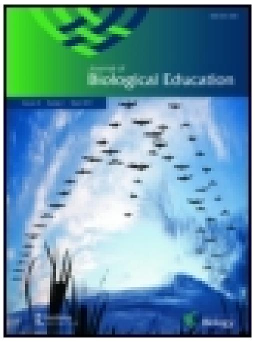

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Measuring Students' Plant Awareness: A Prerequisite for Effective Botany Education

Peter Pany[a,b], Florian D. Meier[c], Benno Dünser[a], Takuya Yanagida[d], Michael Kiehn[a,c] and Andrea Möller[a]

[a]Austrian Educational Competence Centre for Biology – AECCbio, University of Vienna, Vienna, Austria; [b]Department of Education in Secondary Schools, University College of Teacher Education Vienna, Vienna, Austria; [c]Core Facility Botanical Garden, University of Vienna, Vienna, Austria; [d]Department of Developmental and Educational Psychology, University of Vienna, Vienna, Austria

ABSTRACT

The term 'Plant Blindness' describes people tending to overlook plants, even though they have an enormous importance for life on earth, especially because of their ability to photosynthesise. Many attempts have been made to counteract plant blindness in biology education. However, so far there is no comprehensive tool to assess the degree of plant awareness (instead of plant blindness) in students. Here, plant awareness is conceptualised in four domains: (1) visual perception of plants, (2) categorising plants as living organisms, (3) knowledge about plants, and (4) attitudes towards plants. We present results from the two developed scales 'Plants as living organisms' and 'Knowledge about plants'. To test the new scales, 345 Austrian secondary school students took part in a questionnaire study. A confirmatory factor analysis indicates sufficient model fit. Results show that students consider plants as 'less alive' than animals but 'more alive' than bacteria. Those who attribute the characteristics of life to plants have more knowledge about plants, indicating that both domains of plant awareness might have a common basis. The development of a plant awareness questionnaire will eventually provide a powerful tool to investigate the effectiveness of learning environments fostering plant awareness, a prerequisite to reach the sustainable development goals.

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Plant blindness; plant awareness disparity; plant awareness; assessment tool; questionnaire

Introduction

Obstacles specific to botany education have been observed since the 1900s. Nichols (1919) described an underrepresentation of plants during laboratory time in biology classes at university, Monahan (1930) found a significant decrease of enrolments in high school botany courses. Dating back even further, Ganong (1906) criticised the simplification of botany and teaching methods in schools. Moreover, biology students at university as well as pupils often perceive Botany as an uninteresting subject (Elster 2007; Uno 2009). With the introduction of the term 'Plant Blindness', Wandersee and Schussler (2001) took a first step in addressing the underlying issue and started to tried to systematically search for find the roots of the observed mentioned obstacles.

CONTACT Peter Pany peter.pany@univie.ac.at

Plant blindness

The term 'Plant Blindness' was coined by Wandersee and Schussler (2001) describing the phenomenon that people tend to overlook plants in their everyday lives. Meanwhile many studies already confirmed a discrepancy in the recollection (Schussler and Olzak 2008; Schussler et al. 2010) and visual recognition (Balas and Momsen 2014; Zani and Low 2022) of plants compared to animals. At the same time, people tend to categorise plants as non-living organisms (e.g. Yorek, Şahin, and Aydın 2009; Amprazis, Papadopoulou, and Malandrakis 2021). Moreover, botanical knowledge, plant species, and their role in different essential cycles, are topics that are often underrepresented in the curriculum (Hershey 1992) and by extension in collective human knowledge.

As a reason for this phenomenon, researchers assume that plants are rather ignored because they have never actively attacked humans or their ancestors, and, therefore, during evolution, attention focused on animals that move or pose a threat to humans. Moreover, they tend to move only slowly (Attenborough 1995), have no eyes that can look at us (New, Cosmides, and Tooby 2007), and are often seen as less spectacular (Nyberg, Brkovic, and Sanders 2021). Interestingly, even botanical scientific research seems to be biased by plant blindness, as colours and morphological traits influence the choice of research subjects (Adamo et al. 2021).

In the past 20 years, research studies described many facets of Plant Blindness, among them the inability to recall plants from memory (Zani and Low 2022; Schussler and Olzak 2008), the decline of students' as well as teachers' ability to identify and name different plants (Borsos, Borić, and Patocskai 2021; Kaasinen 2019; Bebbington 2005; Frisch, Unwin, and Saunders 2010; Palmberg et al. 2015), as well as the inability to recognise plants on the way to school (Lindemann-Matthies 2006). Also, researchers reported the lack of or incorrect knowledge about the reproduction of plants (Lampert et al. 2020) as well as the lack of knowledge about the necessity of plants being pollinated through zoogamy (Christ and Dreesmann 2022). Therefore, plant blindness is a serious obstacle for studying biology since the role of plants is often ignored by both teachers and students (Hershey 1993).

The importance of knowing about plants

In order to tackle important future challenges like the climate crisis, it is essential that people know the role of plants in important biological processes, for example the carbon cycle (Dillon et al. 2006; Howard, Ougham, and Sanders 2022). However, most people are not aware what plants need to grow (Barman et al. 2006). They often think that plants take up their mass through their roots (Driver et al. 2014). Additionally, there is a misunderstanding about which substances are needed for photosynthesis (Marmaroti and Galanopoulou 2006). Therefore, most people do not understand the necessity of photosynthesis for plant growth (Messig and Groß 2018). Without this knowledge, it is impossible to understand the important function of trees (and woods) as carbon sinks.

Moreover, Ryplova and Pokorny (2020) found a lack of understanding regarding the impact of vegetation on its environment in form of natural cooling due to transpiration. Bofferding and Kloser (2015) described similar findings: less than ten percent of students were able to name possible steps to adapt to the climate crisis, with the help of plants, e.g. planting of trees. These relations between missing basic botanical knowledge and matters that impact humanity on the whole planet are amongst the most important reasons why educators should try to counteract plant blindness and enforce plant awareness.

Counteracting plant blindness

Many attempts have been made to counteract plant blindness by focusing on plants in formal and non-formal biology education. These interventions reach from the introduction of plants as essential for world nutrition (Drea 2011) to the use of specific plant species or groups that students find more interesting than others (Pany 2014). Borsos, Borić, and Patocskai (2021) successfully implicated gamification into the botany learning process. A huge emphasis lies in hands-on approaches through planting and caring for plants to form emotional connections (Strgar 2007; Krosnick, Baker, and Moore 2018; Stagg 2020).

Furthermore, out-of-school learning settings like botanical gardens often attempt to counteract plant blindness (e.g. Lindemann-Matthies 2006). Different studies found a positive impact on students' awareness of plants after visiting educational interventions in botanical gardens which enabled sensory exploration beyond the visual (Krishnan et al. 2019). Kissi and Dreesmann (2018) successfully used digital tools in extracurricular learning areas. Additionally, studying plants in the field improves identification skills (Borsos, Borić, and Patocskai 2021). Moreover, outdoor education not only boosts plant species knowledge, but also influences attitudes towards plants in a positive way (Fančovičová and Prokop 2011).

In addition, Lohr and Pearson-Mims (2005) confirmed that contact with nature in childhood has a positive influence on attitudes towards trees and enables emotional connections with them (Moormann, Lude, and Möller 2021; Gebhard 2001). This is remarkable because in environmental education living organism are commonly used to motivate learners for nature conservation but educators tend to less often emphasise plants (Balding and Williams 2016). This leads to less funding and insufficient protection of plants that are threatened by extinction (Roberson et al. 2020), even though extinction of plant species is at its highest level in human history (Nic Lughadha et al. 2020).

From plant blindness to plant awareness

The core definition of the term 'plant blindness' has not changed since Wandersee and Schussler (2001). Although this initial description of the phenomenon 'plant blindness' has without doubt been a very important step in research since it pointed to an important problem that subsequently has widely been investigated during the last two decades (e.g. Amprazis and Papadopoulou 2020; Mung and Williams 2016; Krosnick, Baker, and Moore 2018; Frisch, Unwin, and Saunders 2010; Zani and Low 2022; Allen 2003; Jose, Wu, and Kamoun 2019; Schussler and Olzak 2008), the construct starts to become obscure and difficult to navigate (Amprazis and Papadopoulou 2020). Therefore, it is necessary to clarify and update the definition of the term to enable a sound discussion about plant blindness.

Recently, Parsley (2020) enriched the discussion about plant blindness by proposing to change the term 'plant blindness' to 'plant awareness disparity' because of ableism. This suggestion has already been picked up by recent researchers (Parsley 2021; Laura and Dreesmann 2022; Brownlee, Parsley, and Sabel 2021). Though, since it is well investigated that language influences our thinking (e.g. Bloom and Keil 2001; Topping et al. 2004), the authors of this paper decided to go one step further and use the bright side of the medal to describe our research. Following recent scientific results (Ädel 2017; Harker, Dean, and Monsen 2017; Watts 2017; Olsen 2018), we want to use a solution-oriented way of thinking about the long-known problem of plant blindness.

Following the ideas of McDonough MacKenzie et al. (2019) we want to add a new impulse to the discussion by not only circling around the problem but focusing on a quality we want students to develop: plant awareness. Maybe this slightly changed point of view enables new attitudes for both scientists and educators alike, and frees them from a struggle against something but leads them to work in favour of something. Therefore, in the present paper we will neither use the terms 'plant blindness' nor 'plant awareness disparity' but 'plant awareness'. In case the term 'plant blindness' is inevitable in the future, we suggest simply considering it as 'lack of plant awareness'.

Evaluating the degree of plant awareness

Although much research has been done on the lack of plant awareness, there is still no comprehensive tool to assess the degree of plant awareness of an individual. Most of the few tools that were developed to identify an individual's degree of plant blindness tested only one or two of the manifold symptoms without clear differentiation (e.g. Batke, Dallimore, and Bostock 2020). Amprazis, Papadopoulou, and Malandrakis (2021) quantified (besides other aspects of plant blindness) how many interviewed students named one or more plants when told to write down five living organisms.

However, in order to develop effective lesson tools to enhance students' awareness of plants it is necessary to test the impact of many different educational interventions on someone's plant awareness. Therefore, the development of a questionnaire that enables researchers and teachers to quantify the degree of plant awareness is the aim of the present study Since recent studies show rather weak (though statistically significant) correlations between attitudes towards plants and other symptoms of low plant awareness (e.g. the number of plants students listed when asked for five living organisms [Amprazis, Papadopoulou, and Malandrakis 2021], knowledge about monocotyls [Kubiatko, Fančovičová, and Prokop 2021]), the main focus of our research lies in the question whether different aspects of plant awareness can be considered as separate components and in what way they may correlate with each other.

Materials and Methods

The paper presented describes the first steps of the construction of a questionnaire to successfully assess and quantify plant awareness. Based on the original definition (Wandersee and Schussler 2001) and following the ideas of Parsley (2020), who started first attempts to redefine the term 'plant awareness disparity' by sorting the possible symptoms into attention, knowledge, attitude, and interest, we reviewed recent literature and finally conceptualised plant awareness as consisting of four domains:

(1) visual perception of plants (e.g. Balas and Momsen 2014; Schussler and Olzak 2008; Zani and Low 2022)
(2) categorising plants as living organisms (e.g. Yorek, Şahin, and Aydın 2009; Ahi, Atasoy, and Balci 2018; Lindemann-Matthies 2005; Amprazis, Papadopoulou, and Malandrakis 2021)
(3) knowledge about plants (identification and plant biology) (e.g. Kaasinen 2019; Palmberg et al. 2015; Sanders et al. 2022; Anderson, Ellis, and Jones 2014; Barman et al. 2006)
(4) attitudes towards plants (e.g. Colon et al. 2020; Kubiatko, Fančovičová, and Prokop 2021; Fančovičová and Prokop 2010; Lohr and Pearson-Mims 2005)

These four domains (see Figure 1) may correlate with each other, since for example Amprazis, Papadopoulou, and Malandrakis (2021) or Kubiatko, Fančovičová, and Prokop (2021) found weak connections between different aspects of plant awareness.

As one domain of plant awareness, we consider the visual perception of plants, the initial main testimony of Wandersee and Schussler (2001). Only if people recognise plants and visually perceive individuals out of the 'green background', they can categorise them as living organisms. If people indeed see plants as living organisms, they may build up knowledge about plants (e.g. physiology, anatomy, and ecology) and learn to identify them. And, finally, if they gather knowledge about the diversity of plants and their manifold important roles in our environment, people may develop positive attitudes towards plants not only because they look or smell attractive. In this study we tested two parts of our assessment tool: the domain 'plants as living organisms' (in comparison to animals and bacteria) and three subscales of the domain 'knowledge about plants'.

After developing the single-choice-items of the two scales (see Tables 2 and 3) based on recent literature (e.g. Campbell et al. 2015; Cooper 2008; Tunnicliffe and Reiss 2000; Kaasinen 2019;

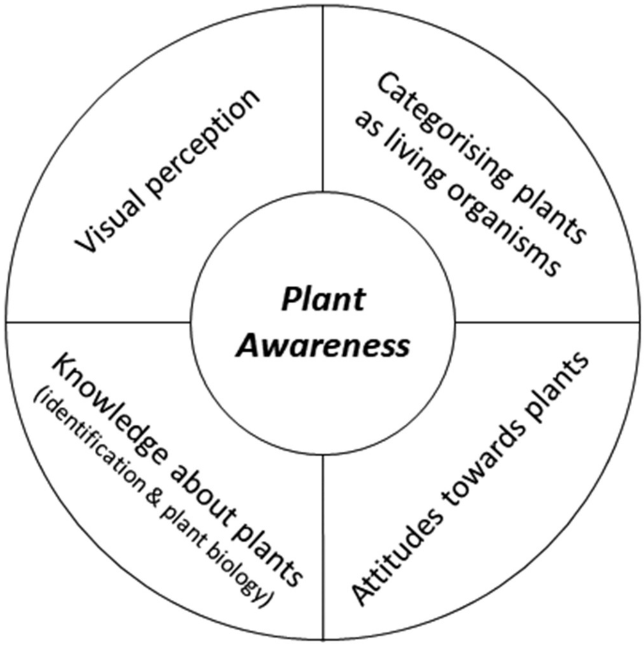

Figure 1. The four postulated domains of plant awareness.

Krüger and Burmester 2005; Amprazis, Papadopoulou, and Malandrakis 2021), the questionnaire was first administered to a group of 41 students who had the opportunity to comment on the items. If necessary, comments were used for item editing.

Participants

409 students from six different secondary schools in the eastern parts of Austria took part in a questionnaire study. 64 questionnaires had to be excluded due to missing answers or zig-zag-patterns. The final sample comprised 345 individuals (58.5% female) aged between 11 and 19 (M_{age} = 14.14 ± 2.36). Students stem from 18 school classes, 10 classes from lower secondary level (grade 5–8, M_{age} = 12.7, 56.6% female, 0.5% others), and 8 classes from upper secondary level (grade 9–12, M_{age} = 15.8, 61% female, 1.3% others).

The research team was guided by the 'Guidelines for Good Scientific Practice' (Austrian Agency for Research Integrity 2016). Prior to participation, students were informed about the aims of the research, duration, procedure, and anonymity of the data. In order to avoid students focusing on their plant awareness and therefore possibly influencing the data, they were only informed that the questionnaire is about plants and should help improve biology lessons. Participation was always voluntary, and only those students, who (or whose parents) gave consent to participate in the study, were included in the data analysis. Data was collected and analysed anonymously. Under Austrian law, approval by an ethics committee was not necessary as this study did not involve patients, was non-invasive, and participation was voluntary and anonymous.

Instruments

In both scales items are coded such that a higher value indicates higher plant awareness. For example, a high value in the subscale 'plants' in the scale 'plants as living organisms' shows that a test person attributes many characteristics of life to plants. 'Plant blindness' is therefore reflected by a low value in a (sub-)scale. The items of the scales as well as the used plant species are shown in Tables 1 and 2.

'Plants as living organisms' scale

The scale 'plants as living organisms' assesses to what degree students categorise plants as living organisms compared to animals and bacteria. For this purpose, students had to choose separately for each group of organisms (animals, plants, and bacteria) whether they show eight characteristics of life following Campbell et al. (2015) (see Table 1). Cronbach's α based on tetrachoric correlation matrices show high item reliabilities for the three subscales (.97 for the sub-scale 'animals', .91 for the sub-scale 'plants', and .87 for the subscale 'bacteria').

Table 1. Results of the Confirmatory Factor Analysis for the 'Plants as living organisms' scale: Unstandardised and standardised factor loadings. N = 345.

	Factors					
	Sub-scale Animals		Sub-scale Plants		Sub-scale Bacteria	
Item	Est.	Std. Est.	Est.	Std. Est.	Est.	Std. Est.
… consist of cells.	0.923	0.838	0.986	0.736	0.369	0.249
… can move.	1.075	0.976	0.619	0.462	1.299	0.875
… reproduce.	0.978	0.888	0.900	0.672	1.312	0.884
… grow	0.965	0.877	1.272	0.949	0.946	0.637
… subsist.	1.039	0.944	1.176	0.878	1.314	0.885
… are excitable	0.891	0.809	0.929	0.693	0.910	0.613
… can get sick.	1.033	0.938	0.893	0.667	0.747	0.503
… die.	1.094	0.994	1.225	0.914	1.103	0.743

Note. Est. = Unstandardised factor loading; Std. Est. = Standardised factor loadings; Effect coding method of factor identification (Little, Slegers, and Card 2006).

Table 2. Results of the Confirmatory Factor Analysis for the 'Knowledge bout plants' scale: Unstandardised and Standardised Factor Loadings. N = 345.

	Factors					
	Sub-scale Plant species identification		Sub-scale Identification of spice plants		Sub-scale Anatomy of edible plants	
Item	Est.	Std. Est.	Est.	Std. Est.	Est.	Std. Est.
Bellis perennis	1.285	0.662				
Taraxacum officinalis	0.864	0.446				
Quercus sp.	0.586	0.302				
Picea abies	0.843	0.435				
Calendula officinalis	1.422	0.733				
Thymus vulgaris			1.326	0.897		
Origanum majorana			1.271	0.860		
Origanum vulgare			1.214	0.822		
Ocimum basilicum			1.208	0.817		
Piper nigrum			0.592	0.401		
Petroselinum crispum			0.475	0.321		
Rosmarinus officinalis			0.914	0.618		
Lactuca sativa					0.592	0.362
Cucumis sativa					1.311	0.801
Malus sp.					1.154	0.705
Pisum sativum					1.303	0.796
Cucurbita pepo					1.349	0.824
Solanum melongena					1.341	0.819
Asparagus officinalis					0.559	0.341
Brassica oleracea var. *italica* (Broccoli)					0.391	0.239

Note. Est. = Unstandardised factor loading; Std. Est. = Standardised factor loadings; Effect coding method of factor identification (Little, Slegers, and Card 2006).

'Knowledge about plants' scale

The scale 'knowledge about plants' assesses basic knowledge about plants. For this purpose, we developed three sub-scales: 'plant species identification' (following Kaasinen 2019; Bebbington 2005), 'identification of spice plants' (following Pany et al. 2019) and 'anatomy of edible plants' (following Pany and Heidinger 2017) (see Table 2). We chose these three subscales for our first approach since their objects are close to students' everyday lives (Krüger and Burmester 2005; Tunnicliffe and Reiss 2000).

The subscale 'plant species identification' was tested by giving the students the name of a common Mid-European plant species (e. g. dandelion Taraxacum officinalis) and showing them four pictures of different plant species. Students had to choose which picture represents the plant species indicated by the name. In the subscale 'identification of spice plants' students either had to choose spice plants out of a list of different plant species or they were given a picture of a spice plant (rosemary and parsley). They then had to pick the correct name out of a list of eight plant species. The subscale 'anatomy of edible plants' showed pictures of edible plants and students had to choose from a list which part of the plant is commonly used for culinary purposes (e.g. 'fruit' for peas *Pisum sativum*). Cronbach's α based on tetrachoric correlation matrices show sufficient to high item reliabilities for the three subscales (.66 for the subscale 'plant species identification', .84 for the subscale 'identification of spice plants', and .83 for the subscale 'anatomy of useful plants').

Analytic Strategy

In order to investigate the factor structure of the 'plants as living organisms' scale and the 'knowledge about plants' scale, in a first step confirmatory factor analysis (CFA) (Brown 2015) for dichotomous indicator variables, using weighted least square mean- and variance- adjusted estimation method (WLSMV), was conducted in Mplus 8.6 (Muthén and Muthen 2017). CFA models were evaluated using the fit indices CFI, TLI, RMSEA, and SRMR based on common cut-off criteria (Kline 2016). Thereafter, weighted sum scores according to the factor loadings of the CFA model for the sub-scale animals, plants, and bacteria of the 'plants as living organisms' scale were computed and subsequently used in the analysis (DiStefano, Zhu, and Mindrila 2009).

In a second step, repeated measures analysis of variance (RM-ANOVA) was conducted in R 4.2.0 (R. Core-Team 2013) to test for mean differences between the sub-scales animals, plants, and bacteria of the 'plants as living organisms' scale to validate the subscales. Based on recent literature (Balas and Momsen 2014; Yorek, Şahin, and Aydın 2009; Lindemann□Matthies 2005), a significantly lower value for plants than for animals could be expected. In order to check whether other life forms also are seen as 'inferior' compared to animals, we included bacteria in a separate subscale. In the last step, we investigated whether students who see plants as rather 'lifeless' beings also have little knowledge

Table 3. Descriptive Statistics: Pearson's Product Moment Correlation Coefficients, Means and Standard Deviations for the 'plants as living organisms' scale and the 'knowledge about plants' scale. N = 345.

	Variable	1.	2.	3.	4.	5.	6.
'Plants as living organisms' scale	1. Animals						
	2. Plants	**0.54**					
	3. Bacteria	**0.41**	**0.47**				
'Knowledge about plants' scale	4. Plant species Identification	**0.14**	**0.19**	0.10			
	5. Identification of spice plants	**0.33**	**0.38**	**0.27**	**0.42**		
	6. Anatomy of edible plants	**0.14**	**0.19**	**0.19**	**0.35**	**0.38**	
	Mean	7.42	5.95	4.96	3.15	4.60	3.65
	Standard Deviation	1.37	2.02	2.24	1.12	1.90	2.54

Note. Statistically significant results at p < .05 are in boldface. Important correlation coefficients are highlighted in grey.

about plants. Consequently, correlation coefficients between the sub-scale 'plants' of the 'plants as living organisms' scale and the sub-scales of the 'knowledge about plants' scale were inspected.

Results

Confirmatory Factor Analysis for the 'plants as living organisms' scale

Results of the CFA showed an acceptable model fit ($\chi^2(241) = 273.44$, CFI = .992, TLI = 0.991, RMSEA = 0.020, SRMR = 0.082) with standardised factor loadings between 0.81 and 0.99 for the sub-scale 'animals', 0.46 to 0.95 for the sub-scale 'plants', and 0.25 and 0.89 for the sub-scale 'bacteria' (see Table 1).

Confirmatory Factor Analysis for the 'knowledge about plants' scale

Results of the CFA showed an acceptable model fit ($\chi^2(167) = 186.30$, CFI = .991, TLI = 0.989, RMSEA = 0.018, SRMR = 0.080) with standardised factor loadings between 0.30 and 0.73 for the sub-scale 'plant species identification', 0.32 and 0.90 for the sub-scale 'identification of spice plants', and 0.24 to 0.82 for the sub-scale 'anatomy of useful plants' (see Table 2).

Mean Differences in the 'plants as living organisms' scale

Results of the repeated-measures ANOVA showed a statistically significant main effect for the factor sub-scale, indicating mean differences between animals, plants, and bacteria, ($F(1.87, 688) = 259.81$, Huynh-Feldt adjusted $p < .001$). Post-hoc tests with Holm correction for multiple testing revealed statistically significant mean differences between animals and plants ($M_{animals} = 7.42 \pm 1.37$, $M_{plants} = 5.95 \pm 2.02$, $p < .001$, Cohen's $d = 0.85$) as well as animals and bacteria ($M_{animals} = 7.42 \pm 1.37$, $M_{bacteria} = 4.96 \pm 2.24$, $p < .001$, Cohen's $d = 1.37$). Moreover, post-hoc testing showed a statistically significant mean difference between plants and bacteria ($M_{plants} = 5.95 \pm 2.02$, $M_{bacteria} = 4.96 \pm 2.24$, $p < .001$, Cohen's $d = 0.45$) (see Table 3). Students attributed the characteristics of life to animals in 80.9% to 97.4% (see Table 4). None of the characteristics of life was attributed to plants to a similar extent (except for the characteristic 'plants grow'), indeed, the characteristic 'plants can move' was only attributed in about 27.5% of the cases. These results clearly show that plants are seen as 'less alive' than animals but 'more alive' than bacteria, although the difference between animals and plants is considerably larger than between plants and bacteria.

Correlation between the 'plants as living organisms' scale and the 'knowledge about plants' scale

Correlation coefficients for the 'plants as living organisms' scale and the 'knowledge about plants' scale are reported in Table 3. Results showed a statistically significant correlation between the sub-scale 'plants' of the 'plants as living organisms' scale and the sub-scales 'plant species identification'

Table 4. Frequencies (in percent) of the characteristics of life attributed to animals, plants, and bacteria. N = 345.

	Animals	Plants	Bacteria
… consist of cells	80.9	76	50.3
… can move	95.1	27.5	80.35
… reproduce	95.1	76.6	79.8
… grow	93.7	91.9	45.1
… subsist	96.24	81.2	71.4
… are excitable	84.1	78	40.2
… can get sick	96.8	51.7	19.1
… die	97.4	84.1	72

(r = 0.19, p < .001), ‘identification of spice plants’ (r = 0.19, p < .001), and ‘anatomy of edible plants’ (r = 0.38, p < .001). This analysis shows that those students who do not attribute the characteristics of life to plants have less knowledge about plants. It also indicates that both domains of plant awareness might have a common basis.

Discussion

The lack of plant awareness (also known as ‘plant blindness’ or ‘plant awareness disparity’) is a serious impediment for understanding the enormous importance of plants for life on this planet (especially because of their ability to carry out photosynthesis and thus being the basis of many food chains as well as acting as carbon sinks) and for developing an integrated view of nature. It is the reason for many problems students have in understanding and evaluating future challenges such as climate change or sustainability (Dillon et al. 2006; Wandersee and Schussler 2001; Roberson et al. 2020; Mung and Williams 2016; Howard, Ougham, and Sanders 2022). Therefore, it is key to find ways for educators to improve students’ awareness of plants.

Validity of the investigated scales

As has to be expected from recent literature (e.g. Yorek, Şahin, and Aydın 2009; Lindemann□Matthies 2005), our results also show that plants are seen as ‘less alive’ than animals, which gives a clue that the ‘plants as living organisms’ scale is well suitable for assessing whether students see plants as living beings. However, in contrast to previous studies where students were asked to write down five living things (e.g. Amprazis, Papadopoulou, and Malandrakis 2021), our results allow a deeper insight into which characteristics of life students rarely apply to plants. The apparent inability to move (like animals do) is one of the most important reasons that plants are seen as ‘less alive’ than animals. Moreover, our results go further by proving that plants are seen as ‘more alive’ than bacteria. This fits well into the idea that organisms that resemble humans are more easily considered ‘living beings’. What regrettably leaves a bitter taste is the fact that plants still are closer to bacteria than to animals.

The three subscales of the ‘knowledge about plants’ scale seem to be an appropriate approach to approximating students’ views on plants in their everyday lives. Whereas previous research only could prove rather weak correlations between different aspects of plant awareness (e.g. Amprazis, Papadopoulou, and Malandrakis 2021), the scales of both domains investigated in this study – ‘plants as living organisms’ and ‘knowledge about plants’ – do correlate (see Table 3). That means that students who do see plants as living beings have more knowledge about plants. This is a useful hint that both domains really have a common basis and can interact with each other. These results may encourage botany educators to further develop learning tools which may finally enable students to understand that plants are living organisms as well as animals.

The construct of plant awareness

Furthermore, these results strengthen the need for future research investigating whether other domains of plant awareness also correlate with each other. For that reason, it is important to better understand the construct plant awareness and its component parts. In contrast to previous research (Wandersee and Schussler 2001; Amprazis and Papadopoulou 2020; Batke, Dallimore, and Bostock 2020; Pedrera et al. 2021) the results of this study show for the first time, on a well-founded statistical basis, that plant awareness indeed consists of at least two different domains (see Tables 1 and 2) that seem to be interconnected. Previously, plant awareness was often assumed to be composed of different parts but without having empirical evidence for this idea. Hence, our data show that plant awareness should be conceptualised in different domains which now can be further explored. These different domains can be specifically addressed to foster plant awareness in formal and informal learning settings alike.

What is still an open field for prospective studies are the relations of the four postulated domains of plant awareness that may be organised in a hierarchical way. Probably, the most fundamental domain of plant awareness is the visual perception of plants, the starting point of Wandersee and Schussler (2001). Only if people visually perceive single plant individuals out of the 'green background', can plants then be categorised as living organisms. If people indeed see plants as living organisms, they may build up knowledge about plants (e.g. physiology, anatomy, and ecology) and learn to identify them. And, finally, if they construct knowledge about the diversity of plants, people may recognise their manifold important roles in our environment and finally develop positive attitudes towards plants which go beyond seeing their flowers as pretty.

To enlighten this possible structure of plant awareness, the investigation of the remaining domains of plant awareness (visual perception and attitudes) must be tackled. For this purpose, there is a need for a reliable and valid instrument with which educators can assess and quantify plant awareness in its four postulated domains. By comparing the correlation of all domains, the plant awareness construct would be the first actualisation of the plant blindness theory on a comprehensive empirical basis.

Assessing plant awareness

A tool that tests all domains of plant awareness can assess the degree of plant awareness in a certain population. This possibility opens a gate into, for example, long-term studies on the development of plant awareness with increasing age. Moreover, a plant awareness questionnaire opens the possibility to assess the effectiveness of educational interventions designed to foster plant awareness (and therefore counteract plant blindness).

Our finalised plant awareness questionnaire could also help enlighten multiple questions already (but not sufficiently) investigated. The correlations between age or gender and plant awareness are such topics that were explored by different scientists (e.g. Sher et al. 2015; Strgar 2007) with contradictory results. However, these studies mostly tested only one domain of plant awareness. The same is true for the degree of plant awareness in rural areas compared to urban environments (Amprazis, Papadopoulou, and Malandrakis 2021; Villarroel et al. 2018).

In a next step, the questionnaire opens a gateway into assessing plant awareness in class in a quite simple way. If different domains of plant awareness actually correlate, one could concentrate in class on the domains simplest to assess, but nevertheless educators will get an impression how plant aware their students are. Based on these results, educators could choose interventions that are tailored to their target group.

Enabling students to comprehend the importance of plants is an important goal of biology education. Ultimately, increased plant awareness is the prerequisite for increased plant knowledge and understanding of biological systems, which is necessary to reach important global goals, like the sustainable development goals (Howard, Ougham, and Sanders 2022). In conclusion, a detailed knowledge about the level of plant awareness is the prerequisite for effective botany education in schools, at university or within informal learning settings, like botanical gardens. By developing a plant awareness questionnaire, we aim to facilitate biology educators around the world in fostering their students' plant awareness.

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ORCID

Peter Pany http://orcid.org/0000-0001-7452-4411
Takuya Yanagida http://orcid.org/0000-0001-9052-4841
Michael Kiehn http://orcid.org/0000-0002-0095-0618
Andrea Möller http://orcid.org/0000-0002-2345-1299

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