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Branches of Plant Blindness and their relationship with biodiversity conceptualisation among secondary students

Oier Pedrera, Unai Ortega-Lasuen, Aritz Ruiz-González, Jose Ramón Díez, Oihana Barrutia

Department of Didactics of Mathematics, Experimental and Social Sciences, University of the Basque Country, UPV/EHU, Spain

Corresponding author:
Oier Pedrera
Department of Didactics of Mathematics, Experimental and Social Sciences
Faculty of Education, Philosophy and Anthropology
University of the Basque Country, UPV/EHU
20018 Donostia – San Sebastián (Spain)
E-mail (1): opedrera001@ikasle.ehu.eus

16-digit ORCID of the author(s):
Unai Ortega Lasuen: 0000-0002-3625-6476
Aritz Ruiz-González: 0000-0001-7409-4634
José Ramón Díez: 0000-0003-3967-0186
Oihana Barrutia: 0000-0003-4118-7791

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Although citizenship’s literacy on biodiversity is a promising way of confronting its loss, the unawareness about this topic is generalised, particularly regarding plants. The latter phenomenon, named Plant Blindness (PB), not only refers to the inability to notice and identify the surrounding plants, but also to the lack of knowledge about the basics of plant biology and to the subsequent ignorance of the value of plants. Hence, the aim of this research has been to assess whether secondary students experience PB and to analyse if this phenomenon can be interrelated with their conceptualisation and attitudes towards biodiversity.

For this purpose, 63 secondary students took a mixed closed- and open-ended questionnaire on different aspects of biodiversity and plant biology. The results revealed that, despite conceptualisation of biodiversity and plant literacy increased during secondary education, most students presented PB “symptoms”. Moreover, some of the dimensions studied were interrelated, such as comprehension of biodiversity and different aspects of plant knowledge. Therefore, these results indicate that PB has multiple branches which are not only related to plant topics *sensu stricto*, but also include biodiversity; which can provide novel insights to the appropriate approach to the plant blindness issue from an educational perspective.

Keywords: biodiversity education; plant blindness; phenomenography; compulsory and post-compulsory secondary education; plant nutrition

Introduction

Plants are virtually ubiquitous and essential for life on Earth because they are the basis of trophic chains, ecosystem services providers and key to preventing or solving most of the environmental and socio-economic problems humanity is facing (Hartley et al. 2011; Isbell et al. 2011). Nevertheless, plants are usually not taken into consideration and people have less knowledge about them they do about animals (Lindemann-Matthies 2005; Schussler and Olzak 2008). As a matter of fact, laypeople tend to overlook common local plant species showing limited knowledge in native plant species identification (Díez et al. 2018; Kaasinen 2019).

This cognitive bias has been observed and investigated for decades and it was Wandersee and Schussler (1999) who coined the term *Plant Blindness* (PB) and described it as the inability to notice surrounding plants. Later on, these authors suggested different aspects this phenomenon encompasses such as understanding plant communities as the background for animal life, the difficulty to differentiate and identify plants in one's own geographical area, incomprehension about basic plant biology, and the inability to recognise the functions and the importance of plants among other traits (Wandersee and Schussler 2001). Thus, plant blindness does not only imply the incapacity to name and identify plant species, but it is also a phenomenon that impedes the integral and holistic comprehension of basic plant biology, the relationship between different living organisms and their role in ecosystems.

Over the last years, several hypotheses regarding the reasons for this phenomenon have been suggested. On the one hand, Bozniak (1994) and Hershey (1993) argue that the reason for the lack of interest and knowledge in plants could be their cultural exclusion since, in our western and zoocentric culture, plants are ignored and relegated to be the background where animals live. In fact, the underrepresentation of plant related contents in educational environments and school curriculums is believed to be a major driver of PB (e.g. Batke, Dallimore and Bostock 2020; Hershey 2005). However, PB and plants' cultural neglect is not a universal phenomenon as indigenous cultures (i.e. Aboriginal Australian, Native North American…) present strong bonds with plants (Descola 2009; Hall 2011).

On the other hand, there have also been evolutionary hypotheses to explain PB including plant immobility and lack of similarity with humans (Kinchin, 1999; Knapp

2019) and the human brain homogenising plants when processing images (Balas and Momsen 2014). Thus, as Balding and Williams (2016) state, PB should be acknowledged as a complex and multifactorial phenomenon which, is affected by both cognitive and evolutionary factors as well as the cultural context.

Recently, concerns regarding this terminology have arisen among the scientific community because of its problematic ableist subtext and the alternative term *Plant Awareness Disparity* (PAD) has been proposed (Parsley 2020; Sanders 2019). However, the problem scientific education faces remains complex, and keeps encompassing several different traits which can be categorised into attention, attitude, knowledge and relative interest (Parsley 2020).

Indeed, it is the aforementioned multifaceted characteristic of the PB phenomenon that renders its assessment difficult (Amprazis and Papadopoulou 2020). To date, several aspects of this phenomenon have already been researched though not in an integrated and interrelated approach. For example, apart from the previously mentioned lack of interest and scarce knowledge about plant biodiversity and species identification, one of the most studied dimensions about this phenomenon is students' comprehension of plant physiology and in particular plant nutrition, as it is the source of numerous and well documented misconceptions and learning difficulties (Wynn et al. 2017).

Furthermore, PB also has cascading effects on biodiversity knowledge as the ignorance of plants causes the majority of people to describe biodiversity as solely the species richness of the animal kingdom without integrating the plant world (Bermudez and Lidemann-Matthies 2018; Dikmenli, 2010). In fact, according to Thomas, Ougham and Sanders (2021) PB and sustainability are connected through conservation and biodiversity. Hence, PB can be considered as a hindrance to biodiversity conservation and, consequently, to the achievement of many Sustainable Development Goals (SDGs) (Amprazis and Papadopoulou 2018; Amprazis and Papadopoulou 2020; Thomas, Ougham and Sanders 2021).

This is alarming since biodiversity loss is one of the most worrying environmental issues nowadays due to its crucial importance for the functioning of ecosystems and survival of humankind (Cardinale et al. 2012; Hooper et al. 2012). Moreover, although literacy on biodiversity is a highly promising way to confront this issue (Schneiderhan-Opel and Bogner 2020), the overall knowledge about the concept of biodiversity held by young people and laypeople in general is scarce or only partially accurate (European Commission 2013; Levé et al. 2019; Menzel and Bögeholz 2009; Schneiderhan-Opel and Bogner 2019). In fact, the most common definition of biodiversity given by laypeople is simply 'the diversity of living things', result of an etymological analysis of the word biodiversity (Hunter and Brehm 2003).

Similarly, species identification skills, which are often emphasised as a prerequisite for the comprehension of biodiversity and ecology (Magntorn and Helldén 2005; Randler 2008), are also poor (Hooykaas et al. 2019; Palmberg et al. 2015), and it is particularly noteworthy the ignorance of native species which negatively affects the perception of local biodiversity (Almeida, García Fernández and Strecht-Ribeiro 2018; Bermudez, Díaz and De Longhi 2017; Dallimer et al. 2012).

According to the bibliography, there are many factors that influence this generalised illiteracy regarding biodiversity and nature in a broad sense. For instance, the ever-growing alienation from the nature that particularly young people experience known as *Extinction of experience* (Louv 2005; Miller 2005; Soga and Gaston 2016), and the underrepresentation of biodiversity related topics in classrooms and school curriculum contents (Amprazis and Papadopoulou 2018; Gayford 2000). Therefore, considering that the grasp of ecological concepts and the acquisition of identification skills helps students understand the complex interactions that take place in natural systems (Puk and Stibbards 2012) and fosters sustainable behaviour by kindling their interest in nature (Palmberg et al. 2015; Skarstein and Skarstein 2020), many authors underline the importance of correctly teaching this concept by implementing student-centred teaching and learning methods and giving enough time to cover it (Yli-Panula et al. 2018).

Hence, as education is an essential tool with which to prevent PB and biodiversity illiteracy (Jose, Wu and Kamoun 2019; Uno 2009), and taking into account that plant related contents are present in the compulsory education curriculum of most, if not all, countries; the aim of this research is firstly, to assess whether secondary school students experience PB based on their conceptualisation, attitudes and interests towards biodiversity, as well as on their preference for animals/plants, their capability to list and identify them, and their knowledge about plant physiology; and secondly, to analyse the relationship between the different aspects of the PB under examination. Accordingly, the main research questions addressed by this research are as follows:

(1) How do secondary students conceptualise biodiversity and its importance?
(2) Do secondary students experience different aspects of PB (i.e. less interest towards plants, different listing ability of plants and animals, scarce local plant species identification skills, misconceptions of plant physiology and unawareness of plant provided ecosystem services)?
(3) Do the abovementioned aspects of PB and biodiversity literacy correlate?
(4) Does this literacy improve through secondary education?

Methods

Study site

This study was conducted in a secondary school of Gipuzkoa (Basque Autonomous Community), in the north of Spain (43º18'N, 1º55'W). This region has a temperate oceanic climate and its potential vegetation consists of temperate deciduous forests. Below 600 m, the most common potential woodlands are mixed oak forests with a canopy dominated by oaks (*Quercus robur* L.). However, other species such as ash (*Fraxinus excelsior* L.), chestnut (*Castanea sativa* Mill.) and maple (*Acer campestre* L.) are also common. On the other hand, in the higher zones above 600 m beech (*Fagus sylvatica* L.) forests prevail, poorer than oak forests in terms of biodiversity (Loidi et al. 2011). However, from the 120 873 ha forest area of the region, only 58 478 ha belong to broadleaf species, the rest being conifer plantations that limit native vegetation (EUSTAT 2018). Thus, the landscape is dominated by fast-growing tree plantations (especially insignis pine, *Pinus radiata* D. Don), rough pastures on mountaintops and meadows in mid to low altitude.

Participants

Our sample consisted of 63 secondary students from a secondary school placed in a medium sized town (40.000 inhabitants). Almost half of the students (n=28) were enrolled in the first year of secondary school (year 8; age 12-13), and the rest (n=35) in the final years (i.e. year 11 and year 12; age 15-17). The students' educational level, age, sample size, gender ratio and Basque education curriculum contents and expected learning outcomes related to plants and biodiversity are shown in Table 1. When the data was collected all the students were enrolled in Biology, however, this was only compulsory for those students in the first year of secondary education.

In order to assess the progression of students' knowledge about the research topics from the first year of secondary education to the final years, students enrolled in Year 8 were compared to those from Year 11 and 12 who were lumped together due to their shared curriculum specifications. As a matter of fact, the contents and, particularly, learning outcomes of the first year of secondary education portrayed static and reductionist perspectives while the final years' emphasised the holistic understanding of biodiversity and the role of plants in a more global scale highlighting the dynamic interrelations that take place in ecosystems. This way, each cohort group represented respectively the knowledge at the beginning and at the end of secondary education, and because of the more complex and systems thinking oriented teaching final years students were expected to obtain better results on average.

Research instrument

The research instrument from the present study consisted of a questionnaire that was specifically designed to consider the main Basque education curriculum specifications (see Table 1) and some key issues related to the PB phenomenon identified in the literature (see below). Thus, the designed questionnaire was separated into six main parts as described in Table 2 (Appendix 1).

Similarly, it is worth mentioning that the students' species naming ability (Q11) was evaluated with a listing task of 10 animals and 10 plants of the students' choice, and the identification skills of local plant species (Q12) were assessed by soliciting students to identify in any language ten of the most common trees and shrubs from the study area (i.e. Birch (*Betula celtiberica* Rothm. & Vasc.), ash (*Fraxinus excelsior*), beech (*Fagus sylvatica*), alder (*Alnus glutinosa* (L.) Gaertn.), chestnut (*Castanea* *sativa*), maple (*Acer campestre*), holly (*Ilex aquifolium* L.), eucalyptus (*Eucalyptus globulus* Labill.), oak (*Quercus robur*) and insignis pine (*Pinus radiata*)).

Data collection was conducted under the supervision of one of the researchers (OP) and a secondary teacher and the test was administered during regular school sessions via an online questionnaire with a time limit of 25 minutes. The methodology of the research was merely quantitative as it consisted of a single questionnaire (Punch 2005). However, as stated above some of the questions were open-ended questions in order to gather the students' conceptions with the most depth and detail possible.

In order to assure the validity and viability of this research instrument, multiple meetings between the authors were conducted in its design, and it was previously tested through a pilot implementation with 16 undergraduate students. As a result, some of the questions about plant physiology were redefined, and one photo from the identification part was changed due to it being potentially confusing.

All ethical principles were taken under consideration in both the design and implementation of the questionnaire. The study was approved by the Ethic Committee of the University of the Basque Country UPV/EHU (CEISH/98/2017). Parents or legal guardians of the students, school directors and teachers were duly informed about the aims and procedure of the research and completed a written consent form expressly authorising the study before it commenced.

Data analysis

Data analysis and visualisation were performed by using the version 3.6.3 of the R software (R Core Team 2019). First, with the aim of identifying the possible significant differences of the studied variables between different educational stages, the homogeneity of the samples was verified according to the Kolmogorov-Smirnov test.

Nevertheless, as the data did not adjust to a normal distribution, parametric tests were discarded and non-parametric statistical tests were performed depending on the type of data. This way, nominal data was analysed by applying the Chi-square test (χ^2) and its *post hoc* described by Beasley and Schumaker (1995); and to verify the significant differences when comparing ordinal and numerical data the Kruskal-Wallis rank test was applied.

Secondly, the open-ended questions where students were asked to define and explain the importance of biodiversity were analysed using a phenomenographic approach with the objective of gaining insight into the entire spectrum of conceptions presented by secondary education students (Marton 1986; Marton 2015). In fact, phenomenographic research shows us that these different ways of understanding reality can be analysed and categorised. That is, individual interpretations are qualitatively grouped and categories are established to understand students' comprehension of the studied topic. In this study, the range of conceptions of the term biodiversity given by secondary students were grouped into a hierarchic series of descriptive categories, following the criteria of Marton and Booth (1997). These categories were constructed based on students' responses, and the system of categories intends to reflect an increasing level of understanding and experiencing of what nature and biodiversity are.

This analysis was performed independently by two researchers to assure the viability and trustworthiness of the categories. Indeed, the final system of categories as well as categorisation by which the students' answers and consequently conceptions were analysed was obtained via an iterative process of comparison, discussion and re-definition until an agreement was reached.

Finally, in order to establish relationships between the different aspects of the PB phenomenon under study (i.e. PAInt, SpL, PIdS, PSigh, PPhyK, and PEcoS), as well as their relationship with conceptualisation level regarding biodiversity, the Spearman correlation coefficient was calculated via pairwise correlations. For such purpose, the sum of the correct answers was calculated in the aspects that lumped several questions together (e.g. PPhyK) and the dimensions that were composed of a single question were treated as ordinal (e.g. SpL). Thus, the interpretation of Spearman's rho (rs) coefficient is as follows: rs = .3, weak effect size; rs = .6, moderate effect size; and from rs = .6 onward strong effect size based on Akoglu (2018).

Results

Interest, contact and self-perceived knowledge about nature and biodiversity

Regarding the Likert-type questions, first-year students reported a significantly higher contact with nature (CN; Q4) than final-years students ($H = 4.065$, $p = .044$) (Figure 1). However, while the interest in nature (BioInt; Q7) was relatively high for both groups, significant differences were observed in the self-perception of knowledge about nature and biodiversity (BioKP; Q5), with students in the final years estimating their knowledge as being significantly higher ($H = 20.621$, $p < .001$).

Moreover, when asked about their interest in plants and animals (PAInt; Q8), students significantly preferred animals, especially in the final years, while only 2% of the total students exclusively chose plants ($\chi^2 = 37$, $p < .001$) (Figure 2; A). The main information sources regarding nature and biodiversity (InfS; Q6) students identified were school (75%) and the media (65%) (Figure 2; B). These were followed by natural areas (57%), family (52%) and zoos and museums (29%), while the remaining options were mentioned significantly less ($\chi^2 = 128.19$, $p < .001$). From among those who chose school as an important source of information, 57% identified teachers as their main sources; and among those who declared the media as a major source the Internet prevailed (49%).

Conceptions about biodiversity and its importance

By means of phenomenographic analysis six and five hierarchic categories of growing complexity were inductively described for the definition (BioC; Q9) and for the importance of biodiversity (BioIC; Q10) questions respectively (Cohen's Kappa reliability coefficient average .86) (Table 3). The hierarchic series of the descriptive categories are enclosed in Appendix 2.

The conceptions students held about the term biodiversity (Table 3) presented significant differences between different educational stages (Figure 3). On the one hand, the definitions of biodiversity (BioC; Q9) presented by higher educational level students were more detailed and resembled more the scientific consensus by being on higher level categories than the ones of the younger students ($H = 24.368$, $p < .001$). Thus, as seen on Figure 3; A, the majority of first-year students found the concept of biodiversity unknown (61%); and even though older students were more familiar with the term, only 9% included genes, ecosystems and other elements in their definitions, exhibiting, overall, a correct but partial and simple interpretation of biodiversity. In addition, it is worth mentioning that 58% of students whose answers were categorised above the D category (NA/unknown) explicitly mentioned plants and animals, ignoring the rest of organisms.

On the other hand, regarding the importance of biodiversity (BioIC; Q10), students from the final years of secondary school showed a more systemic understanding of biodiversity while comprehending significantly better than younger students the role of biodiversity in the functioning of ecosystems and its relationship with the survival of humankind ($H = 24.959$, $p < .001$). As in the previous question, the vast majority of first-year students left this question unjustified, showing that even if they knew biodiversity was important, they were not able to explain the reason (68%) (Figure 3; B). Most older students, besides, showed a consistent grasp of the importance of biodiversity as the majority explained the interactions between the components of the complex natural systems (e.g. 'Each species influences ecosystems and in most cases having many species benefits nature') (A category, 29%), or at least justified the importance with a utilitarian argument (e.g. 'Biodiversity is important because it is the source of everything we have: medicines, food…') (B1 category, 43%). However, it is remarkable that among the 19 answers that were categorised as utilitarian, 47% presented epistemic or aesthetic reasons for the importance of biodiversity such as 'It is important because it helps us understand our planet and how it has evolved' and 'It is important because nature can be boring if it is all the same'.

Lists of plants and animals

In the lists of plants and animals (SpL; Q11) students overall named 111 animal species, 74 by the first-year students, and 94 by the students in their final years with 57 species being named by both groups. Regarding the number of animals listed, 68% of first-year and 73% of final-years students named ten animal species as requested, with the average number of animals listed being 9.26±0.22.

The ten most mentioned animals were dog, cat, lion, horse, tiger, eagle, snake, shark, rabbit and monkey respectively, so only three were native wild animals from the region (i.e. eagle, snake and rabbit). Additionally, regarding the biomes of the listed animals, and without taking into account the 28.1% that were pets and farm animals, 43.1% of the animals listed were native (from temperate forests), while the remaining

56.9% were from exotic biomes, particularly from the savannah (21.9%) and tropical rainforests (15.6%).

Finally, in regard to the taxonomy of the listed species, 66.3% of the named animals were mammals, while the animals from the rest of the taxonomic groups were listed significantly less frequently ($\chi^2 = 1285.4$, $p < .001$) (Figure 2; C).

On the other hand, the list of plants was shorter than that of animals. Overall, 87 different species were named, the first-year student group and the final years student group were both able to name 60 species of which 33 were listed by both groups. Unlike in the animals' list, only 14% of younger students and 23% of older students managed the ten species request, and the average number of plants listed was 5.43±0.59 for the first-year and 6.48±0.5 for the final-years students.

The ten most mentioned plant species were rose, daisy, pine, oak, cactus, tulip, beech, sunflower, palm tree and apple tree respectively; so, in this case, four of the most listed species were native wild plants (i.e. daisy, pine, oak, beech), because even though rose and apple tree can be considered native, they are mainly known as introduced species in plantations and gardening.

Thus, 57.1% of the plants listed were edible or decorative plants which were mentioned significantly more than others ($\chi^2 = 47.415$, $p < .001$) (Figure 2; D). Hence, the autochthonous plants represented only the 37.2% of the listed species taking into account the native plants classified in all three 'Woody', 'Herbaceous' and 'Others' categories.

Students' identification skills of the most abundant plants

Regarding the identification of the most abundant plant species from the study area region (PIdS; Q12), no student was capable of naming all ten species. The average number of identifications was two species per student for both cohort groups. Thus, the two most identified species were the pine and the chestnut (χ^2 = 1116.4, p < .001), with 71% of students able to identify the pine tree and 65% the chestnut tree (Figure 2; E).

However, it is important to underline the fact that even if most students were not able to identify these species, they acknowledged sightings of these in their natural environment (PSigh; Q13), showing therefore the ability to, at least, differentiate them by their characteristics. Additionally, the most observed plant species were also the most frequently identified. This way, the most observed plant species were radiata pines and chestnuts as 87% of students admitted to having seen these species in the natural environment, followed by oak (75%), holly (63%), birch (54%), maple (54%), beech (49%), ash (38%), eucalyptus (21%), and alder (19%) respectively.

Knowledge about plant physiology and plant services

Students' answers about plants' physiology (PPhyK; Q14-Q18) and the services (PEcoS; Q19) provided by them significantly varied by educational stage as the students finishing secondary education achieved more correct answers than those starting it (H = 22.017, p < .001) (Table 4).

The question about the source of plants' biomass (Q14) was incorrectly answered by the majority of the students (χ^2 = 15.254, p < .001) (Table 4). In fact, 75% stated that plants get their biomass mainly from the soil with explanations such as 'Plants absorb matter and substances through their roots'. Moreover, even if 25% of students got the question correct by answering that the source of plant biomass is the atmosphere, only 11% of students explained this answer correctly (e.g. 'Plants get the inorganic substances they need from the atmosphere (CO_2), in order to transform them to organic matter later'), all of them belonging to the final years of secondary education.

Therefore, although there were no significant differences between academic levels regarding the close-ended answers, the explanations of the students from the final years were significantly more accurate ($\chi^2 = 5.414$, $p = .02$).

In the question where students had to complete a sentence relating to plant nutrition (Q15), similar significant results regarding the differences between academic levels were observed ($\chi^2 = 13.302$, $p = .004$), even though, in this case, the correct answer was the most common answer ($\chi^2 = 20.619$, $p < .001$) (Table 4). However, most of the first-year students presented the common misconception that plants obtain their nourishment through their roots (43%).

Regarding the questions about the occurrence of photosynthesis (Q16) and respiration (Q17), most of the answers were correct ($\chi^2 = 61.238$, $p < .001$; $\chi^2 = 34.46$, $p < .001$ respectively). 79% of the students correctly acknowledged that photosynthesis takes place during the day (when there is sunlight) and 54% identified that respiration is a constant process (Table 4). Nevertheless, some students, especially those from the lower educational stages, answered incorrectly, being noticeable that 25% of first-year students answered that photosynthesis was a continuous phenomenon and 27% were under the typical misconception that plants only respire at night.

In the last question about physiology in which a scenario was proposed in order to analyse the knowledge students had about plant/tree growth and meristems (Q18), the wrong answer prevailed and was chosen by 60% of the students ($\chi^2 = 19.81$, $p < .001$) (Table 4). However, the results showed that the final-years students' explanations were scientifically more accurate ($\chi^2 = 10.031$, $p = .006$); including, in most cases, concepts such as meristems (e.g. 'plants grow via meristemic tissues, not from the bottom but by creating new surface on the tips'), or at least, apical growth (e.g. 'trees grow from the tips').

On average students did not identify the services plants provide us (PEcoS; Q19) from an anthropocentric viewpoint as only 4% of the students starting secondary education and 17% finishing it identified all of the seven services in the questionnaire. In addition, there were significant differences between educational stages with the students from the final years being those who were able to recognise more services ($H = 8.073$, $p = .004$). With respect to the services, the most identified one was that plants are oxygen suppliers (95.2%) followed by their use in medicine (74.6%) and nutrition (66.7%) ($\chi^2 = 45.188$, $p < .001$) (Figure 2; F). However, it is worth highlighting that the current relevant and vital roles of plants against climate change, soil erosion and pollution went largely unnoticed by students.

Are Plant Blindness, biodiversity knowledge and educational level related?

With regard to the correlations between the different variables analysed and students' age and educational level, the aforementioned results were confirmed, as BioC, BioIC, BioKP, PPhyK and PEcoS positively correlated with both variables (Figure 4).

As far as the correlations between the remaining analysed variables are concerned (all significant at $p < .01$), the results exhibited evidence of PB being a multifaceted phenomenon which is related to biodiversity conceptualisation too (Figure 4). Primarily, when analysing students' comprehension regarding biodiversity (BioC), a strong positive correlation between the level of conceptualisation of biodiversity and the understanding of its importance (BioIC) was discerned. Relationships between the comprehension of the biodiversity concept (BioC) and various aspects of PB were also detected, since the knowledge about plant physiology (PPhyK) and the number of services identified (PEcoS) correlated positively with the conceptual level of the definition.

Similarly, moderate positive correlations were found between some of the Likert-type answers and different variables relating to biodiversity knowledge and PB. In particular, students' self-estimated knowledge (BioKP) correlated with the conceptualisation level of the definition of biodiversity (BioC), knowledge about plant physiology (PPhyK), the awareness of the importance of biodiversity (BioIC), the number of plants listed (PSpL), the sightings of common plant species (PSigh), and the number of plant-provided ecosystem services identified (PEcoS) among others.

Furthermore, correlations between different dimensions of PB were detected. Thus, facets such as the performance in the plant identification task (PIdS) had moderate positive correlations with the number of plant services identified (PEcoS), the number of plants listed (PSpL), and the number of sightings of native species in their natural environment (PSigh). In fact, this last relation indicates that students who had higher identification skills or better knowledge of common plant names were presumably also more in the habit of noticing plants or had a more trained eye when it came to differentiating between them. Likewise, the number of plants named in the list (PSpL) had moderate positive correlations with the number of ecosystem services identified (PEcoS), the performance in the questions about plant physiology (PPhyK), and the number of sightings of common plant species (PSigh). Moreover, although weak, a positive correlation was noticed between the number of plants and animals listed (ASpL) showing that the students who were capable of naming more animals were better at listing plants too.

Discussion

The conclusions drawn from the analysis of the questionnaire revealed that, despite the conceptualisation of biodiversity and comprehension of plant biology topics increased during secondary education, most of the students in this research experience PB at least to some extent. Additionally, the correlation results among the studied variables also highlighted that PB is a multifaceted phenomenon which is related to biodiversity conceptualisation. Thus, it is evident that the expected curricular learning outcomes of acquiring scientific knowledge about the functioning of ecosystems and the organisms in them described in Table 2 (Decree 236/2015, 22nd December) has not been totally met by the end of secondary education. This is doubly worrisome because several students from the sample were finishing or had already finished their compulsory education, which means that some of them will not continue to study biology and will face the future challenges of life with scant knowledge about these issues key to take informed decisions (Krosnick, Baker and Moore 2018).

This way, PB was present in several of the studied variables. For example, and in accordance with previous works (Kinchin 1999; Wandersee 1986), not only did secondary school students from the current study show more interest in animals, but they also neglected plants in most cases.

Relatedly, despite plants being widespread and seen every day, the lists of animals were larger and more diverse than those of plants, indicating a poorer knowledge of the latter. Even so, the most named animals on the lists were mammals as observed in other works (Yli-Panula and Matikainen 2014); and these were mainly pets and farm animals along with dangerous and charismatic exotic ones. Indeed, even if plants are usually neglected and animals are more present on students' everyday lives (e.g. pictures, information, etc.) (Serpell 1999), the greater part of this information is about animals from which humans benefit, such as livestock (Patrick and Tunnicliffe 2011), and with regard to wild animals, the information that predominates in media (Ballouard, Brischoux and Bonnet 2011), textbooks (Celis-Diez et al. 2016) and zoos and museums (Hancocks 2007) is about allochthonous species. Consequently, not only can it be concluded that the animals that appear in the main information sources of the students we recorded in this study are, for the most part, exotic or domestic, but also, as our connection to nature data suggest, it can be assumed that the contact students experience with these animals is mainly virtual, causing a disconnection from their immediate biological environment (Campos et al. 2012).

Besides, from among all the plant species mentioned, most were edible or decorative, and many exotic (e.g. Bermudez, Díaz and De Longhi 2017). So, the plants that, *a priori*, had no direct benefit for humans were named in small numbers; a previously reported phenomenon consisting of classifying species by their functionality and showing more interest towards species that are somehow useful or aesthetic (Grace and Ratcliffe 2002; Kellert 1993).

In a similar vein, and as another facet of PB, the common and abundant local plant species followed the same tendency witnessed above resulting broadly unknown. In accordance with its wide distribution throughout the study area (i.e. the Basque Country), the most identified species was the exotic insignis pine, and aside from the native chestnut, the rest of the native species remained largely unidentified. Thus, the phenomenon described in other countries concerning students being unable to identify native plant species was found here too (Bebbington 2005; Díez et al. 2018; Kaasinen 2019; Palmberg et al. 2015).

Additionally, it is worth noting that both the plant listing and plant species identification indicated that students' knowledge regarding plants, and native species in particular, was scant. Lindemann-Matthies (2005) states that children have the ability to learn and remember the names of species if they find them interesting and have direct experiences with them. Hence, a plausible explanation for this widespread ignorance of native plant names might be the lack of opportunities to learn them as a result of the recorded scarce contact with nature and the consequent aforementioned extinction of experience (Soga and Gaston 2016). A further example of this is the fact that the two most listed native wild species (oak and daisy); as well as the four most identified local plant species (pine, chestnut, holly and oak) are plant species of high cultural value and wide distribution (in the Basque Country), characteristics which guarantee opportunities to learn their names. Hence, these findings, in agreement with Kaasinen (2019) and Nyberg, Brkovic and Sanders (2019), demonstrate that students identify plant species better if they have experienced direct contact and created memories with them, with it also being essential that someone points them out and teaches their name. Indeed, in spite of the poor performance in this task, students did not present much trouble at recognising the species as it can be inferred by the answers about sightings, which reinforces the previous statement that the main impediment to species identification literacy is the lack of instruction and experiences with them.

PB was also discerned in the questions on plant physiology because, although they presented the most noticeable knowledge progression between educational stages probably thanks to the prominence of these contents in education curriculums including the Basque as described in the Methods section (e.g. Amprazis and Papadopoulou 2018), students held common and thoroughly documented misconceptions at every academic level (Wynn et al. 2017). The vast majority of the students presented the common alternative scientific model in which plants gain biomass via root absorption instead of through atmospheric CO_2 fixation (e.g. Barman et al. 2006; Barrutia and Díez 2019; Métioui, Matoussi and Trudel, 2015; Thorn et al. 2016; Wandersee 1983). Thus, this observation reveals deficiencies in both plant nutrition comprehension and understanding of the photosynthetic reaction itself which is usually classified as complex and troublesome to learn due to its abstractness and dissimilarity to the more familiar animal nutrition (Marmaroti and Galanopoulou 2006; Stavy, Eisen and Yaakobi 1987).

Similarly, the students that thought of photosynthesis as a constant process presumably held the mistaken conception by which photosynthesis is understood as the respiration of plants (Amir and Tamir 1994; Haslam and Treagust 1987); and the extended belief that respiration takes place at night when there is no light for photosynthesis to happen was also present (Köse 2008). Clearly, these two examples show the difficulties students face in understanding the coexistence of both processes that exchange the same gases and the importance of a holistic understanding of plant nutrition, because it can be assumed that the better comprehension presented by final-years students was thanks to a more complete ecological and biochemical understanding of the whole process (Barrutia and Díez 2019).

Regarding plant growth, it was inferred that students, and particularly those in lower educational stages, did not fully understand how the growth of plants is apical due to the specialised growth tissues such as meristems. However, this knowledge could be useful in everyday life, for example regarding how to properly prune plants, in order to achieve sustainable practices and healthier urban environments (Badrulhishama and Othmanb 2016), which also contribute to climate mitigation strategies (Parsa et al. 2019).

Finally, with respect to the services that plants provide humans, it is noticeable how few students identified them all. Even if, last year students in general identified more ecosystem services showing a more holistic and dynamic comprehension of plants' biology as expected by the curriculum specifications above reviewed, it seems clear that the school curriculums of different countries do not pay enough attention to the importance of plants and natural ecosystems and the services they provide (Amprazis and Papadopoulou 2018; Batke et al. 2020). Students, generally speaking, are aware that plants are important but, in the same way that they are not able to explain the importance of biodiversity, neither can they justify the relevance of plants (Amprazis, Papadopoulou and Malandrakis 2019). Furthermore, it is worth noting that students identified the most direct anthropocentric services, also known as provisioning services (e.g. O_2, food…), but the roles plants can play in mitigating three of the most worrying current environmental issues (i.e. climate change, soil erosion and pollution) were unknown by around half of the students, who exposed the previously mentioned utilitarian view (Grace and Ratcliffe 2002; Small, Munday and Durance 2017; Suárez and Gutiérrez 2017).

Comparably, this utilitarian or anthropocentric viewpoint was also detected in students' conceptualisation regarding biodiversity. As a matter of fact, although biodiversity is common curricular content in both primary and secondary education (Decree 236/2015, 22nd December), conceptions of biodiversity and students' biodiversity knowledge self-perception were quite limited, particularly in the first year of secondary school. As elucidated by the phenomenographic analysis, the conceptual understanding of the term was, as expected by the curricular learning outcomes, progressively acquired throughout the academic lives of the students from a more simple and aseptic understanding to a more complex and integral in the final years. However, even at the end of secondary school only a reduced group of students reached the required complex understanding of the term biodiversity and its different elements. Previous research has stated that laypeople and students identify diversity as the fundamental component of biodiversity (Bermudez and Lindemann-Mathies 2018; Buijs et al. 2008; Fiebelkorn and Menzel 2013). Despite that, our investigation found that although a third of the students explicitly mentioned diversity, a considerable number of students had a biophysical quantitative conception of biodiversity, this meaning they perceived biodiversity as a physical phenomenon (the biota of a place or the place itself) rather than an abstract one (the diversity of these elements). Similar results were recorded by Kilinc et al. (2013) who attributed their findings to the fact that biodiversity related content is mostly taught along with other ecological concepts such as biota, habitat and taxonomy. Additionally, it is worth noting that even though the curriculum proposes its acquisition for the final years of secondary education, as Levé et al. (2019) and Pérez-López et al. (2020) report, most students hold static conceptions about nature and biodiversity with the dynamic nature of it being virtually absent in this study too, which can be a problem when attempting to gain an understanding of the value of its conservation.

Similarly, when asked about the importance of biodiversity, although every student identified it as important, the first-year students' justifications were superficial and limited; and even if the final years students' explanations were more elaborated and detailed as expected based on the education curriculum specifications, only one third of them attained the highest level of conceptual understanding being able to explain the complex interdependence between different elements of natural systems. Moreover, almost half of the students held the aforementioned anthropocentric conceptions of the importance of biodiversity, which has several connotations. First, this implies humans are not part of the biodiversity (Sharma and Buxton 2018), and second, particularly among the students with the utilitarian view, biodiversity is understood as being important only due to it directly affecting human wellbeing, which is closely linked to the modern western worldview (Fletcher 2017). Therefore, though it is present, the lack of sufficient ecocentric reasoning among students is evident, an issue that should be addressed in education because, as previous studies have agreed, individuals who hold ecocentric values are more prone to develop pro-environmental attitudes than those with anthropocentric and egocentric values (Quinn, Castéra and Clément 2015; Steg and Vlek 2009; Washington et al. 2017).

Altogether, considering and accepting the limits of our reduced sample size, since the phenomenon arose in various positively interrelated dimensions, the multifaceted nature of PB was confirmed in our study which, as far as we know, is the first implementing such multidimensional approach. For instance, the students who listed more plants were also able to identify more native plant species, the ones who had a higher conceptual knowledge of the term biodiversity understood its importance better and were able to identify more of the ecosystem services provided by plants; and the students who performed better in the questions about plant physiology revealed a better comprehension of the importance of both plants and biodiversity.

Therefore, these results suggest that PB has multiple branches which are not only related to plant topics *sensu stricto*, but also include biodiversity conceptualisation; and for that reason, the alphabetisation on these topics should be as interrelated and holistic as possible. Indeed, the results imply that plant literacy is a predictor of more complex biodiversity conceptualisation. Thus, in order to fully grasp biodiversity, a minimum level of knowledge regarding plants is required given they are a major component of biodiversity and backbone of life on Earth (Amprazis and Papadopoulou, 2018). Not only that, but also several studies underline that when knowledge about plants increases, their appreciation also rises (Lindemann-Matthies 2005); and the same thing has been observed when analysing the relationship between biodiversity knowledge and the attitudes towards it (Lindemann-Matthies, Junge and Matthies 2010; Moss, Jensen and Gusset 2016; Otto and Pensini 2017; Pitman, Daniels and Sutton

2017). Hence, these two interrelated knowledges seem to be promising triggers for attitudinal changes.

Educational implications

Considering plant literacy is an essential part of biodiversity education and appreciation, all these findings make evident the compelling urge to address and approach both the PB and the knowledge gap concerning biodiversity during compulsory education.

In the first place, acquiring a correct understanding of the biodiversity concept can be helpful not only to improve the understanding of ecological concepts, but also to foster an interest in nature (Lindemann-Matthies and Bose 2008; Magntorn and Helldén 2005; Yücel and Özkan 2015). To this end, and as an effective way of enhancing knowledge of biodiversity and promoting sustainability, Palmberg et al. (2017) reported the efficiency of systems thinking, which can also be useful to prevent PB via activities that highlight the vital role plants play in most of the ecosystems. Furthermore, Çil (2016) disclosed that indicating the importance of plants and the services they provide generates more interest in them, as well as, enhancing the understanding of ecological systems and promoting pro-environmental behaviours (Taylor and Bennett 2016; Torkar 2016). Indeed, given the widespread utilitarian and anthropocentric values prevailing among the participants of this study, and the many positive relationships detected between students' plant provided ecosystem services identification and several other PB related aspects, it seems reasonable that this approach would augment students' interest and knowledge regarding plants and biodiversity. For instance, as a way of engaging students and optimising their learning process, teaching based on students' specific interests regarding certain plants related to human affairs could be effective (Pany et al.

2019), and this could also be a useful approach with which to work on scientific argumentation via socio-scientific debates (Cavagnetto 2010; Grace 2009).

Similarly, the learning of identification skills as a key component of biodiversity literacy can help students get to know and appreciate native plant species (Selvi and Çelepçikay Islam 2021), increase their comprehension of biodiversity and systems ecology (Magntorn and Helldén 2007; Randler 2008), and promote sustainable and naturalist behaviours (Palmberg et al. 2017). Many research papers have highlighted the importance that direct and hands-on interactions with nature can have in both the process of learning about biodiversity and overcoming PB, as well as in the development of conservationist behaviours (Beery and Jørgensen 2016; Krosnick, Baker and Moore 2018; Randler and Bogner 2006; Soga and Gaston 2016). Thus, in these current times in which biodiversity education and outdoor activities are more necessary than ever, and bearing in mind that based on our findings the mere contact with nature does not seem to improve students' attitudes, interest and knowledge, the use of didactically well planned contextualising field trips as a way of working on the identification skills that are essential in biodiversity education (Fančovičová and Prokop 2011; Jeronen, Palmberg and Yli-Panula 2016; Palmberg et al. 2019; Skarstein and Skarstein 2020) and the use of the everyday environment (Frisch, Unwin and Saunders 2010), while taking advantage of the aforementioned utilitarian viewpoint (Pany and Heidinger 2017) should all be contemplated as these are acknowledged as being both motivating for students and successful in combating PB.

All things considered, taking into account the current critical situation regarding environmental issues in which, even though 21% of the world's plant species are endangered (Brummitt et al. 2015), plants are still neglected in the broader biodiversity and sustainability debate (Sharrock and Jackson 2017); it is essential that students become literate in these topics not only in order to acquire knowledge, but also to become aware of the importance of these subjects and to act consequently towards a sustainable future. In fact, preventing PB can have implications such as enhancing students' interest in plants, increasing the understanding of the natural systems and fostering the development of conservationist and sustainable behaviours (Amprazis and Papadopoulou 2020). However, as Kissi and Dreesman (2017) expose, PB is not a phenomenon to be treated through a single educational intervention. Hence, given that it is a deep-rooted phenomenon, a set of systematic specifically designed long-term activities might be needed, integrated within a proper education curriculum that takes into account all of the dimension this phenomenon can have (Amprazis and Papadopoulu 2018).

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Bibliography

Akoglu, H. 2018. "User's Guide to Correlation Coefficients." *Turkish Journal of Emergency Medicine* 18: 91–93. doi: 10.1016/j.tjem.2018.08.001

Almeida, A., B. García Fernández, and O. Strecht-Ribeiro. 2018. "Children's Knowledge and Contact with Native Fauna: A Comparative Study between Portugal and Spain." *Journal of Biological Education* 54 (1): 17–32. doi:10.1080/00219266.2018.1538017

Amir, R., and P. Tamir. 1994. "In-Depth Analysis of Misconceptions as a Basis for Developing Research-Based Remedial Instruction: The Case of Photosynthesis." *The American Biology Teacher* 56 (2): 94–100. doi:10.2307/4449760

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., and 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. doi:10.1080/13504622.2020.1768225

Amprazis, A., P. Papadopoulou, and G. Malandrakis. 2019. “Plant Blindness and Children’s Recognition of Plants as Living Things: A Research in the Primary Schools Context.” *Journal of Biological Education*. doi:10.1080/00219266.2019.1667406

Badrulhisham, N., and N. Othman. 2016. “Knowledge in Tree Pruning for Sustainable Practices in Urban Setting: Improving Our Quality of Life.” *Procedia - Social and Behavioral Sciences* 234: 210–217. doi:10.1016/j.sbspro.2016.10.236

Balas, B., and J. L. Momsen. 2014. “Attention “Blinks” Differently for Plants and Animals.” *CBE Life Sciences Education* 13 (3): 437–443. doi:10.1187/cbe.14-05-0080

Balding, M., and K. J. H. Williams. 2016. “Plant Blindness and the Implications for Plant Conservation.” *Conservation Biology* 30 (6): 1192–1199. doi:10.1111/cobi.12738

Ballouard, J. M., F. Brischoux, and X. Bonnet. 2011. “Children Prioritize Virtual Exotic Biodiversity over Local Biodiversity.” *PLoS ONE* 6 (8): e23152. doi:10.1371/journal.pone.0023152

Barman, C. R., M. Stein, S. McNair, and N. S. Barman. 2006. “Students’ Ideas about Plants & Plant Growth.” *The American Biology Teacher* 68 (2): 73–79.

Barrutia, O., and J. R. Díez. 2019. “7 to 13-Year-Old Students’ Conceptual Understanding of Plant Nutrition: Should We Be Concerned about Elementary Teachers’ Instruction?” *Journal of Biological Education*. doi:10.1080/00219266.2019.1679655

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): 98–105. doi: 10.11648/j.jps.20200804.14

Beasley, T. M., and R. E. Schumacker. 1995. “Multiple Regression Approach to Analyzing Contingency Tables: Post Hoc and Planned Comparison Procedures.” *The Journal Of Experimental Education* 64 (1): 79–93. doi:10.1080/00220973.1995.9943797

Bebbington, A. 2005. “The Ability of A-Level Students to Name Plants.” *Journal of Biological Education* 39 (2): 63–67. doi:10.1080/00219266.2005.9655963

Beery, T., and K. A. Jørgensen. 2016. “Children in Nature: Sensory Engagement and the Experience of Biodiversity.” *Environmental Education Research* 24: 13–25. doi: 10.1080/ 13504622.2016.1250149

Bermudez, G. M. A., and P. Lindemann-Matthies. 2018. “"What Matters is Species Richness" – High School Students’ Understanding of the Components of Biodiversity.” *Research in Science Education*. doi:10.1007/s11165-018-9767-y

Bermudez, G. M. A., S. Díaz, and A. L. De Longhi. 2017. “Native Plant Naming by High-School Students of Different Socioeconomic Status: Implications for Botany Education.” *International Journal of Science Education* 40 (1): 46–66. doi:10.1080/09500693.2017.1397297

Bozniak, E. C. (1994). “Challenges Facing Plant Biology Teaching Programs.” *Plant Science Bulletin* 40: 42–46.

Brummitt, N. A., S. P., Bachman, J. Griffiths-Lee, M. Lutz, J. F. Moat, A. Farjon, J. S. Donaldson, et al. 2015. “Green Plants in the Red: A Baseline Global Assessment for the IUCN Sampled Red List Index for Plants.” *PLOS ONE* 10 (8): e0135152. doi:10.1371/journal.pone.0135152

Buijs, A. E., A. Fischer, D. Rink, and J. C. Young. 2008. “Looking beyond Superficial Knowledge Gaps: Understanding Public Representations of Biodiversity.” *The International Journal of Biodiversity Science and Management* 4 (2): 65–80. doi:10.3843/Biodiv.4.2:1

Campos, C. M., S. Greco, J. J. Ciarlante, M. Balangione, J. B. Bender, J. Nates, and P. Lindemann-Matthies. 2012. “Students’ familiarity and initial contact with species in the Monte desert (Mendoza, Argentina).” *Journal of Arid Environments* 82: 98–105. doi:10.1016/j.jaridenv.2012.02.013

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. doi:10.1038/nature11148

Cavagnetto, A. R. 2010. “Argument to Foster Scientific Literacy: A Review of Argument Interventions in K-12 Science Contexts.” *Review of Educational Research* 80: 336–371. doi:10.3102/0034654310376953

Celis-Diez, J. L., J. Díaz-Forestier, M. Márquez-García, S. Lazzarino, R. Rozzi, and J. J. Armesto. 2016. “Biodiversity Knowledge Loss in Children’s Books and Textbooks.” *Frontiers in Ecology and the Environment* 14 (8): 408–410. doi:10.1002/fee.1324

Çìl, E. 2016. “Instructional Integration of Disciplines for Promoting Children’s Positive Attitudes Towards Plants.” *Journal of Biological Education* 50 (4): 366–383. doi:10.1080/00219266.2015.1117512

Dallimer, M., K. N. Irvine, A. M. J. 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. doi:10.1525/bio.2012.62.1.9

Decree 127/2016 6th September. “Establishing the Baccaulaureate Curriculum and Implementing It in the Basque Country.” (BOPV 23-09-2016)

Decree 236/2015 22nd December. “Establishing the Basic Education Curriculum and Implementing It in the Basque Country.” (BOPV 15-01-2016)

Descola, P. 2009. “Human Natures.” *Social Anthropology* 17: 145–157.

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 and Social Sciences* 12 (3): 396–400. doi:10.5281/zenodo.1316197

Dikmenli, M. 2010. “Biology Student Teachers’ Conceptual Frameworks Regarding Biodiversity.” *Education* 130: 479–489.

Dor-Haim, S., R. Amir, and J. Dodick. 2011. “What do Israeli High School Students Understand about Biodiversity? An Evaluation of the High School Biology Programme, «Nature in a World of Change».” *Journal of Biological Education* 45 (4): 198–207. doi:10.1080/00219266.2010.546695

England Marketing. 2009. *Report to Natural England on Childhood and Nature: A Survey on Changing Relationships with Nature across Generations.* Cambridgeshire, UK: England Marketing.

European Commission. 2013. “Flash Eurobarometer 379: Attitudes Towards Biodiversity.” Retrieved from http://ec.europa.eu/commfrontoffice/publicopinion/flash/fl_379_en.pdf

EUSTAT. 2018. “Inventario Forestal CAE 2018.” Retrieved from http://www.euskadi.eus/web01-a3estbin/es/contenidos/informacion/inventario_forestal_2018/es_def/index.shtml

Fančovičová, J., and P. Prokop. 2010. “Development and Initial Psychometric Assessment of the Plant Attitude Questionnaire.” *Journal of Science Education and Technology* 19 (5): 415–421. doi:10.1007/s10956-010-9207-x

Fančovičová, J., and P. Prokop. 2011. “Plants Have a Chance: Outdoor Educational Programmes Alter Students’ Knowledge and Attitudes Towards Plants.” Environmental *Research* 17 (4): 537–551. doi:10.1080/13504622.2010.545874

Fiebelkorn, F., and S. Menzel, S. 2013. “Student Teachers’ Understanding of the Terminology, Distribution, and Loss of Biodiversity: Perspectives from a Biodiversity Hotspot and an Industrialized Country.” *Research in Science Education* 43 (4): 1593–1615. doi:10.1007/s11165-012-9323-0

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. doi:10.1080/00958964

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 S. Weaver and B. S. Klein, 143–157. Netherlands: Springer. doi:10.1007/978-90-481-9222-9_10

García, S. 2018. “La Biodiversidad. Una Reflexión Sobre el Contenido que se Debe Enseñar.” *Alambique* 94: 7–12.

Gayford, C. 2000. “Biodiversity Education: A teacher’s perspective.” *Environmental Education Research* 6 (4): 347–361. doi:10.1080/713664696

Grace, M. 2009. “Developing High Quality Decision-Making Discussions about Biological Conservation in a Normal Classroom Setting.” *International Journal of Science Education* 31 (4): 551–570. doi:10.1080/09500690701744595

Grace, M. M., and M. Ratcliffe. 2002. “The Science and Values That Young People Draw upon to Make Decisions about Biological Conservation Issues.”

International Journal of Science Education 24 (11): 1157–1169. doi:10.1080/09500690210134848

Hall, M. 2011. *Plants as Persons: A Philosophical Botany*. Albany: State University of New York Press.

Hancocks, D. 2007. “The Future and Ethics of Zoos.” Retrieved from http://www.zoocheck.com/wpcontent/uploads/2015/04/The-Future-and-Ethics-of-Zoos-Hancocks-07.pdf

Hartley, L. M., B. J. Wilke, J. W. Schramm, C. D’Avanzo, and C. W. Anderson. 2011. “College Students’ Understanding of the Carbon Cycle: Contrasting Principle based and Informal Reasoning.” *BioScience* 61 (1): 65–75. doi:10.1525/bio.2011.61.1.12

Haslam, F., and D. F. Treagust. 1987. “Diagnosing Secondary Students’ Misconceptions of Photosynthesis and Respiration in Plants Using a Two-Tier Multiple Choice Instrument.” *Journal of Biological Education* 21 (3): 203–211. doi:10.1080/00219266.1987.9654897

Hershey, D. R. 1993. “Plant Neglect in Biology Education.” *BioScience* 43 (7): 418.

Hershey, D. R. 2005. “Plant Content in the National Science Education Standards.” Retrieved from https://eric.ed.gov/?id=ED501357

Hooper, D. U., E. C. Adair, B. J. Cardinale, J. E. K. Byrnes, B. A. Hungate, K. L. Matulich, A. Gonzalez, J. E. Duffy, L. Gamfeldt, and M. I. O’Connor. 2012. “A Global Synthesis Reveals Biodiversity Loss as a Major Driver of Ecosystem Change.” *Nature* 486 (7401): 105–108. doi:10.1038/nature11118

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. doi:10.1016/j.biocon.2019.108202

Hunter, L. M., and J. Brehm. 2003. “Qualitative Insight into Public Knowledge of, and Concern with, Biodiversity.” *Human Ecology* 31: 309–320. doi:10.1023/A:1023988914865

Isbell, F., V. Calcagno, A. Hector, J. Connolly, W. S. Harpole, P. B. Reich, M. Scherer-Lorenzen, et al. 2011. “High Plant Diversity is Needed to Maintain Ecosystem Services.” *Nature* 477 (7363): 199–202. doi:10.1038/nature10282

Jeronen, E., I. Palmberg, and E. Yli-Panula. 2016. “Teaching Methods in Biology Education and Sustainability Education Including Outdoor Education for Promoting Sustainability–A Literature Review.” *Education Sciences* 7 (1). doi:10.3390/educsci7010001

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

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

Kellert, S. R. 1993. “Attitudes, Knowledge, and Behaviour toward Wildlife among the Industrial Superpowers: United States, Japan, and Germany.” *Journal of Social Issues* 49 (1): 53–69. doi:10.1111/j.1540-4560.1993.tb00908.x

Kilinc, A., N. K. Yeşiltaş, T. Kartal, U. Demiral, and B. Eroğlu. 2013. “School Students’ Conceptions about Biodiversity Loss: Definitions, Reasons, Results and Solutions.” *Research in Science Education* 43 (6): 2277–2307. doi:10.1007/s11165-013-9355-0

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): 344–363. doi:10.1080/00219266.2017.1385506

Knapp, S. 2019. “Are Humans Really Blind to Plants?” *Plants, People, Planet* 1: 164–168. doi:10.1002/ppp3.36

Köse, S. 2008. “Diagnosing Student Misconceptions: Using Drawings as a Research Method.” *World Applied Sciences Journal* 3 (2): 283–293.

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. doi:10.1525/abt.2018.80.5.339

Levé, M., A. Colléony, P. Conversy, A.-C. Torres, M.-X. Truong, C. Vuillot, and A.-C. Prévot. 2019. “Convergences and Divergences in Understanding the Word

Biodiversity among Citizens: A French Case Study." *Biological Conservation* 236: 332–339. doi:10.1016/j.biocon.2019.05.021

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. doi:10.1080/09500690500038116

Lindemann-Matthies, P., and E. Bose. 2008. "How Many Species Are There? Public Understanding and Awareness of Biodiversity in Switzerland." *Human Ecology* 36 (5): 731–742. doi:10.1007/s10745-008-9194-1

Lindemann-Matthies, P., X. Junge, and D. Matthies. 2010. "The Influence of Plant Diversity on People's Perception and Aesthetic Appreciation of Grassland Vegetation." *Biological Conservation* 143 (1): 195–202. doi:10.1016/j.biocon.2009.10.003

Loidi, J., I. Biurrun, J. A. Campos, I. García-Mijangos, and M. Herrera. 2011. *La Vegetación de la Comunidad Autónoma del País Vasco. Leyenda del Mapa de Series de Vegetación a Escala 1:50.000.* Euskal Herriko Unibertsitatea.

Louv, R. 2005. *Last Child in the Woods: Saving our Children from Nature-Deficit Disorder*. Chapel Hill, NC: Algonquin Books of Chapel Hill.

Magntorn, O., and G. Helldén. 2005. "Student-Teachers' Ability to Read Nature: Reflections on Their Own Learning in Ecology." *International Journal of Science Education* 27 (10): 1229–1254. doi:10.1080/09500690500102706

Magntorn, O., and G. Helldén. 2007. "Reading Nature from a "Bottom-up" Perspective." *Journal of Biological Education* 41 (2): 68–75. doi:10.1080/00219266.2007.9656065

Marmaroti, P., and D. Galanopoulou. 2006. "Pupils' Understanding of Photosynthesis: A Questionnaire for the Simultaneous Assessment of All Aspects." *International Journal of Science Education* 28 (4): 383–403. doi:10.1080/09500690500277805

Marton, F. 1986. "Phenomenography: A Research Approach to Investigating Different Understandings of Reality." *Journal of Thought* 21 (3): 28–49. doi:10.2307/42589189

Marton, F. 2015. *Necessary Conditions of Learning*. New York, NY: Routledge.

Marton, F., and S. Booth. 1997. *Learning and awareness*. Mahwah, NJ: Lawrence Erlbaum.

Menzel, S., and S. Bögeholz. 2009. "The Loss of Biodiversity as a Challenge for Sustainable Development: How Do Pupils in Chile and Germany Perceive Resource Dilemmas?" *Research in Science Education* 39: 429–447. doi:10.1007/s11165-008-9087-8

Métioui, A., F. Matoussi, and L. Trudel. 2015. "The Teaching of Photosynthesis in Secondary School: A History of the Science Approach." *Journal of Biological Education* 50 (3): 275–289. doi:10.1080/00219266.2015.1085427

Miller, J. R. 2005. "Biodiversity Conservation and the Extinction of Experience." *Trends in Ecology & Evolution* 20 (8): 430–434. doi:10.1016/j.tree.2005.05.013

Moss, A., E. Jensen, and M. Gusset. 2016. "Probing the Link between Biodiversity-Related Knowledge and Self-Reported Proconservation Behavior in a Global Survey of Zoo Visitors." *Conservation Letters* 10 (1): 33–40. doi:10.1111/conl.12233

Nyberg, E., I. Brkovic, and D. Sanders. 2019. "Beauty, Memories and Symbolic Meaning: Swedish Student Teachers Views of Their Favourite Plant and Animal." *Journal of Biological Education* 1. doi:10.1080/00219266.2019.1643761

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. doi:10.1016/j.gloenvcha.2017.09.009

Palmberg, I., I. Berg, E. Jeronen, S. Kärkkäinen, P. Norrgård-Sillanpää, C. Persson, R. Vilkonis, and E. Yli-Panula. 2015. "Nordic-Baltic Student Teachers' Identification of and Interest in Plant and Animal Species: The Importance of Species Identification and Biodiversity for Sustainable Development." *Journal of Science Teacher Education* 26 (6): 549–571. doi:10.1007/s10972-015-9438-z

Palmberg, I., M. Hofman-Bergholm, E. Jeronen, and E. Yli-Panula. 2017. "Systems Thinking for Understanding Sustainability? Nordic Student Teachers' Views on the Relationship between Species Identification, Biodiversity and Sustainable Development." *Education Sciences* 7 (3). doi:10.3390/edusci7030072

Palmberg, I., S. Kärkkäinen, E. Jeronen, E. Yli-Panula, and C. Persson. 2019. “Nordic Student Teachers’ Views on the Most Efficient Teaching and Learning Methods for Species and Species Identification.” *Sustainability* 11 (19): 5231. doi:10.3390/su11195231

Pany, P., and C. Heidinger. 2017. “Useful Plants as Potential Flagship Species to Counteract Plant Blindness.” In *Cognitive and Affective Aspects in Science Education Research. Contributions from Science Education Research 3*, edited by K. Hahl, K. Juuti, J. Lampiselkä, A. Uitto and J. Lavonen, 127–140. Cham: Springer. doi:10.1007/978-3-319-58685-4_10

Pany, P., A. Lörnitzo, L. Auleitner, C. Heidinger, P. Lampert, and M. Kiehn. 2019. “Using Students’ Interest in Useful Plants to Encourage Plant Vision in the Classroom”. *Plants, People, Planet* 1: 261–270. doi:10.1002/ppp3.43

Parsa, V. A., E. Salehi, A. R. Yavari, and P. M. van Bodegom. 2019. “Evaluating the Potential Contribution of Urban Ecosystem Service to Climate Change Mitigation.” *Urban Ecosystems* 22: 989–1006. doi:10.1007/s11252-019-00870-w

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

Patrick, P., and S. D. 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: 630–642. doi:10.1007/s10956-011-9290-7

Pérez-López, R., M. Eugenio-Gozalbo, D. Zuazagoitia, and A. Ruiz-González. 2020. “Organic Learning Gardens in Higher Education: Do They Improve Kindergarten Pre-service Teachers’ Connectedness to and Conception of Nature?” *Frontiers in Psychology* 11: 282. doi:10.3389/tpsyg.2020.00282

Pitman, S. D., C. B. Daniels, and P. C. Sutton. 2017. “Ecological Literacy and Psychographics: Lifestyle Contributors to Ecological Knowledge and Understanding.” *International Journal of Sustainable Development & World Ecology* 25 (2): 117–130. doi:10.1080/13504509.2017.1333047

Puk, T. G., and A. Stibbards. 2012. “A Systemic Ecological Illiteracy? Shedding Light on Meaning as an Act of Thought in Higher Learning.” *Environmental Education Research* 18 (3): 353–373. doi:10.1080/13504622.2011.622840

Punch, K. F. 2005. *Introduction to social research: Quantitative and qualitative approaches.* London: SAGE.

Quinn, F., J. Castéra, and P. Clément. 2015. "Teachers' Conceptions of the Environment: Anthropocentrism, Non-anthropocentrism, Anthropomorphism and the Place of Nature." *Environmental Education Research*. doi:10.1080/13504622.2015.1076767

R Core Team. 2019. *R: A Language and Environment for Statistical Computing (R-3.6.3)*. R foundation for statsitical computing, Vienna, Austria.

Randler, C. 2008. "Teaching Species Identification - A Prerequisite for Learning Biodiversity and Understanding Ecology." *Eurasia Journal of Mathematics, Science & Technology Education* 4 (3): 223–231.

Randler, C., and F. X. Bogner. 2006. "Cognitive Achievements in Identification Skills." *Journal of Biological Education* 40: 161–165. doi:10.1080/00219266.2006.9656038

Sanders, D. L. 2019. "Standing in the shadows of plants." Plants, People, Planet 1 (3): 130–138. doi: 10.1002/ppp3.10059

Schneiderhan-Opel, J., and F. X. Bogner. 2019. "Between Environmental Utilization and Protection: Adolescent Conceptions of Biodiversity." *Sustainability* 11: 4517. doi:10.3390/su11174517

Schneiderhan-Opel, J., and F. X. Bogner. 2020. "FutureForest: Promoting Biodiversity Literacy by Implementing Citizen Science in the Classroom." *The American Biology Teacher* 82 (4): 234–240. doi:10.1525/abt.2020.82.4.234

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): 122–119. doi:10.1080/00219266.2008.9656123

Selvi, M., and E. Çelepçikay Islam. 2021. "The Predictors of Ninth Grade Students' Attitudes Towards Plants." *Journal of Baltic Science Education* 20(1): 108–118. doi: 10.33225/jbse/21.20.108

Serpell, J. 1999. "Guest Editor's Introduction: Animals in Children's Lives." *Society & Animals* 7 (2): 87–94. doi:10.1163/156853099x00013

Sharma, A., and C. Buxton. 2018. "The Received Curriculum: Nature as Understood by Students." In *The Natural World and Science Education in the United States*, edited by A. Sharma and C. Buxtons, 149–167. London: Palgrave Macmillan. doi:10.1007/978-3-319-76186-2_6

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.

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*. doi:10.1080/09500693.2019.1710782

Small, N., M. Munday, and I. Durance. 2017. "The Challenge of Valuing Ecosystem Services That Have No Material Benefits." *Global Environmental Change* 44: 57–67. doi:10.1016/j.gloenvha.2017.03.005

Soga, M., and K. J. Gaston. 2016. "Extinction of Experience: The Loss of Human-Nature Interactions." *Frontiers in Ecology and the Environment* 14 (2): 94–101. doi:10.1002/fee.1225

Stavy, R., Y. Eisen, and D. Yaakobi. 1987. "How Students Aged 13-15 Understand Photosynthesis." *International Journal of Science Education* 9 (1): 105–115. doi:10.1080/0950069870090111

Steg, L., and C. Vlek. 2009. "Encouraging Pro-Environmental Behaviour: An Integrative Review and Research Agenda." *Journal of Environmental Psychology* 29 (3): 309–317. doi:10.1016/j.jenvp.2008.10.004

Suárez, M. L., and M. R. V.-A. Gutiérrez. 2017. "Biodiversity, Ecosystem Services and Teaching: Do Our Students Understand How the Functioning of Ecosystems Contributes to Human Well-Being?" *Limnetica* 36 (2): 479–490. doi:10.23818/limn.36.16

Taylor, Z. P., and Bennett, D. E. 2016. "Ecosystem Services Valuation as an Opportunity for Inquiry Learning." *Journal of Geoscience Education* 64 (3): 175–182. doi:10.5408/15-138.1

Thomas, H., H. Ougham, and D. Sanders. "Plant Blindness and Sustainability". *International Journal of Sustainability in Higher Education*. doi: 10.1108/IJSHE-09-2020-0335

Thorn, C. J., K. Bissinger, S. Thorn, and F. X. Bogner. 2016. “"Trees Live on Soil and Sunshine!"-Coexistence of Scientific and Alternative Conception of Tree Assimilation.” *PLOS ONE* 11 (1): e0147802. doi:10.1371/journal.pone.0147802

Torkar, G. 2016. “Secondary School Students’ Environmental Concerns and Attitudes Toward Forest Ecosystem Services: Implications for Biodiversity Education.” International Journal of Environmental & Science Education 11 (18): 11019–11031.

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

Wandersee, J. H. 1983. “Student Misconceptions about Photosynthesis: A Cross-Age Study.” In *Proceedings of the International Seminar: Misconception in Science and Mathematics*, edited by H. Helm and J. D. Novak, 441–466. Ithaca, NY: Cornell University Press.

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

Wandersee, J. H., and E. E. Schussler. 1999. “Preventing Plant Blindness.” *The American Biology Teacher* 61 (2): 82–86. doi:10.2307/4450624

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

Washington, H., B. Taylor, H. Kopnina, P. Cryer, and J. J. Piccolo. 2017. “Why ecocentrism is the key pathway to sustainability.” *The Ecological Citizen* 1: 35–41.

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). doi:10.1128/jmbe.v18i1.1253

Yli-Panula, E., E. Jeronen, P. Lemmetty, and A. Pauna. 2018. “Teaching Methods in Biology Promoting Biodiversity Education.” *Sustainability* 10: 3812. doi:10.3390/su10103812

Yli-Panula, E., and E. Matikainen. 2014. “Students and Student Teachers’ Ability to Name Animals in Ecosystems: A Perspective of Animal Knowledge and Biodiversity.” *Journal of Baltic Science Education* 13 (4): 559–572.

Yücel, E. O., and M. Özkan. 2015. “Determination of Secondary School Students Cognitive Structure, and Misconception in Ecological Concepts through Word Association Test.” *Educational Research and Reviews* 10 (5): 660–674. doi:10.5897/err2014.2022

Appendix 1

Questionnaire on biodiversity and plant blindness. The section titles and scope/justification of each question is provided but this information was not given to the students:

General information (Q1-Q3)

Q1-How old are you? _________________

Q2-What is your gender identity?

☐ Female.
☐ Male.
☐ Non-binary.

Q3-In what educational level are you?

☐ Year 8.
☐ Year 11.
☐ Year 12.

Contact with, information sources and self-perceived knowledge about nature and biodiversity (Q4-Q6)

Q4-How often do you visit natural environments (e.g. trips to mountains, rivers, lakes…)?

☐ Very rarely (< than 5 times a year).
☐ Rarely (around 5-7 times a year).
☐ Occasionally (around 8-10 times a year.
☐ Frequently (1-2 times a month).
☐ Very frequently (> once a week).

<u>*Scope/justification of the question:*</u> *Estimation of the students' contact with nature.*

Q5-What would you say is your knowledge about the concept "biodiversity"?

☐ I have never heard of it.

☐ I do not fully understand it but I have heard it.
☐ I know something.
☐ I know and comprehend it pretty well.
☐ I fully understand it and I would be able to explain it to a friend.

*<u>*Scope/justification of the question:</u> Analysis of students' self-perceived knowledge regarding biodiversity.*

Q6-What are your main information sources regarding nature and biodiversity? (Choose the three most important from this list)

☐ School.
☐ Family.
☐ Media.
☐ Zoos, museums, aquariums…
☐ Natural environments (mountains, natural parks…).
☐ Everyday environment (parks in my city/town, streets, gardens…).
☐ Classmates.
☐ Other: ____________________________________

*<u>*Scope/justification of the question:</u> Analysis of students' main information sources regarding nature to observe their perception regarding the importance of different cultural agents as well as direct and indirect experiences with nature.*

Q6.1-If you chose school, which information source is the most important among these?

☐ Teachers.
☐ Textbooks.
☐ Field trips.
☐ Classroom activities.
☐ Other: ____________________________________

Q6.2-If you chose media, which information source is the most important among these?

☐ TV.
☐ Radio.
☐ Newspapers.
☐ Specialised magazines and journals (about animals, nature…).
☐ The Internet.
☐ Social media (Instagram, Twitter…).
☐ Other: ____________________________________

Interest in biodiversity and plants and animals (Q7-Q8)

Q7-How would you define your interest in nature and biodiversity related topics?

☐ Very low.
☐ Low.
☐ Moderate.
☐ High.
☐ Very high.

*<u>*Scope/justification of the question:</u> Assessment of students' interest in nature and biodiversity.*

Q8-Do you have interest in the plants and/or animals of the Basque Country?

☐ Animals.
☐ Plants.
☐ Animal and Plants.
☐ Neither plants nor animals.

*<u>*Scope/justification of the question:</u> Analysis of students´ preferences towards native plants and/or animals.*

Knowledge about biodiversity and its importance (Q9-Q10)

Q9-Define in your own words what biodiversity is.

____

Q10-Do you think it is important? Try to justify why biodiversity is important.

____

*<u>*Scope/justification of the question:</u> Assessment of students' conceptual knowledge regarding the term biodiversity and its importance.*

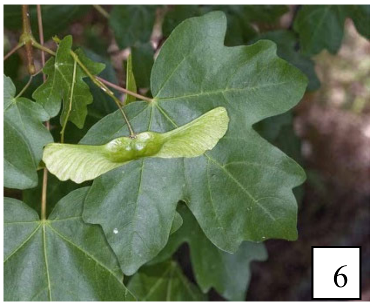
Species listing, sighting and identification skills (Q11-Q13)

Q11-List 10 animals and 10 plants of your choice in any language.

____

*<u>*Scope/justification of the question:</u> Analysis of students' species listing ability, including the taxonomy, origin, biome, domesticity, etc. of the species listed as well as comparison between animal versus plant listing abilities.*

Q12-Name the species shown in the photos (1-10).



*<u>*Scope/justification of the question:</u> Assessment of common local plant species´ identification skills and knowledge of native species.*

Q13-Have you ever seen any of these in their natural environment? List the ones you have seen.

____

<u>*Scope/justification of the question:*</u> *Analysis of students' ability to recall and recognise local plant species even if they are not able to name it.*

Knowledge about plant physiology and ecosystem services provided (Q14-Q17)

Q14-What is the source of plants' biomass?

☐ Soil.
☐ Atmosphere.

Explain your answer:

____

<u>*Scope/justification of the question:*</u> *Assessment of students' knowledge of plant nutrition due to the importance that comprehending plants' biomass comes from the inorganic CO_2 in the atmosphere has in the correct conceptualisation of plant nutrition and photosynthesis.*

Q15-Complete the sentence: *In order to grow plants need the .... they absorb from the soil, the .... they get from the atmosphere, and the ...... which they synthesise.*

☐ Minerals and water / O_2 and CO_2 / food.
☐ Food and water / CO_2 / O_2.
☐ Water / CO_2 / food and O_2.
☐ Minerals / O_2 / food.

<u>*Scope/justification of the question:*</u> *Assessment of students' knowledge of plant nutrition and their conceptions on the role that soil has in plant nutrition particularly.*

Q16-When does photosynthesis take place?

☐ At night.
☐ In the day.
☐ Constantly.
☐ Never.

<u>*Scope/justification of the question:*</u> *Analysis of students' knowledge of C3 photosynthesis as expected from the curricular learning outcomes.*

Q17-When does respiration take place?

☐ At night.
☐ In the day.
☐ Constantly.
☐ Never.

<u>*Scope/justification of the question:*</u> *Analysis of students' knowledge of C3 plants respiration as expected from the curricular learning outcomes.*

Q18- At what height will a nail be if it was nailed at 1 m when the tree was young (2 m high) and the tree now is 20 m?

☐ 19 m.
☐ 1 m.
☐ 20 m.

Explain your answer:

____

<u>*Scope/justification of the question:*</u> *Analysis of students' knowledge of plant growth and their conceptualisation of how plant tissues divide and grow.*

Q19-Which of these functions can plants carry out from an anthropocentric point of view?

☐ They can supply oxygen.
☐ They can prevent soil erosion.
☐ They can be used as fuel to make energy.
☐ They can be used in medicine and pharmacology.
☐ They can mitigate climate change.
☐ They can serve as food.
☐ They can reduce pollution.

<u>*Scope/justification of the question:*</u> *Assessment of students' ability to identify plant-provided ecosystems services and, consequently, the importance of plants.*

Appendix 2

Regarding the conceptions of the term biodiversity (BioC), leaving aside the D category in which students explicitly answered that the term was unknown to them or left it unanswered, in the first and simplest conception (C) students considered biodiversity to be a study subject (‘it is kind of a science that studies plants and animals’) or a form of knowledge (‘it is the classification of plants and animals’) related to biological elements.

The next conceptions (B-A), however, were qualitatively different since biodiversity is understood as a biophysical entity. The B2 and B1 conceptions encapsulate a view of biodiversity in which the phenomenon is comprehended as a biophysical quantitative element. This way, the differences between the less informed conception (B2) and the more accurate one (B1) is that students with the B2 conceptualisation described biodiversity as a physical ‘place in which plants and animals live’ or ‘an environment formed by the living and non-living organisms’, while the B1 conception focuses on the biological elements. Hence, conception B1 understands biodiversity as a group of biological elements (e.g. plants, animals, living organisms…) with definitions such as ‘all the living organisms living on Earth’ and ‘the plants and animals living on a place’.

Finally, the most informed group of conceptions (A) depicted the view of an abstract or qualitative concept of the term biodiversity. The simpler conception of the two (A2) describes biodiversity as the variety of living things explicitly mentioning the ‘variability’, ‘differences’ and ‘diversity’ of species and living organisms (e.g. ‘the variability of life in an ecosystem’, ‘the diversity or group of different species in the world’…). Besides, the most complex conception (A1) also includes other elements such as ‘the genetic differences’ and ‘the different ecosystems’ along with the aforementioned diversity of living organisms, thereby presenting a wider and more global understanding of biodiversity.

Similarly, with regard to the importance of biodiversity (BioIC) without taking into account the D category in which students did not know how to justify this importance, the first conception (C) encompasses a view in which the diversity of biological elements is intrinsically good for nature without any further explanation (e.g. ‘it is important to have different animals’ and ‘it is good to have many species of animals and many animals’).

The next group of conceptions (B) are aligned to the belief that biodiversity is important for the mere reason of it influencing and directly affecting humankind, which shows an anthropocentric viewpoint. The B2 conception differs from the B1 because, even though both hold anthropocentric values, the less informed one (B2) encompasses an inherent wellness similar to the one explained in the previous category with the difference that this explicitly mentions that there is a human-nature interaction in which humans should protect biodiversity since ‘we live here’ and ‘it is our obligation to take care of the different plants and animals because they are indispensable’. The B1 conception, instead, justifies the importance of biodiversity by appealing to the direct relationship and interdependence between humans and all other living things. Thus, biodiversity is understood as being important because the survival of humankind depends on it (‘it is the source of everything we have: medicine, food’ and ‘we live thanks to it’), it provides us goods and services (‘animals give us pillows and plants oxygen’), or at least it is useful for purposes that benefit humans (‘biodiversity allows us to understand our planet and use it appropriately’).

Finally, the most informed conception is embraced in A. This conception broadens the previously mentioned interdependence between humans and nature to the interactions between all the different elements of living systems. Thus, it presents a systemic or holistic viewpoint by which the correct functioning of natural systems is affected and dependent on biodiversity and the complex relationships between its different elements. Some examples of statements categorised in this conception are ‘it is important because every species influences the ecosystem’ and ‘each animal, plant, bacteria… carries out some function’.

Tables and table captions

Table 1. Characteristics of the studied sample and school curriculum specifications regarding biodiversity and plant biology in compulsory education (Decree 236/2015, 22nd December) and baccalaureate (Decree 127/2016, 6th September).

	Educational level	Age	Sample size (n)	Male / Female	Specific contents	Learning outcomes
First year of secondary education (FirstSE)	Year 8	12-13	28	0.47	Biodiversity on planet Earth: Life functions (e.g. plant nutrition), classification of living organisms and biodiversity	Explains the autotrophic nutrition in detail. Identifies the main species of the Basque Country. Realises of what biodiversity is and how important is its conservation.
Final years of secondary education (FinalSE)	Year 11	15-16	11	1.2	Origin of life and evolution Ecology and environment: Ecosystem structure and dynamics	Realises how important biodiversity is for ecosystem functioning. Understands the flow of matter and energy in ecosystems (e.g. the importance of plants as primary producers).
	Year 12	16-17	24	2	Living organisms and their organisation Biodiversity: Classification of the main groups and diversity Plants: Functions and environmental adaptations	Recognises plants as complex systems understanding their morphology, physiology and their importance in ecosystems in detail. Interprets the concept of biodiversity and justifies its importance for the stability of the biosphere.

Table 2. Content of the questionnaire items, type of question and bibliographic reference.

Number	Description	Type	Reference (*modified from)
General information (Q1-Q3)			
Q1	Age	Open-ended	-
Q2	Gender (G)	Single choice	-
Q3	Educational level (EL)	Single choice	-
Contact with, information sources and self-perceived knowledge about nature and biodiversity (Q4-Q6)			
Q4	Contact with nature (CN)	Likert	England marketing 2009*; Soga and Gaston 2016*
Q5	Biodiversity knowledge self-perception (BioKP)	Likert	Dor-Haim, Amir and Dodick 2011
Q6	Information sources regarding nature and biodiversity (InfS)	Multiple choice	Palmberg et al. 2015
Interest in biodiversity and plants and animals (Q7-Q8)			
Q7	Interest in nature and biodiversity (BioInt)	Likert	Palmberg et al. 2015
Q8	Interest in plants and animals (PAInt)	Single choice	Palmberg et al. 2015
Knowledge about biodiversity and its importance (Q9-Q10)			
Q9	Conception of biodiversity (BioC)	Open-ended	García 2018; Kilinc et al. 2013
Q10	Conception of biodiversity importance (BioIC)	Open-ended	Kilinc et al. 2013*
Species listing, sighting and identification skills (Q11-Q13)			
Q11	Plant and animal species listing ability (SpL)	Open-ended	Díez et al. 2018; Patrick and Tunnicliffe 2011
Q12	Common plant species identification skills (PIdS)	Open-ended	Díez et al. 2018*; Kaasinen 2019*; Palmberg et al. 2015*
Q13	Common plant species sightings in their natural environment (PSigh)	Open-ended	Almeida, Fernández and Strecht-Ribeiro 2018*
Knowledge about plant physiology and ecosystem services provided (Q14-Q17)			
Q14	Biomass source	Two-tier (Single choice and open-ended)	This study
Q15	Plant nutrition	Single choice	This study
Q16	Photosynthesis	Single choice	Marmaroti and Galanopoulou 2006
Q17	Plant respiration	Single choice	Marmaroti and Galanopoulou 2006
Q18	Plant growth	Two-tier (Single choice and open-ended)	This study
Q19	Plant ecosystem services (PEcoS)	Multiple choice	Dor-Haim, Amir and Dodick 2011*; Fančovičová and Prokop 2010*

Table 3. Categories of students' conceptions of the term biodiversity and its importance unveiled by the phenomenographic analysis.

	Category	Definition	Anchor example
Q9-Definition of biodiversity (BioC) (Cohen's Kappa = .9)	A1-Biophysical qualitative complex	Biodiversity is defined as the diversity of living things as well as of other elements such as genes, species and/or ecosystems.	'In my opinion biodiversity is the diversity of species and ecosystems we have on our planet.'
	A2-Biophysical qualitative simple	Biodiversity is acknowledged as the diversity of living things.	'The plant and animal species diversity of a certain place.'
	B1-Biophysical quantitative – Biological elements	Biodiversity is defined as the biological elements (biota) in a physical place.	'The living organisms of a place.'
	B2-Biophysical quantitative – Physical place	Biodiversity is explicitly described as a physical place with biological elements in it.	'A place where different plants and animals live.'
	C-Epistemic	Biodiversity is understood as a form of knowledge, discipline or system of classification.	'In my opinion biodiversity is a form of knowledge about nature (plant, animals…).'
	D-No answer/Unknown	The answer explicitly expresses that biodiversity is an unknown concept or it is left unanswered.	-
Q10-Importance of biodiversity (BioIC) (Cohen's Kappa = .81)	A-Interdependence	Biodiversity is described as important because the stability of natural systems and consequently life on Earth is dependent on the complex relationships and processes different living organisms take part in.	'Yes, the waste products of different organisms are beneficial to other living organisms. However, if biodiversity changed ecosystems would totally change.'
	B1-Anthropocentric – Utilitarian	Biodiversity is defined as important because from an explicitly anthropocentric view it allows the humankind to survive or it is somehow useful for humans.	'Yes, it is very important. In fact, we are able to eat, drink, dress and look at landscapes thanks to biodiversity.'
	B2-Anthropocentric – Preservation	Biodiversity is identified as important and explicitly explained that we have to protect it because it is our obligation.	'Yes, every species living on Earth has to be protected as the planet is not ours.'
	C-Intrinsic	Biodiversity is believed to be inherently good to nature.	'Yes, I find it important. Because it is very good to have many animal species and many animals on Earth.'
	D-No answer/Unjustified	The answer does not justify the importance of biodiversity or it is left unanswered.	-

Table 4. Answers to the questions about plant physiology (PPhyK; Q14-Q18). Correct answers in bold. Abbreviations as in Figure 1.

Question	Response	Educational level	
		FirstSE (%)	FinalSE (%)
Q14-What is the source of plants' biomass?	Soil	79	71
	Atmosphere	21	29
Q15-In order to grow plants need the .... they absorb from the soil, the .... they get from the atmosphere, and the ...... which they synthesise.	**Minerals and water / O_2 and CO_2 / food**	25	66
	Food and water / CO_2 / O_2	43	14
	Water / CO_2 / food and O_2	11	14
	Minerals / O_2 / food	21	6
Q16-When does photosynthesis take place?	At night	7	3
	In the day	68	89
	Constantly	25	9
	Never	-	-
Q17-When does respiration take place?	At night	39	17
	In the day	18	11
	Constantly	36	69
	Never	7	3
Q18-At what height will a nail be if it was nailed at 1 m when the tree was young (2 m high) and the tree now is 20 m?	19 m	71	37
	1 m	18	57
	20 m	11	6

Figure captions

Figure 1. Students' responses (%) to the Likert-type questions about their contact with nature (CN; Q4), self-perceived knowledge (BioKP; Q5) and interest in nature and biodiversity (BioInt; Q7). Abbreviations: FirstSE, first year of secondary education; FinalSE, final years of secondary education.

Figure 2. Students' responses (%) regarding: A) interest in plants and animals (PAInt; Q7); B) information sources regarding nature and biodiversity (InfS; Q6); C) taxonomic groups of the listed animals (Q11); D) listed plants (Q11) according to their origin, most common use and what they bear; E) correct identifications of the ten most abundant plant species (PIdS; Q12); and F) services plants provide to humans (Q19; PEcoS). Abbreviations as in Figure 1.

Figure 3. Categories and frequencies (%) of the main conceptions regarding: A) the term biodiversity (BioC; Q9); and B) the importance of biodiversity (BioIC; Q10) unveiled by means of phenomenographic analyses. Abbreviations as in Figure 1.

Figure 4. Matrix showing the Spearman's coefficient ($r_s(63)$) of only the significant ($p < .01$) correlations. Gradient intensity shows higher correlation coefficient values, and green and grey colours stand for positivity and negativity, respectively.