and S. Tunnicliffe. 2011. “What Plants and Animals Do Early Childhood and Primary Students’ Name? Where Do They See Them?” *Journal of Science Education and Technology* 20 (5): 630–642. https://doi.org/10.1007/s10956-011-9290-7.

Pedrera, O., U. Ortega, A. Ruiz-González, J. R. Díez, and O. Barrutia. 2021. “Branches of Plant Blindness and Their Relationship with Biodiversity Conceptualisation Among Secondary Students.” *Journal of Biological Education* 57 (3): 566–591. https://doi.org/10.1080/00219266.2021.1933133.

Randler, C. 2008. “Teaching Species Identification – a Prerequisite for Learning Biodiversity and Understanding Ecology.” *EURASIA Journal of Mathematics, Science and Technology Education* 4 (3). https://doi.org/10.12973/ejmste/75344.

Sanders, D. L. 2007. “Making Public the Private Life of Plants: The Contribution of Informal Learning Environments.” *International Journal of Science Education* 29 (10): 1209–1228. https://doi.org/10.1080/09500690600951549.

Sanders, D. L. 2019. “Trapped in Time: Lingering with “Plantness”.” *Plants, People, Planet* 1 (2): 64–66. https://doi.org/10.1002/ppp3.6.

Sanders, D. L., and D. Jenkins. 2018. “Plant Biology.” In *Teaching Biology in Schools: Global Issues, Research and Trends*, edited by K. Kampourakis and M. J. Reiss. New York: Routledge. https://doi.org/10.4324/9781315110158-11.

Savary, S., L. Willocquet, S. J. Pethybridge, P. Esker, N. McRoberts, and A. Nelson. 2019. “The Global Burden of Pathogens and Pests on Major Food Crops.” *Nature Ecology & Evolution* 3 (3): 430–439. https://doi.org/10.1038/s41559-018-0793-y.

Schussler, E. E., M. A. Link-Pérez, K. M. Weber, and V. H. Dollo. 2010. “Exploring Plant and Animal Content in Elementary Science Textbooks.” *Journal of Biological Education* 44 (3): 123–128. https://doi.org/10.1080/00219266.2010.9656208.

Schussler, E. E., and L. A. Olzak. 2008. “It’s Not Easy Being Green: Student Recall of Plant and Animal Images.” *Journal of Biological Education* 42 (3): 112–119. https://doi.org/10.1080/00219266.2008.9656123.

Sharrock, S., and P. W. Jackson. 2017. “Plant Conservation and the Sustainable Development Goals: A Policy Paper Prepared for the Global Partnership for Plant Conservation.” *Annals of the Missouri Botanical Garden* 102 (2): 290–302. https://doi.org/10.3417/D-16-00004A.

Shwartz, A., A. Turbé, L. Simon, and R. Julliard. 2014. “Enhancing Urban Biodiversity and Its Influence on City-Dwellers: An Experiment.” *Biological conservation* 171:82–90.

Sjøberg, S., C. Schreiner, L. M. Ickenstein, S. Sjöberg, J. Carlsson, and L. Gedda. 2010. “The ROSE Project. An Overview and Key Findings.” *European Journal of Nuclear Medicine and Molecular Imaging* 37 (1): 114–123. https://doi.org/10.1007/s00259-009-1225-7.

Skarstein, T. H., and F. Skarstein. 2020. "Curious Children and Knowledgeable Adults–Early Childhood Student-teachers' Species Identification Skills and Their Views on the Importance of Species Knowledge." *International Journal of Science Education* 42 (2): 310–328.

Smith, R. J., D. Veríssimo, N. J. B. Isaac, and K. E. Jones. 2012. "Identifying Cinderella Species: Uncovering Mammals with Conservation Flagship Appeal." *Conservation Letters* 5 (3): 205–212. https://doi.org/10.1111/j.1755-263X.2012.00229.x.

Snæbjörnsdóttir, B., M. Wilson, and D. Sanders, Eds. 2020. *Beyond Plant Blindness: Seeing the Importance of Plants for a Sustainable World*. Berlin: The Green Box.

Soga, M., K. Gaston, Y. Yamaura, K. Kurisu, and K. Hanaki. 2016. "Both Direct and Vicarious Experiences of Nature Affect Children's Willingness to Conserve Biodiversity." *International Journal of Environmental Research and Public Health* 13 (6): 529. https://doi.org/10.3390/ijerph13060529.

Strgar, J. 2007. "Increasing the Interest of Students in Plants." *Journal of Biological Education* 42 (1): 19–23. https://doi.org/10.1080/00219266.2007.9656102.

Thomas, H., H. Ougham, and D. Sanders. 2022. "Plant Blindness and Sustainability." *International Journal of Sustainability in Higher Education* 23 (1): 41–57. https://doi.org/10.1108/IJSHE-09-2020-0335.

Thorogood, C. 2020. "Astonishing Plants." *Trends in Plant Science* 25 (9): 833–836. https://doi.org/10.1016/j.tplants.2020.06.007.

Tunnicliffe, S. D., and M. J. Reiss. 2000. "Building a Model of the Environment: How Do Children See Plants?" *Journal of Biological Education* 34 (4): 172–177. https://doi.org/10.1080/00219266.2000.9655714.

Tunnicliffe, S. D., and C. Ueckert. 2007. "Teaching Biology — the Great Dilemma." *Journal of Biological Education* 41 (2): 51–52. https://doi.org/10.1080/00219266.2007.9656061.

UICN. (2012). *Categorías y Criterios de la Lista Roja de la UICN: Versión 3.1. Segunda edición*. www.%0Aiucnredlist.org/technical-documents/categories-and-criteria.

UNESCO. 1977. *Intergovernmental Conference on Environmental Education. The Tbilisi Declaration, (October)*. Paris: UNESCO.

Uno, G. E. 1994. "The State of Precollege Botanical Education." *The American Biology Teacher* 56 (5): 263–267. https://doi.org/10.2307/4449818.

Uno, G. E. 2009. "Botanical Literacy: What and How Should Students Learn About Plants?" *American Journal of Botany* 96 (10): 1753–1759. https://doi.org/10.3732/ajb.0900025.

Voigt, A., and D. Wurster. 2015. "Does Diversity Matter? The Experience of Urban Nature's Diversity: Case Study and Cultural Concept." *Ecosystem Services* 12:200–208.

Wandersee, J. H. 1986. "Plants or Animals—Which Do Junior High School Students Prefer to Study?" *Journal of Research in Science Teaching* 23 (5): 415–426. https://doi.org/10.1002/tea.3660230504 .

Wandersee, J. H., R. M. Clary, and S. M. Guzman. 2006. "A Writing Template for Probing students' Botanical Sense of Place." *American Biology Teacher* 68 (7): 419–422. https://doi.org/10.1662/0002-7685(2006)68[419:AWTFPS]2.0.CO2.

Wandersee, J. H., and E. E. Schussler. 2001. "Toward a Theory of Plant Blindness." *Plant Science Bulletin* 47 (1): 2–9.

Wolff, L.-A., and T. H. Skarstein. 2020. "Species Learning and Biodiversity in Early Childhood Teacher Education." *Sustainability* 12 (9): 3698. https://doi.org/10.3390/su12093698.

Wynn, A. N., I. L. Pan, E. E. Rueschhoff, M. A. B. Herman, and E. K. Archer. 2017. "Student Misconceptions About Plants – a First Step in Building a Teaching Resource." *Journal of Microbiology & Biology Education* 18 (1). https://doi.org/10.1128/jmbe.v18i1.1253.

Zani, G., and J. Low. 2022. "Botanical Priming Helps Overcome Plant Blindness on a Memory Task." *Journal of Environmental Psychology* 81:101808. https://doi.org/10.1016/j.jenvp.2022.101808.

Ziska, L. H., P. R. Epstein, and W. H. Schlesinger. 2009. "Rising CO 2, Climate Change, and Public Health: Exploring the Links to Plant Biology." *Environmental Health Perspectives* 117 (2): 155–158. https://doi.org/10.1289/ehp.11501.