Initial Development and Validation of the Plant Awareness Disparity Index

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Subject/Problem

Plant awareness disparity (PAD, formerly known as plant blindness) is the tendency not to notice plants within one's environment leading to naïve and anthropocentric points of view such as plants are not important to humans, are boring, or do not do anything (Wandersee & Schussler, 1999). PAD does not mean that people are incapable of seeing plants, but rather that humans group plants together into a green mass that is often visualized as a backdrop for animals. For example, Schussler and Olzak (2008) noted that university students recall more animal names than plant ones, even if they are equally nameable. This phenomenon is a result of a visual cognition bias: human visual systems evolved to notice things that move and/or look like us and therefore do not perceive plants as distinctly as animals (Balas & Momsen, 2014). Thus, PAD leads to a potential negative impact on students' reasoning about the importance of plant life to the biosphere and human affairs.

Many interventions have been proposed to address PAD in K-12 classrooms, as well as university learning environments. Krosnick et al., (2018) utilized a Pet Plant Project where university students were asked to grow an unknown plant from seed, monitor its progress, and relate lecture concepts to its development. They found that students noticed plants more, wanted to plant their own plants, and made connections with their plant that supported the content they learned in lecture. Wandersee, Clary, and Guzman (2006) probed community college students' botanical sense of place to help them see and understand how plants are important to not only the students, but also humans in general. Frisch et al., (2010) used this approach to help educate science teachers about why teaching plants in elementary school is important as well. While these studies provide valuable insight into how PAD works and what interventions have been tried thus far, it is difficult to determine how effective they are when a valid and reliable tool to measure PAD does not exist. Previously, the Plant Attitudes Questionnaire (PAQ) developed by Fančovičová and Prokop (2010) was used to measure attitudes toward plants, specifically, but no instrument exists to measure the entirety of PAD: attention, attitude, knowledge, and relative interest, as described by Dr. Elisabeth Schussler. Additionally, this questionnaire was only validated in Slovakian students 10 to 15 years of age and was specifically intended to help determine if having a garden improved PAD.

To address the lack of a more universal instrument, we have developed the Plant Awareness Disparity Index (PADI). The PADI is designed to evaluate students' level of PAD based on the four aspects of PAD (formerly plant blindness). The development of this instrument is also a way to determine whether these four theorized components can operate as subscales within the PADI, and whether these components are supported by the data collected.

Methods

Initial Development of the PADI

To develop the Plant Awareness Disparity Index (PADI) we considered each of the four components of PAD separately and created items that would address each component. We used the Plant Attitudes Questionnaire (PAQ) as a reference for how plant-related attitude items could be written but decided to create our own items that would address attitudes towards plants

(Fančovičová, & Prokop, 2010). While the PAQ is valuable in that it measures how students feel about plants and what their attitudes toward plants are, PAD is about more than attitude. Therefore, we opted to create an instrument that would measure all the facets of PAD. We created items that aligned with the other three components based upon conversations with Dr. Schussler and previous findings within the literature. We went through multiple rounds of revisions before we settled on a semi-final version which we sent to Dr. Schussler to review for clarity and soundness of ideas. After incorporating her edits, we came to the first version of the PADI which included eight items about attitude, eight items about knowledge, six items about relative interest, and six items about attention, for a total of 28 items.

We used a Likert-style scale consisting of, “Completely Disagree, Somewhat Disagree, Somewhat Agree, and Completely Agree,” as answer options. Positive and negative items were used in the instrument, and the negative items were reverse scored. We scored, “Completely Disagree,” as one, “Somewhat Disagree,” as two, “Somewhat Agree,” as three, and “Completely Agree,” as four (except where items were negative and reverse-coded). The minimum score was 28 if students answered all items with a negative (plant-unaware) answer, and the maximum score was 112 if they answered all the items with a positive (plant-aware) answer.

Survey Pilot and Proof of Concept

All methods were approved by the University of Memphis IRB. In the pilot study we utilized a mixed methods research design by administering the survey as a pre/post-test (n=60 across two semesters) and collecting interview data (n=10 across two semesters) to establish face validity and proof of concept during the causal map study. The survey was administered at the beginning and end of two trimesters in an undergraduate botany course at a small Midwestern university. Interview participants were selected based on having a range of scores on the PADI so as to get at student ideas about plants from differing levels of PAD. In the interviews, we asked students if they had trouble understanding the survey, answering any of the questions, and if they had any suggestions for how to make the survey more accessible and clearer. A preliminary reliability analysis on the PADI gave an acceptable Cronbach’s alpha score at 0.79. We analyzed the interview data to look for any face validity problems with the instruments and after, finding none, we moved on to round 1 of exploratory factor analysis (EFA).

Exploratory Factor Analysis

Data collection. In the first round of EFA, we used a quantitative factor analysis design and sent out emails through two existing science education list serves, the Society for Advancement of Biology Education Research (SABER) and National Association for Research in Science Teaching (NARST) to recruit instructors who were willing to have their students participate. The survey was administered via Qualtrics with a consent form at the beginning before the items. Students spent approximately 15-20 minutes total on the survey, and our target population was undergraduate students taking a biology class. We received a total of 1231 respondents for the PADI which came to 1062 after data cleaning to remove any incomplete responses or any participants that did not respond correctly to the quality control item. The quality control item instructed the respondent to select the answer, “Somewhat Agree.” If the respondent answered this item incorrectly, we removed the data for that participant, as this indicated the participant did not pay attention while answering the survey.

In the second round of EFA, we again we sent out emails through the two existing science education list serves that we used for the first round of EFA (SABER and NARST) to recruit instructors who were willing to have their students participate.

Data Analysis. In the first round of EFA, we analyzed the results of the first round of EFA using a maximum likelihood factor extraction with direct oblimin rotation within the *psych* package in R (Revelle, 2019). We used the fa.parallel function within the *psych* package to generate a scree plot and determine how many factors should be extracted for the analysis. Maximum likelihood extraction and direct oblimin rotation are often used for confirmatory factor analysis (CFA) which is used to confirm the hypothesized factors of an instrument. However, this methodology has also been used to create factor loading scores that can then be transformed into item discrimination parameters for use in item response theory (IRT) and Rasch analyses that will give us insight into how individual items are operating within the instrument (Revelle, 2019).

In the second round of EFA, we cleaned the data to remove any incomplete responses or any responses that did not respond correctly to the quality control item as described above in the first round of EFA. Before cleaning, we had 700 responses and after cleaning we had 553 due to the large amount of incomplete responses and some participants who did not answer the quality control item correctly. We used another maximum likelihood factor extraction with direct oblimin rotation within the *psych* package to determine if the six-factor model is still appropriate (Revelle, 2019). However, this time we tested a few different models based on feedback we received from the second EFA indicating that a few of the items were not loading as we had hypothesized after the first round of EFA. Of the four models we tested, two included seven factors and two included six. We reviewed goodness-of-fit indices to make our decision about the model that would best fit our data. The variations in the models were in the number of factors (six or seven) and which items we removed (items that loaded on the wrong factor, and items that did not have a loading score of 0.3 or higher).

Results

EFA Round 1.

Our first EFA results for the PADI revealed a six-factor model, differing from the original hypothesized four-factor model (attitude, attention, knowledge, and relative interest). The six factors were: Caring for or Investment in Plants (three items), Necessity of/Importance of Plants (four items), Plants Better than Animals (five items), Animals Better than Plants (three items), Attention to Food Plants (three items), and Positive Affect (five items). All items loaded onto their respective factors with a score of 0.3 or higher as required for EFA ($\chi^2 = 666.92$, df = 225, $p < 0.01$, TLI = 0.917, RMSEA = 0.043).

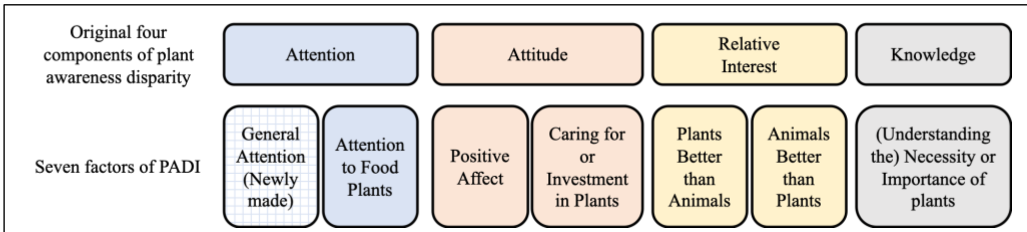

Figure 1. Alignment of preliminary hypothesized factors from factor analysis with previously hypothesized factors based on the four components of PAD.

The six factors of the PADI still aligned well with the original attitude, attention, knowledge, and relative interest components of PAD (see Figure 1), so we proceeded with edits to remove any items that did not load onto a factor, as well as clarify and re-word items that loaded poorly onto a factor. We also added a newly hypothesized factor called, "General Attention," which includes three items, two of which were recycled from the original PADI instrument and one item that was newly created. We did this because the only attentional factor that was gleaned from factor analysis was attention to food plants, which may point to a tendency for students to only notice plants in the context of what they do for humans. We added the general attention factor to compare the two to determine if this was the case in the next round of analysis. After adding the new factor, we went through more rounds of revisions with Dr. Schussler before settling on the second version of the instrument. The second version was 30 items long with each factor containing three to six items per factor. This change in length meant that the new minimum score that could be obtained with the instrument was 30 if student chose all negative (plant-unaware) answers, and 120 if the student chose all positive (plant-aware) answers.

EFA Round 2.

The scree plot originally generated using the fa.parallel function in *psych* indicated that our instrument had seven factors. These factors were almost identical to the factors we found at the end of EFA round one, with the exception of a few items that loaded onto different factors than they had originally. We decided to test another seven-factor model without these items, a six-factor model without these items, and a six-factor model that excluded a few extra items that did not load (see Table 1).

Table 1. A comparison of the four models tested during EFA study two using goodness-of-fit indices.

Model	Description	χ^2	df	TLI	RMSEA	*p*
One	Seven factors; no items removed	474.98	246	0.936	0.042	< 0.001
Two	Seven factors; 13, 14, and 20 removed	331.48	183	0.951	0.039	< 0.001
Three	Six factors; 13, 14, and 20 removed	426.46	204	0.934	0.046	< 0.001
Four	Six factors; 13, 14, and 20-22 removed	301.73	165	0.955	0.04	< 0.001

Note: TLI = Tucker Lewis Index; RMSEA = Root Mean Square Error of Approximation

The scree plot indicated that a six-factor model would be a better fit for our data, so we moved forward with the fourth model, one that included six factors and had the best goodness-of-fit scores. Every item in this model loaded with a score of 0.3 or above. Model four removed the Attention to Food Plants factor entirely, and instead focuses on one factor named Attention toward Plants (see Figure 2). This new factor combines items from the previous General Attention and Attention to Food Plants factors to create a well-rounded representation of the fact that attention to all types of plants is an important component in the PADI. The rest of the factors remained the same across all four models, which indicates that our factor structure is very stable. A stable factor structure will help us moving forward as we explore the items individually through IRT and Rasch analyses. In our presentation, we will describe these factors in more detail and discuss the IRT and Rasch analyses.

Contribution

Our model of the PADI includes six factors: Caring for or Investment in Plants, Necessity of Plants/Importance of Plants, Attention toward Plants, Positive Affect toward Plants, Plants Better than Animals, and Animals Better than Plants (see Figure 2). The evidence would indicate that these factors continue to align well with and support the original theorized components of PAD. The development of this tool will allow instructors to measure how well their interventions work in reducing student levels of PAD. It will also allow for comparative studies regarding how PAD changes over time. The final version of this instrument will be useful for those who are interested in the problem of PAD and how we can find concrete ways to address it both in and outside of the formal classroom setting. PAD has been shown to begin and continue throughout the K-12 education experience, and it is for this reason that we intend to validate the instrument for a younger population next. Partnerships with informal education venues such as science centers, botanical gardens, and environmental education programs will be able to determine if a particular informal education approach differs in effectiveness compared to more formal education approaches, and as such, we will be validating the instrument in these settings too.

General interest

This research will be of value to educators who are specifically interested in PAD (formerly plant blindness) but also those interested in botany and environmental education. This work also has the potential to inform how the development of valid and reliable tools affect the ability to do science education research. Here we provide an example for how one approach to instrument development can be taken, should educators want to learn more on the subject or develop instruments of their own. This work also demonstrates how important it is to have valid and reliable measures of educational phenomena to help design and deliver targeted interventions in the classroom, something that will be of interest and benefit to all NABT members.

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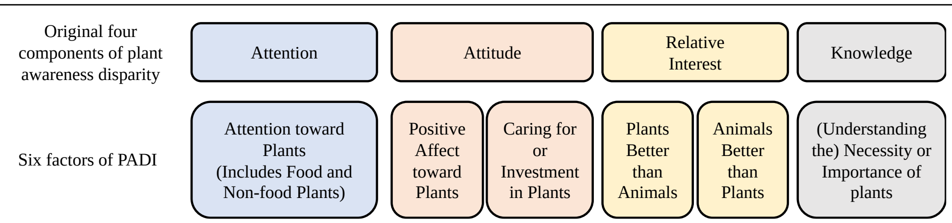

Figure 2. Alignment of EFA-reinforced six-factor model with original four components of PAD.

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