Plants to the fore: Noticing plants in designed environments

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Societal Impact Statement
Educational experiences where the ecological and social significance of plants is the main focus are crucial tools to help us to overcome "plant blindness" and challenge "zoocentric" views. By examining how student teachers respond to two different educational environments; one where animals are in the foreground, and another where plants take center stage, we conclude that for plants to be noticed in animal-rich environments, they need to be prominent in the design of spaces with information about them displayed clearly. This work will help inform the design and creation of tools that will enhance and develop plant science education.

Summary
- Plants are not only essential for human health and well-being, but are fundamental to life on Earth. Despite their central importance in sustaining life on this planet, many humans do not notice plants to the same extent as they do animals, a phenomenon described as "plant blindness". Research indicates that multimodal and sensoric experiences might be significant tools for bringing about a shift away from plant blindness toward recognizing plants and their importance for life on Earth.
- This study seeks to explore the affordances of sensory-rich indoor environments in two different settings; one where living animals are in the foreground (a science center), and one where living plants are in the foreground (a greenhouse in a botanical garden). The participants in this study were elementary school student teachers. Data were collected through individual questionnaires that examined the student teachers’ experiences visiting the two sites.
- The student teachers’ answers are rich in aesthetic expressions, both regarding the animals and plants mentioned and regarding the environments studied. There is a dominance of animal references at the science center and a dominance of plant references from the botanical garden.
- In order for plants to be noticed in animal-rich environments, they need to be foregrounded in the design of spaces and information about them clearly exposed to human view.

KEYWORDS
aesthetics, affordances, botanic garden, experiences, plant blindness, science education, sensory-rich environments
1 | INTRODUCTION AND BACKGROUND

Given the critical role of plants in sustaining life on Earth (Galbraith, 2003; Knapp, 2019; Raven, 2019), it is vital to motivate teaching and learning that can move students beyond the state of “plant blindness” (Wandersee & Schussler, 1999) via educational experiences where the ecological and social significance of plants is in focus. Wandersee and Schussler (1999) summarized their theory of plant blindness as “the inability to see or notice the plants in one's own environment”.

More recently, Balding and Williams (2016) presented a review of research related to plant blindness in the context of the implications for plant conservation. In the period between the original publication of Wandersee and Schussler’s theory and Balding and William’s review, a substantial body of research work, in a range of disciplines, has contributed to diverse interpretations. Critically, for the current study, Balas and Momsen (2014) suggest that “whether plant blindness is normal and inevitable remains an open question; indeed, we might ask whether humans are blind to plants or simply more attentive to animals.” In addition, the argument put forward by Sanders (2019), that the apparent “slowness” of plants could be one reason for not noticing them, might also be a factor.

This mirrors much of the research work in educational science that concerns questions of preference for animals or plants (e.g., Wandersee, 1986; Kinchin, 1999); student responses to diverse plant education interventions (e.g., Lindemann-Mathies, 2005; Fančovičová, & Prokop, 2011; Nyberg & Sanders, 2014; Krosnick, Baker, & Moore, 2018; Pany et al., 2019); student reactions to specific plant displays in botanic gardens (e.g., Tunnicliffe, 2001; Sanders, 2007); considerations of plants in science curricula content (e.g., Hershey, 2002; Galbraith, 2003; Ebert-May & Holt, 2014); and the relatively few visual cognition studies concerned with plants (e.g., Schussler and Olzak, 2008; Balas & Momsen, 2014). Furthermore, a large body of educational research has concerned itself with the identification of plants and the perceived connections between knowledge of, and attitudes to, plants (e.g., Bebbington, 2005; Frisch, Unwin, & Saunders, 2010).

Multimodal approaches to teaching and learning science have been shown to be effective in engaging students (Ainsworth, Prain, & Tytler, 2011; Hartman, Lydon, & Rasmussen, 2019; Jewitt, Kress, Ogborn, & Tatsarelis, 2001). Furthermore, science teaching appears to benefit from varied language practices through the use of metaphors and analogies, stories and models (e.g., Jewitt et al., 2001; Matruglio, Maton, & Martin, 2013; Wilson & Mant, 2011). Likewise, it has been shown that emotions and aesthetic experiences are involved in science teaching and learning (e.g., Jakobson & Wickman, 2008) and sensoric experiences might enrich students’ experience of living organisms (Nyberg & Sanders, 2014). Various aesthetic plant characteristics, such as color, shape/size and smell, drew elementary students’ attention in botanic garden studies conducted by Tunnicliffe (2001) and Sanders (2004) respectively. Moreover, special characteristics, such as survival-relevant knowledge about the plants have also been demonstrated to be important to plant-based education (Pany, 2014; Prokop & Fančovičová, 2014, 2018).

In relation to varied environments Sanders (2007) for example, found that students’ reasons for liking visits to zoos were that the organisms in themselves drew the children’s attention, whereas at the botanic garden the reasons given for a positive experience related to the place, such as the activities they engaged in and “children’s feelings” while being there. Studies of aesthetic experiences in museums (Mangione, 2016) demonstrate that aesthetic practices vary depending on how artifacts are made accessible, and exemplify how botanical gardens rely on multisensory affordances. These findings imply that multimodal and sensoric experiences might be significant for bringing about a shift from plant blindness toward noticing plants and their importance for life on earth.

1.1 | Aim and research questions

This study examined the educational affordances of sensory-rich indoor environments. We undertook a survey of student teachers in two different settings; the first, a science center, that featured living animals in the foreground; the second, a greenhouse in a botanical garden, that featured living plants in the foreground (Figure 1a,b). We formulated the following open research questions to allow us to capture broad aspects of student teachers’ experiences.

a What do the student teachers observe?
b How do they describe their experiences?

The results presented here are part of a 3-year interdisciplinary research project, Beyond “Plant Blindness”: Seeing the importance of plants for a sustainable world, funded 2015–2017 by the Swedish Research Council (Dnr 2014–2013) in which we conducted a range of studies in diverse settings, not only targeting plants in themselves, but also how humans interact with their “plantness” (Darley, 1990).

2 | MATERIALS AND METHODS

The study took place in an enclosed rainforest setting at a science center, and in a greenhouse rainforest setting in a botanical garden in Gothenburg, the second largest city in Sweden. These indoor settings have different layouts. The rainforest at the science center consists of five levels, that begins with a recreation of a rainforest canopy that leads visitors down toward the ground, passing tree-dwelling and ground-dwelling animals and ending under water with an aquarium. In the botanical garden, the rainforest greenhouse is comparatively small, and visitors only see it from ground level, looking up toward the treetops. The greenhouse has exits to four more greenhouses with different botanical themes, so visitors can choose to break up the rainforest tour or experience it all in one go. Both settings serve to inform and teach about rainforests, but in different manners. The science center aims to attract a wide audience, as there are other parts of the center with different scientific themes. They have also chosen to represent a Costa Rican rainforest with plants and animals typical of Costa Rica. The botanical garden...
rainforest presents different plants from diverse tropical rainforests and regions. The rainforest at the science center presents a selection of tropical animals from various groups, for example amphibians, primates, birds, whereas the rainforest at the botanical garden has fish (Koi Carp) in a centrally placed pond and also potentially some poison arrow frogs and ants (according to signs). The two settings differ not only in visual terms, but also when it comes to sound levels, with the botanical setting being much quieter and calmer than the science-center setting. The view visitors receive in the science center rainforest is a more expansive habitat-based view than at the botanical garden tropical rainforest setting, which can be considered, in visual and sensoric terms, to be an intimate close-up view of individual plants brought together to offer a snapshot rainforest experience.

The science center had, at the time of the study, many colorful and relatively large signs with pictures of the birds and animals to be found in the setting and general information about the rainforest. Little information about the plants was to be found at the site. The botanical garden, on the other hand, had the typical plant labels stuck in the ground or hanging around branches, partly obscured by foliage. Further, these labels warrant a floristic key to be able to interpret (unless you are a plant collector) and this key is posted on a window inside the greenhouse. In addition, the science center has information signs about not touching or feeding animals whereas there are no such signs concerning plants, in the botanical garden.

Data were collected over a period of four days, with two days in each setting. The participants in the study were elementary student teachers visiting the sites as part of a teacher training course in natural sciences, specifically on biology didactics. The student teachers visiting the science center were not the same students that visited the botanical garden. In total 94 student teachers participated in the data collection, out of which 53 student teachers were at the science center and 41 at the botanical garden.

Data analyzed for this paper were collected through individual questionnaires. Using open-ended questions, these questionnaires aimed to explore the student teachers’ experiences and aesthetic consciousness upon visiting the two sites. The questions were as follows:

1. How did you like being in the rainforest?
2. What did you see?
3. Any specific animal?
4. Any specific plant?
5. If you were to phone a friend and tell her/him about your visit to the rainforest today, how would you briefly describe your visit? Which three words would you use?

The students were divided into groups of four or five and given instructions to walk through the rainforest. At each site observations were carried out as a one-stop visit of each rainforest experience. Hence, the students in the botanical garden rainforest were encouraged to only walk through the rainforest and not take any detours into the other sections and at the science center they were encouraged to walk the whole route, from the canopy at the top to the aquarium at the bottom. They were informed that the research focus was not on individual performances, but on what might draw participants’ attention in the spaces being studied. After walking through a rainforest experience the students were asked to complete individual questionnaires. Along with the questionnaires, the students were also observed and their conversations were recorded. These data are not included in this paper.

2.1 Ethical considerations

The research followed the ethical considerations described by the Swedish Research Council (Swedish Research Council, 2017).
The student teachers gave their written consent to participate and were informed about the aims of the study, the use of the data, and their rights to confidentiality and to withdraw from participation.

3 | ANALYSES

The questionnaires were analyzed qualitatively in order to explore the observations the students made and the words the students used to describe their experiences in the two settings. The answers provide information on what is noticed and also evaluations and attitudes toward experiences at the sites. The words and phrases used provide indications of how the setting is "read" by students and reflects their response to the rainforest.

The questionnaires were coded by two researchers, one of whom specialized in biology educational research, and one specialized in linguistic educational research. Expressions were coded at every occurrence in each questionnaire, even if they were mentioned as answers to different questions. If the same expression appeared more than once in the same answer and related to the same phenomenon, it was, however, categorized only once.

The main categories of plants, animals, and aesthetics were defined in advance, but subcategories emerged as a result of "open coding" (Cohen, Manion, and Morrison, 2011). The categorization of mentions into the three main categories was considered to be unproblematic as they are distinctly different. However, the coding of mentions into the subcategories was subjected to repeated readings of the answers given and negotiated between the coders and the theoretically grounded aspects of mentions relating to plants and animals (e.g., Knight, 2008; Balding & Williams, 2016) and from studies regarding humans and plants (e.g., Sanders, 2007; Balding & Williams, 2016). This process is similar to the one presented in Andersson and Wallin (2000); "[the] categories emerge by a process of hypothesizing them and checking them against actual answers". This resulted in a number of subcategories such as smell, color, scale, adaptive features (Sanders, 2004) and other new ones established by the researchers in the analytical process (e.g., sensoric, experiential, holistic, and specific). As shown in the coding scheme of the questionnaires (Figure 2), we distinguished between specific and nonspecific animal and plant references. This was done in order to learn more in detail about what is noticed and what students know about the plants and animals they do notice. These distinctions are, however, crude; a mention of a frog and an avocado, for example, is noted as a specific reference, as would the more scientifically precise poison dart frog. Animal, tree, fish, or flower however were categorized as nonspecific.

The aesthetic mentions in the questionnaires relate to the broad sense of the word as used by Wickman (2006), that is, aesthetics not only refers to that which is beautiful or nice, but also includes ugly and unpleasant or negative impressions and experiences. Aesthetic mentions were categorized in two main subcategories: sensoric and experiential experiences.

Sensoric experiences refer to words and expressions related to senses and were placed in subcategories: touch, smell, climate, sound, and visual. Visual experiences were further divided into the subcategories of: size, behavior, appearance and color. A mention was given the code behavior when a student teacher commented on for example, how a monkey behaved (cheeky), and the code appearance if students, for example, noted that a plant was spikey. Instances where students noted that birds were noisy with their calls have been coded as sound, as we could not tell if the students would distinguish between calls related to behavior (warning or courting). The same applies if, for example, a student teacher noted that a plant had a particular smell; this mention was coded as smell, as we cannot tell if the students know it is a plant behavior.

Experiential experiences relate to how the environment, plants, or animals were perceived by the students. These experiences were
categorized either as holistic or specific. Holistic experiences refer to the impressions of the environment as such, for example an appreciation of the rainforest as a whole or the experience of walking through a rainforest. Specific experiences refer to when students in their questionnaires describe their impressions in more detail, as for example the rainforest as a tropical experience. An overview of the coding scheme is shown in Figure 2, with examples of mentions in each category.

In the analyses, the two settings have been separated and are presented in parallel. As our main aim with the study was not to compare the two sites, but to qualitatively explore the affordances these kinds of sensory-rich and multimodal settings possess, we do not offer any statistical comparisons of the two sites—and the analysis was therefore not made on an individual level. However, we present the two sites in parallel in order for the reader to see indications of differences and similarities in what the students notice at either site. As the number of students who participated at the science center was larger than at the botanical garden, we have presented the number of mentions as percentages of the total number of mentions per site.

4 | RESULTS

The results are divided into three sections; the first giving an overall picture based on the three main categories; the second dealing with what the students observe, which relates to questions 2–4 in the questionnaire; the third deals with how they describe their experiences, which relates to questions 1 and 5 in the questionnaire.

4.1 | Overall picture

The total number of data points, that is, mentions coded into the three main categories aesthetic experiences, plants, and animals respectively, added up to 1,474 mentions for the two sites together. Of these, the majority (54%, 802 mentions) were categorized as aesthetic experiences, and nearly one-third (30%, 439 mentions) were coded as animals and 16% (233 mentions) as plants (Figure 3 and Table 1).

4.2 | What do the students observe?

With regard to mentions of plants they are, as might be expected, more frequent in the botanical rainforest where plants are in the foreground, than at the science center rainforest where animals are foregrounded. Similarly, mentions of animals are more common in the science center rainforest, where animals are in the foreground, than in the botanical rainforest where animals are not in focus (Figure 4).

| Place            | No. of students | Aesthetics | %  | Animal | %  | Plant | %  | Total |
|------------------|----------------|------------|----|--------|----|-------|----|-------|
| Botanical garden | 41             | 258        | 32 | 49     | 11 | 164   | 70 | 471   |
| Science center   | 53             | 544        | 68 | 390    | 89 | 69    | 30 | 1,003 |
| Total            | 94             | 802        | 100| 439    | 100| 233   | 100| 1,474 |

FIGURE 3 | Mentions of the main categories at the two sites together presented as a percentage of overall mentions

4.2.1 | Specific and nonspecific plant and animal mentions

There are nonspecific references to plants and animals in the questionnaires such as plants, flowers, animals, and different animals, as well as specific references to plants and animals such as fig, cotton, koi, and sloth.

The results indicate a higher amount of specific references to plants in the botanical garden than in the science center; 59% in the botanical garden and 8% in the science center. Further, there are more mentions of nonspecific references to plants in the botanical garden (18%) than to nonspecific references to plants in the science center (6%). (Figure 5).

One example from the science center (digitalized and translated) illustrates the types of answers found in the questionnaires:

Q2. What did you see? Butterflies, fish & rays, sloth, frogs, and birds
Q3. Any specific animal? The sloth was cool, looked almost unreal
Q4. Any specific plant? -

Here we see the student’s response stating that they saw different animals, also making specific animal references and selecting the sloth for a special mention. In many responses in the science center a selection of animals were “seen” and little or no attention was directed toward plants.

Another example—from the botanical garden:

Q2. What did you see? Fish, cacao plant, cotton, bamboo, many nice plants.
Q3. Any specific animal? Fish and ants
Q4. Any specific plant? The cacao plant was fun to see.

4.3 | What do the students experience?

Our analysis reveals that the students’ answers are rich in aesthetic expressions, both regarding the animals and plants mentioned and regarding the environment as such (in total 802 of total 1,474 mentions coded) as shown in Table 1. The amount of aesthetic expressions in the science center tropical rainforest setting is 544 (54% of all mentions at the site) while in the botanical rainforest setting it is 258 (55% of all mentions at the site). If we take into account the different number of student teachers present at each site, we see that the average number of aesthetic mentions-per-student teacher is 10.3 for Science center and 6.3 for Botanical garden. These results indicate that the tropical rainforest in the science center provides more affordances for aesthetic impressions than the rainforest in the botanical garden.

As detailed in the coding scheme (see Figure 2), aesthetic expressions were coded as either experiential or sensoric, the results are presented in Figure 6.

4.3.1 | Experiential mentions

Experiential expressions amount to 76% of mentions and sensoric to 24% of mentions, for the combined sites. Each site demonstrates similar division of expressions (Figure 6).

The main category of experiential expressions was divided into two subcategories; holistic and specific. These two categories were intended to illuminate how and what was experienced in the rainforests. Holistic mentions included positive exclamations relating to the pleasure of being in a rainforest, the cacophony of sounds of being in a rainforest, or a general negative experience based on concerns for animals in the rainforest. The specific experiential mentions concerned, for example the diversity of the rainforest or of it seeming realistic.

Some answers from the botanical garden illustrate the difference between the environment the students are used to, and the rainforest:

Q1. How did you like being in the rainforest? It was interesting to see so many new plants. Lovely climate.
Q5. If you were to call a friend/pal and tell her/him about your visit to the rainforest today, how would you briefly describe your visit? Which three words would you use? Inspiring, cool, interesting.

In the science center rainforest similar responses were made. There were also responses that related positively to being near the animals in the science center:

Q1. How did you like being in the rainforest? It was fun and interesting to see animals and nature that you don’t find in Sweden.
Q5. If you were to call a friend/pal and tell her/him about your visit to the rainforest today, how would you briefly describe your visit? Which three words would you use? Nice, unusual, interesting.
To conclude, the experiential expressions in the questionnaire suggest that most students at both sites were positive about the visit. There were however 16 references (of 613 experiential references) that were coded as negative experiences and these covered aspects of the setting at the science center having too little information and being questioned from an animal rights perspective. Many students’ experiential references, such as “realistic”, “nature-like”, suggest a positive aspect of meeting a different environment and seeing animals and plants in an environment that seems, and feels, to them natural and realistic.

4.3.2 | Sensoric expressions

When looking at sensoric experiences (Figure 7) and the subcategories of touch, smell, climate, sound, and visual, we find that there are no mentions of either touch or smell. It is not forbidden to touch plants in either setting, however the animals are not to be touched. This might have an influence on the results here, along with a museum norm of not touching objects on display. The lack of mentions about smell is also interesting, when concerned with the science center, as there are places along the directed routes in which the smell of animals is prominent. In the botanical garden, had the visits taken place at a time when more plants were flowering perhaps there might have been more mentions of smell.

The largest category among the sensoric experiences at both sites, was visual experiences, with the subcategories of size, behavior, color, and appearance. The category of color was the most frequently mentioned along with a few mentions of behavior and appearance. The questionnaires included responses describing the settings as colorful, containing colorful plants and colorful fish. In the botanical garden, the color green stood out in the responses, both as the main color but also as a contrast (other colors – than green). In the science center, more specific colors were mentioned in the questionnaires such as blue, red, and green. Climate is the second largest category of sensoric mentions in both settings and students note the humidity and realistic feel of the rainforest, with both positive and negative connotations.

![Figure 7](image.png)

**Figure 7** Percentages of mentions of sensoric experiences with the subcategories of visual, climate, and sound found in the questionnaires

5 | DISCUSSION

In this study we explored student teachers’ observations in two sensory-rich indoor settings—both tropical rainforests—one in a science center, where animals are in the foreground and one in a greenhouse in a botanical garden, where plants are in the foreground. As is concluded by Mangione (2016), sensoric affordances offered in museums vary and thereby have an impact on visitor experience. Our results indicate that both sites offer the visitor a richness of aesthetic experiences. Although the number of aesthetic expressions seem to dominate at the science center, a fair amount of aesthetic expressions are also prevalent in the botanical garden setting. Climate is the second largest category of the sensoric mentions in both settings and students noted the humidity and realistic feel of the rainforest. It would appear as if the uncommon (for Sweden)—feeling of the high humidity and temperature—has a significant impact on the student teachers’ experiences. The largest category among the sensoric experiences, though, is visual experiences, with a predominance of diverse colors as noted in the two settings. The colors referred to are either mentioned in relation to plants and animals, or are unspecified impressions. The results of the study thus suggest that the environment in the science center, provides more affordances for aesthetic impressions than the rainforest in the botanical garden. This can probably be explained by the sensory-rich environment in the science center; the presence of colorful birds and butterflies that moved around in the science center as well as animal calls, sounds of water, smell of animals, smell of humic matter etc. that drew attention, and a lack of flowering plants in the botanical garden, where a lush greenness was foregrounded with no similar contribution from animals or sound of water. Another factor might be that plants do not easily draw peoples’ attention due to a perception of plants operating in the “slow lane”, as noted by Sanders (2019).

In combining data from both sites, we find that mentions of animals in the questionnaires are more frequent than mentions of plants. Our analyses reveal a dominance of animal references at the science center and a dominance of plant references in the botanical garden, which is in accordance with that which is foregrounded in the two settings. Previous studies suggest, however, that reasons for liking visits to a botanic garden are not always about the plants themselves, but rather a positive place-based experience, that is, the affordances of the environment in which the plants play a crucial role are important (Sanders, 2007). In addition, Sanders (2007), found that positive experiences from zoo visits were described by the children with zoo animals at the center of their attention.

A further site-related reason for the differences in plant versus animal references could possibly be found in the disparities in information signs at the two sites. The science center had, at the time, many colorful and relatively large signs with pictures of birds and animals inhabiting the rainforest as well as general information about the rainforest, with little information about the plants at the site. The botanical garden, on the other hand, had the typical plant labels stuck in the ground or hanging around plants. Also other
information, such as the use of plants, was available at the botanical garden but not at the science center.

Regardless, the difference in number between noticed plants and noticed animals indicates that plants in these types of indoor environments need to be presented in a way that enables them to better compete for attention as is described by Darley (1990): "As animals, we identify much more immediately with other animals than with plants. Plants do not move around, they do not eat or drink and they do not respond (in an obvious way) to anything in their environment." Since most of the plant observations were made in the botanical garden setting, we suggest that in order to notice plants—the basis for most life on earth—in an animal rich environment, plants need to be foregrounded in the design of such settings and information about them clearly displayed for visitors. This should help give plants the prominence they deserve and ensure they are not overlooked as simply forming the backdrop to an animal-rich setting.

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**AUTHOR CONTRIBUTION**

Eva Nyberg, Anna Maria Hipkiss and Dawn Sanders, jointly planned and designed the research. Nyberg and Hipkiss conducted the main fieldwork and analyzed the data. Nyberg and Hipkiss have jointly authored the paper with substantive contributions by Sanders to the introduction and background.

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