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Integrating Perspectives from Education for Sustainable Development to Foster Plant Awareness among Trainee Science Teachers: A Mixed Methods Study

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Abstract: This mixed-method study aimed to investigate the efficacy of an intervention unit that integrates perspectives from Education for Sustainable Development (ESD) to foster plant awareness, within the context of botanical lessons for trainee science teachers. Third-year undergraduate students (n = 91) studying to become lower secondary school (grade 7–9) science teachers from a public university in East Java, Indonesia, participated in this study. Data were collected through a self-reported questionnaire, reflective journal entries, and focus group interviews. The findings revealed a statistically significant increase in the participants' attention and attitude towards plants, relative interest in plants, and self-efficacy in teaching plant-related topics. The triangulation of the analysis results from the reflective journals and focus group interviews demonstrated that through transformative learning, the participants' experiences, perceptions, and learning evolved throughout the intervention unit, leading to their more comprehensive understanding of plant-related issues and their connection to broader sustainability concerns. These findings imply that the integration of ESD perspectives into botanical education positively affects plant awareness. Future research could further investigate the long-term impact of integrating ESD perspectives on teacher training programs.

Keywords: education for sustainable development; transformative learning; botanical education; science teacher education; plant awareness; mixed-method study; Indonesia

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1. Introduction

1.1. From "Preventing Plant Blindness" to "Fostering Plant Awareness"

Imagine a koala in a eucalyptus tree, leisurely munching on its leaves. The koala captures our attention with its endearing appearance and unusual behavior, while the eucalyptus tree, which acts as both a habitat and nourishment for the koala, often goes unnoticed. Our tendency to disregard the vital role of the eucalyptus tree in this scenario highlights a phenomenon that has been impeding botanical education in recent centuries [1,2]. Over two decades ago, Wandersee and Schussler [3,4] coined the term "plant blindness" to label this phenomenon, which refers to the tendency of individuals to underestimate or ignore the significance of plants in the environment and on human life. This widespread issue has far-reaching consequences [2,5,6] and leads to a lack of appreciation and understanding of plant biodiversity and the essential roles plants play in ecosystems, e.g., providing habitats for numerous species such as the koala. Moreover, plant blindness can result in diminished interest in plant conservation efforts [7]; cause weakened support for plant-related research, education, and policy [8,9]; and even perpetuate misconceptions about the importance of plants which may eventually snowball into an impediment to the achievement of the Sustainable Development Goals (SDGs) [7–11].

In recognizing the need to both address plant blindness and its ableist implication (which associates visual impairment with a negative connotation) [12,13], there have been

calls to shift the goal of botanical education from "preventing plant blindness" [3,4] to actively "fostering plant awareness" [12–15]. This latter approach aims to promote a comprehensive understanding of plants and their critical environmental roles, ultimately inspiring future generations to become proactive environmental stewards and contribute to a more sustainable world [7–11]. By emphasizing the importance of understanding plant structures, functions, and roles within ecosystems, educators can prioritize plant awareness and facilitate the development of innovative teaching strategies and educational resources [14–16]. This shift in perspective encourages appreciation for plants' intricate relationship with other organisms, their adaptations to diverse environments, and their significance in maintaining ecological balance. Furthermore, the transition from preventing plant blindness to fostering plant awareness also underscores the need for collaboration between educational institutions, researchers, policymakers, and the public to effectively engage all stakeholders in biodiversity conservation [7–11].

Plant awareness can be defined as the ability to recognize, comprehend, and interact with the plant kingdom in a meaningful and informed manner. It encompasses cognitive, emotional, and perceptual awareness [12,13] of the ecological and anthropogenic roles of plants, as well as their aesthetic, cultural, and scientific significance [17–20]. This awareness involves acknowledging plants as living organisms and recognizing their essential contributions to the well-being of the environment and humans [17–20]. Valuing and respecting plants and understanding their role in maintaining ecological balance and ensuring the sustainability of our planet are among the key tenets of plant awareness [9–11]. Through a review of the relevant literature, the components of plant awareness in the context of science teacher education can be identified as follows.

1.1.1. Attention towards Plant

Parsley [12,13] explained that the limited awareness of plants can be traced back to research on visual attention [12,13]. Our attention is selective, and we can only process a certain amount of visual data. Dynamic stimuli, such as movement, tend to take precedence over others, putting plants at a disadvantage since they do not display the same degree of visible motion as animals. Although our brains recognize plants, they are frequently overshadowed by other organisms, particularly animals [12,13]. For example, research by Balas and Momsen [21] and Schussler and Olzak [22] indicates that university students are more aware of and have better recall for animals than plants. Yorek, Şahin, and Aydın [23] discovered evidence suggesting that students might not view plants as living entities due to their minimal observable movement. Studies have shown that people may perceive plants but not be fully aware of them, which could be due to "inattentional blindness, a failure to notice unexpected objects when attention is otherwise engaged" [12,13].

1.1.2. Knowledge about the Importance of Plant

As elaborated by Parsley [12,13], the knowledge component of plant awareness is distinct from the knowledge deficit model, which suggests that a lack of general scientific knowledge is the main reason for the public's lack of support or understanding of scientific issues. In contrast, the knowledge component of plant awareness focuses on a deeper understanding of the ecological, cultural, economic, and medicinal values of plants that go beyond basic botanical literacy [12,13]. Having this specific knowledge is crucial to developing a greater appreciation for the roles that plants play in sustaining life on Earth. Educational interventions that aim to improve this type of knowledge have been shown to have a positive impact on students' attitudes and interests in botany. For instance, Wandersee et al. [24] conducted a study on activities that prompted students to reflect on their past experiences surrounding plants, and recalling why they viewed plants as important which could enhance their knowledge of plants. Therefore, to foster plant awareness, educators should also recognize and leverage pre-existing knowledge that individuals may have about plants [12,13].

1.1.3. Relative Interest in Plants

The relative interest component is also a significant aspect of plant awareness, indicating that people tend to be more interested in animals than in plants [12,13]. This is reflected in the animal-centric nature of biology courses, which can result in less attention and interest in plants [25]. However, research suggests that people may be more interested in certain types of plants, such as medicinal and recreational plants [26]. According to Wandersee [27], interest and motivation are crucial factors in promoting plant awareness, and educators should take this into account when designing educational interventions to enhance plant knowledge and appreciation. By understanding the relative interest component of plant awareness, educators can develop strategies to foster greater interest in plants and highlight their importance in the environment and human life.

1.1.4. Attitude towards Plant

Negative attitudes towards plants are common among students, particularly at the lower secondary school level, and can contribute to plant blindness [12,13]. Hands-on outdoor activities that enable students to interact with plants have been found to be effective in improving their attitudes towards plants. Additionally, teacher involvement, including specialist knowledge, enthusiasm, and interest in plants, can greatly influence students' interest in and attitudes towards plants [26]. Balding and William [7] suggested that anthropomorphizing and empathizing with plants can also lead to more interest in plants, thus fostering plant awareness and increasing support for plant conservation. In other words, encouraging students to attend to plants can lead to more interest in them and can ultimately result in students learning more about plants. Therefore, educators must focus not only on providing students with plant knowledge but also on promoting positive attitudes towards plants, as developing a positive attitude towards plants is crucial for enhancing plant awareness and appreciation [12,13]. Intentional visual attention can increase the intensity of emotions and trigger interest in plants, suggesting that attention and attitude are related to plant awareness [13].

1.1.5. Self-Efficacy to Teach about Plants

Bandura's self-efficacy theory [28] asserts that an individual's belief in their ability to perform a task influences motivation, persistence, and success. When applied to education, teachers' self-efficacy impacts the effectiveness of their teaching and students' engagement. Fostering plant awareness is one application of this theory, addressing the tendency to undervalue plants in the environment. Lindeman-Matthieu et al. [28] found that teachers with high self-efficacy engage students in learning about plants more effectively, promoting plant awareness and understanding. By instilling self-efficacy, teachers are more likely to view teaching about plants as a challenge to master rather than avoid [28], leading to commitment, persistence, and innovative teaching approaches. Consequently, this fosters environmentally conscious individuals who appreciate and understand the significance of plants in our environment [28].

1.2. Integrating Perspectives from ESD to Foster Plant Awareness

Integrating Education for Sustainable Development (ESD) principles into botanical education is essential to amplify the positive effects of promoting plant awareness. Endorsed by the United Nations, ESD aspires to weave sustainable development concepts throughout all aspects of education, from early childhood to higher education and continuing into lifelong learning [29,30]. ESD deepens plant awareness by emphasizing the interrelationships between human activities, plant diversity, and ecosystem health. This multidisciplinary approach empowers learners to become responsible guardians of the environment by fostering critical thinking, problem-solving, and decision-making abilities [29,30]. As instrumental influencers of future generations, trainee teachers must receive training in ESD principles to develop engaging and contextually relevant curricula that highlight the interconnectedness of plants, humans, and other organisms, as well as the

economic, social, and ecological dimensions of sustainable development [9,18]. This foundation may allow them to inspire students to think critically and creatively about the challenges facing plant conservation and sustainable agriculture. Furthermore, cultivating plant awareness through ESD among trainee teachers helps establish a robust network of educators dedicated to raising environmental consciousness and advocating for sustainable practices, fostering a more informed and engaged society that values the importance of plant biodiversity in ensuring a sustainable future [9,10].

1.2.1. "Plants, People, Planet" Concept as Educational Content in ESD

The concept of "Plants, People, Planet" (PPP) [31,32] offers a perspective that integrates ESD principles into botany education by emphasizing the interdependence of plant life, human societies, and the health of our planet. This concept aligns with the three pillars of sustainability—economic, social, and environmental [33–35]. The economic pillar focuses on managing plant-based resources sustainably and equitably to support long-term economic development. The social pillar acknowledges the vital role plants play in promoting human health and well-being, providing livelihoods and cultural values, and enhancing social equity and justice [33–35]. The environmental pillar emphasizes the importance of protecting and restoring ecosystems and natural resources while reducing the ecological footprint of human activities. As such, the sustainable use and conservation of plant biodiversity are essential for the future of our planet [31,32,34].

The gear model depicted in Figure 1 serves as a metaphor that emphasizes the complex interdependent system between plants, people, and the planet. The model situates plants at the center, with gears representing people and the planet. This configuration highlights the critical role of plants in driving the ecosystem, providing essential ecosystem services, and supporting human societies [31,32,34]. Furthermore, the equal size of the plant and people's gears underscore the significance of plants in maintaining the balance of the ecosystem and their equal importance to human well-being. The largest gear, representing the planet, highlights the vital role of plants in sustaining life, and the model illustrates the essential interdependence of these gears in supporting sustainability. In the context of botany and plant biodiversity education, the PPP concept can be broken down into three distinct components, each addressing specific educational content and corresponding to relevant topics in botany, as shown in Figure 1.

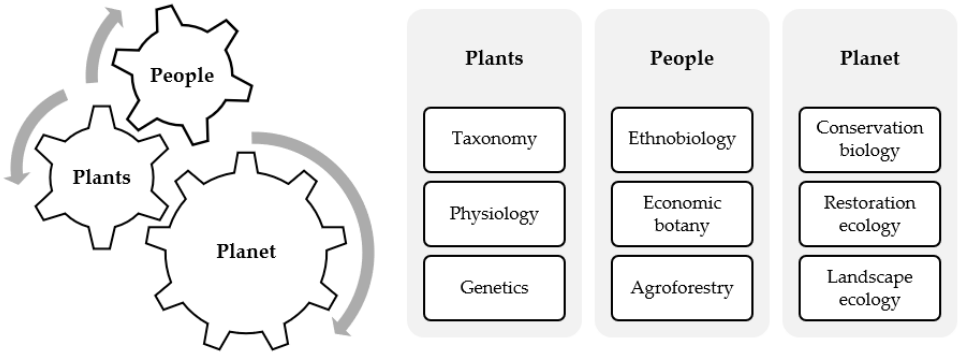

Figure 1. Gear model for the "Plants, People, Planet" concept and representative topics in botany.

1.2.2. Transformative Learning as an Educational Strategy in ESD

Transformative learning [36], another perspective from ESD, can be a valuable educational strategy to operationalize the PPP concept in fostering plant awareness. According to Mezirow [36], transformative learning involves engaging individuals in critical reflection and self-examination, leading to a deep change in their beliefs, values, and behaviors [36,37]. This learning process enables learners to re-evaluate their assumptions about the world and their roles in it, empowering them to become active agents of change in their communities and beyond. In the context of the PPP concept, transformative learning can be employed to help students better understand the interconnectedness of plants, human societies, and the

environment. By incorporating transformative learning experiences into botany, educators can encourage students to critically reflect on their own relationships with the plant world; recognize the social, economic, and environmental consequences of their actions; and develop a sense of responsibility towards the sustainable management of plant resources.

The narrative-based approach is one of the potential tools for transformative learning, as it harnesses the power of storytelling to facilitate deep personal reflections, challenge assumptions, and inspire change [38]. By sharing and examining personal narratives or stories related to plant biodiversity, human societies, and the environment, learners can gain a better understanding of their own perspectives, beliefs, and values, as well as those of others. In the context of botany education, a narrative-based approach can be employed to explore the rich cultural, historical, and ecological dimensions of the PPP concept. Educators can use stories from diverse sources, such as traditional indigenous knowledge, local community experiences, and global case studies, to stimulate discussions and critical reflections on the importance of plants [14].

Several studies have explored the potential of different variants of narrative-based approaches to foster plant awareness. Balding and Williams [6] and Mackenzie [14] recommended incorporating creative activities, such as story writing, drawing, imagining, and role-playing, in educational programs to promote empathy towards plants. This approach aims to engage students on a personal level and foster an emotional connection with plants, leading to a greater appreciation for their role in daily life. Iriart et al. [16] proposed blogging about plant science as an approach that combines education with personal reflections and encourages individuals to share their newfound knowledge and insights with others, thus raising awareness about the importance of plants. Stagg and Verde [39] demonstrated the potential of theatrical performance to educate and deepen individuals' understanding of the significance of plants in their lives and the environment.

Overall, the narrative-based approach encourages students to reflect on their own stories and experiences with plants, their connections to local and global communities, and their roles in shaping a sustainable future [38]. By sharing their stories, students can better understand the complex relationships between plants, people, and the planet and become more aware of the underlying values, assumptions, and expectations that shape their worldviews and actions. Engaging with narratives can also foster empathy and compassion, as students are exposed to diverse perspectives and experiences related to plant biodiversity and its conservation [7]. Through this process, learners can challenge their existing beliefs, discover new ways of thinking, and develop a greater sense of responsibility towards the sustainable management of plant resources. Arguably, incorporating a narrative-based approach into transformative learning experiences can inspire learners to become active agents of change advocating for the conservation of plant biodiversity and the promotion of sustainable practices. By weaving personal narratives into plant biodiversity education, educators can cultivate a deeper sense of connection and responsibility among students, fostering plant awareness and a commitment to a more sustainable future for both people and the planet [34].

1.3. Focus of the Study

In the context of Indonesia, the necessity of research on integrating ESD principles into science teacher education programs with a focus on plant awareness is of utmost importance. Indonesia is a mega-biodiverse country, home to an estimated 25,000 species of flowering plants [40], many of which are endemic to the country. Indonesia's rich biodiversity plays a vital role in supporting the livelihood of millions of people and maintaining ecosystem services that are essential for the environment. However, the country faces various challenges, such as deforestation, habitat loss, and climate change, which are putting immense pressure on its plant diversity and ecosystems [41]. With a growing population and rapid development, raising awareness about the importance of plant conservation and sustainable resource management is crucial for the long-term well-being of the nation [42]. By conducting research to identify effective strategies for the incorporation of

plant awareness in science teacher training programs, we can ensure that future Indonesian science teachers will be better equipped to inspire their students to become responsible environmental stewards. This will ultimately help students understand the critical roles plants play in maintaining ecosystem health and the importance of conserving Indonesia's unique plant diversity.

The objective of this study was to examine the effectiveness of an intervention unit that incorporates ESD perspectives, with a specific focus on the PPP concept and transformative learning through the narrative-based approach. Ninety-one (n = 91) third-year teacher trainee students who were studying to become lower secondary school (grade 7–9) science teachers and were enrolled in a public university in East Java, Indonesia, participated in the study. By employing a mixed-methods approach, this research sought to provide a comprehensive understanding of the impact of ESD-integrated botanical lessons on the participants. Data were collected through self-reported surveys, reflective journals, and focus group interviews to gain insights into the participants' experiences, perceptions, and learning processes. This study sought to contribute to the growing body of research on plant awareness and informed the development of effective strategies for the promotion of sustainability-oriented botanical education in science teacher training programs in line with the ESD framework and the SDGs. Specifically, the research questions (RQs) that guided this study were as follows:

RQ 1. *How does an intervention unit that integrates ESD perspectives affect the plant awareness of trainee science teachers in a biodiversity course?*

The first research question sought to determine the effectiveness of an intervention unit that integrates ESD perspectives on the plant awareness of trainee science teachers. Indonesia's rich biodiversity is at risk due to deforestation, habitat loss, and climate change, and it is crucial to raise awareness about plant conservation and sustainable resource management [42]. While previous studies have examined the implementation of ESD in teacher education, particularly in chemistry education [43,44], there is limited research on the impact of ESD-integrated interventions on botanical education [15]. Moreover, by addressing this gap in the literature, this research question aimed to provide insights into whether incorporating ESD principles can effectively enhance the plant awareness of trainee teachers. The findings of this study contribute to the identification of effective strategies for the promotion of plant awareness in science teacher training programs and help to achieve the SDGs.

RQ 2. *What are the key features of the ESD-integrated intervention unit that may contribute to the change in plant awareness of trainee science teachers?*

This second research question aimed to identify the key features of the ESD-integrated intervention unit that may have contributed to the change in the plant awareness of trainee science teachers. Pertinent studies have explored effective strategies to foster plant awareness among students, including hands-on learning activities, outdoor activities, and improving situational interest in plants [45–47]. However, the same has not been adequately explored in the context of science teacher education programs. By addressing this gap in the literature, this research question sought to provide a comprehensive understanding of the "Plant, People, Planet" concept and "transformative learning" as content and as strategy to foster plant awareness, respectively. The findings contribute to the growing body of research on plant awareness and inform the development of effective strategies for the promotion of sustainability-oriented botanical education in science teacher training programs in line with the ESD framework and the SDGs.

RQ 3. *How do trainee teachers' experiences, perceptions, and learning processes change due to engaging with the ESD-integrated intervention unit?*

The third research question aimed to gain insights into how trainee teachers' experiences, perceptions, and learning processes changed when engaging with the ESD-integrated

intervention unit. This question sought to provide a comprehensive understanding of the impact of the intervention unit on trainee teachers' learning processes, as well as their perceptions and experiences. The findings of this study can contribute to the identification of the strengths and weaknesses of the approach and provide a basis for future improvements in science teacher education programs. By addressing this gap in the literature, this research question helps to inform the development of effective strategies for the promotion of sustainability-oriented botanical education in science teacher education programs in line with the ESD framework and the SDGs.

2. Materials and Methods

2.1. Study Design

This study employed an explanatory sequential mixed-methods approach [48]. We chose this research design to benefit from the complementary strengths of both quantitative and qualitative data, providing a more comprehensive understanding of the intervention's impact. The research design included pre- and post-intervention surveys to collect quantitative data, evaluating the participants' plant awareness before and after the intervention. This allowed for the measurement of changes in plant awareness due to the intervention. Furthermore, qualitative data obtained from the reflective journals and focus group interviews offered insights into the participants' experiences, perceptions, and learning processes, providing a deeper understanding of how the intervention influenced their plant awareness. In this study, both quantitative and qualitative data were considered equally significant [49], ensuring a balanced and holistic perspective on the intervention's effectiveness.

2.2. Study Participants

At the outset, one hundred and six (n = 106) consenting participants were recruited for the study, all of whom were trainee teachers enrolled in a biodiversity course (a hybrid of introductory-level botany and zoology) within a science teacher education program in a public university in East Java, Indonesia. These participants were undergraduate students who were studying to become lower secondary school (grade 7–9) science teachers and who had already completed basic biology courses. The participants were 21 to 24 years old (mean = 22.5 years, SD = 0.90 years) and they were all in their third year of the four-year teacher education program. The majority of these participants were female (87%) and from rural areas (55%). Only the data from ninety-one participants (n = 91) who attended all sessions without fail were included in the final analysis. This decision ensured data consistency and allowed for a more precise assessment of the intervention's impact on plant awareness.

2.3. Intervention Unit

The intervention lasted for six weeks and was composed of seven lessons in theoretical botany, which made up part of the biodiversity course. Table 1 provides an overview of the topics covered in each lesson. Each lesson lasted for 150 min, with the lecture being 60 min long and the activities taking up to 90 min. The lecture covered PPP concepts and fundamental botanical topics, including morphology, anatomy, physiology, and classification. The cognitive learning objectives aligned with SDG 15 "Life on Land" in UNESCO's Education for Sustainable Development Goals Framework [29]. These objectives covered a wide range of topics related to biodiversity, including different levels of biological diversity (e.g., genetic, species, and ecosystem), ecosystem services (e.g., provisioning, regulating, cultural, and supporting services), threats to biodiversity (e.g., invasive alien species, overexploitation, and global warming), the impact of poor forestry and agricultural practices (e.g., monoculture) on soil regeneration, and conservation strategies beyond natural reserves (e.g., through land legislation).

Table 1. Summary of the intervention unit.

Lesson	Lecture Theme (60 min)	Activity (90 min)
W1	Orientation sessions	Workshop on reflective journal
W2	Botany and biodiversity	Sharing personal experiences about plants
W3	Ecosystem services (ESs) and	Comparing the ESs of different plants
W4	Ecosystem disservices (EDs) of plants	Discussing controversial issues about plants
W5	Invasive alien species (IAS)	Writing a management scenario for a fictional IAS Fieldwork to identify invasive alien species
W6	Plants and global issues	Role-playing activity/stakeholder analysis

As an educational strategy, the intervention unit employed transformative learning through a narrative-based approach. This approach was guided by the interlocking narrative idea introduced by Levinson [50], which combined storytelling and critical realism to contextualize basic botanical concepts in the wider contexts of global sustainability and biodiversity issues, such as invasive alien species. The activity section of the intervention unit was developed to expand on the ESD perspectives explored during the lecture section. The activities included in the intervention unit were designed to enhance the participants' understanding of plants and sustainability while imparting knowledge about different pedagogical approaches. The participants shared personal experiences related to plants, such as memories of gardening or interactions with nature [14]. They also engaged in fieldwork, such as observing and identifying invasive alien plants in a nearby ecosystem [51], and keeping reflective journals to promote critical thinking and reflection [37]. Additionally, the participants engaged in activities to understand the benefits and controversies of certain plants, drew pictures of new invasive alien plants, and wrote management scenarios [52]. A role-playing activity [53] was conducted to analyze an agricultural issue through stakeholder analysis, providing an opportunity to apply their learning in a practical way. These activities aimed to provide an immersive learning experience, ultimately increasing the participants' plant awareness and self-efficacy in teaching about plants and sustainability.

2.4. Quantitative Data Collection and Analysis

A 30-item questionnaire (Table 2) was utilized to measure five components of plant awareness: attention, attitude, interest, knowledge, and self-efficacy to teach about plants, as translated from previous studies [13,54]. Prior to data collection, the translated draft was reviewed by an external team of reviewers, including an experienced science school teacher, a botanical expert from a national research agency, and a lecturer from a faculty of education. Four undergraduate students from the same affiliation as the participants also reviewed the draft for readability. The questionnaire's reliability was confirmed by calculating Cronbach's alpha coefficient. The study sample included 91 trainee teachers, and the data were analyzed using a dependent *t*-test through IBM SPSS 29. The significance level was set at $p < 0.05$, and the mean scores of the pre-test and post-test were compared. The effect size was calculated using Cohen's *d*.

Table 2. Overview of the self-reported survey utilized in this study.

Aspect	n	Cronbach α		Sample Item
		Pre	Pre	
Attention	(7)	0.65	0.83	I notice that all the plants in my environment, not just those I eat
Knowledge	(6)	0.82	0.89	Plants can be a source of new medicines
Relative interest in plants	(4)	0.74	0.78	I think plants are more interesting to learn about than animals
Relative interest in animals	(3)	0.84	0.88	Animal conservation is more interesting than plant conservation
Attitude	(4)	0.81	0.81	I care about the plants that are in my environment
Self-efficacy	(5)	0.85	0.83	I am confident in teaching about plants

2.5. Qualitative Data Collection and Analysis

The qualitative data from the participants' reflective journals were analyzed using conceptual content analysis [55]. Two groups of coders conducted the analysis, including the first and second authors and two trained students. The participants' journal entries were quantified, and any discrepancies were resolved through discussion and consensus to enhance the analytical rigor. The coding reliability was assessed using Cohen's Kappa Coefficient [49], and an overview of the coding is presented in Table 3. To provide further clarification on the analysis of the reflective journals, ten participants volunteered to participate in a focus group interview conducted through an online video conference tool. The focus group comprised three sessions, and each session lasted an average of 55.67 min (SD = 2.05). The interview transcripts were used to supplement and elaborate upon the results of the quantitative survey and content analysis of the reflective journal.

Table 3. Overview of the coding guideline.

No	Prompt Label	Prompt	Code	Example
P1	Engagement to lesson	What did you do during the class?	Passive Active	e.g., focused on the lecture topic e.g., focused on an activity topic
P2	Emotional response	How did you feel during the class?	Negative Positive	e.g., showing dissatisfaction e.g., showing satisfaction
P3	Conceptual focus	What was the essential finding?	Plant People Planet	e.g., morphology e.g., agriculture, cash crop e.g., invasive species
P4	Future reflection	How will you apply it in the future?	Reflection Non-reflection	e.g., adding a personal idea e.g., verbatim copy of P1

2.6. Ethics, Validity, and Reliability

The authors used several strategies to ensure validity and reliability, and ethical considerations were adhered to [49]. The university's Institutional Review Board mandated that all participants provide informed consent and use pseudonyms to protect their identities during data analysis and reporting. The survey instrument was based on an established measurement of plant awareness developed by Parsley [13] and was pilot tested with a similar population (n = 10) to ensure its validity and reliability; the necessary modifications were made to improve the clarity and relevance of the items. The data sources, including surveys, reflective journals, and focus group interviews, were triangulated to provide a comprehensive perspective of the participants' experiences and to validate the findings. The thematic analysis results were shared with the participants of the focus group interview to confirm the accuracy and authenticity of their responses.

3. Results

3.1. Plant Awareness Questionnaire

Figure 2 and Table 4 present a statistical analysis examining the impact of the ESD-integrated botanical lesson on the participants' plant awareness. A dependent t-test was used to analyze the data. The results showed a statistically significant difference but small effect sizes in favor of the post-test mean scores for the attention (t (90) = −2.64, $p < 0.05$, Cohen's d = 0.28) and attitude (t (90) = −2.61, $p < 0.05$, Cohen's d = 0.28) dimension of plant awareness. However, no statistically significant difference was found for the knowledge dimension (t (90) = 2.15, $p > 0.05$, Cohen's d = 0.23). While there was a statistically significant difference and a large effect size in favor of the post-test mean scores for relative interest in plants (t (90) = −7.54, $p < 0.05$, Cohen's d = 0.70), there was no significant difference for relative interest in animals (t (90) = −7.54, $p < 0.05$, Cohen's d = 0.00). Finally, for self-efficacy, there were both statistically significant differences in favor of the post-test mean scores and a very large effect size (t (90) = −12.48, $p < 0.05$, Cohen's d = 1.31).

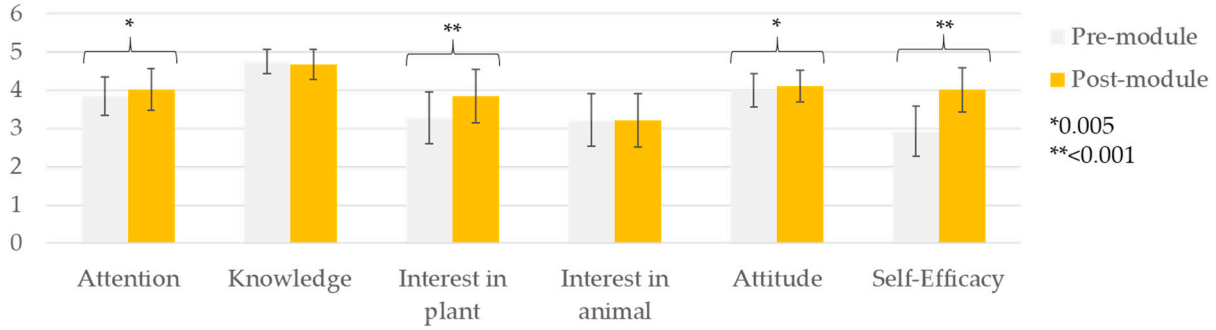

Figure 2. Dependent *t*-test result of the plant awareness questionnaire.

Table 4. Details of the dependent *t*-test results of the plant awareness questionnaire.

Aspect	Mean (±SD)				** *t*	*p*	**** r	Cohen's *d*
	Pre		Post					
Attention	3.85	(±0.50)	4.02	(±0.54)	−2.64	0.00 ***	0.33	0.28
Knowledge	4.74	(±0.32)	4.67	(±0.39)	2.15	0.17	0.55	0.23
Interest in plants	3.28	(±0.68)	3.84	(±0.69)	−7.54	0.00 ***	0.48	0.70
Interest in animals	3.22	(±0.69)	3.21	(±0.69)	0.04	0.48	0.33	0.00
Attitude	3.99	(±0.43)	4.10	(±0.42)	−2.61	0.00 ***	0.56	0.27
Self-efficacy	2.93	(±0.65)	4.01	(±.058)	−12.48	0.00 ***	0.14	1.3

** *t*-value; *** $p < 0.05$; **** correlation.

3.2. Reflective Journals

The reflective journals consisted of 6 entries for each of the 91 participants, totaling 546 entries and covering four prompts: engagement with the lesson (P1), emotional response (P2), conceptual focus (P3), and future reflection (P4). The inter-rater agreement was evaluated using Cohen's Kappa Coefficient [49], and the results indicated good to very good agreement between raters for four of the questions: good for P1, very good for P2, very good for P3, and good for P4. The conceptual analysis of the reflective journal is summarized in Figure 3. The majority of the participants (68%) reported active engagement with the ESD-integrated botanical lesson. The participants' positive responses to the lessons were evident, with 68% expressing their satisfaction and appreciation for the learning experience. The participants noted that the lessons expanded their knowledge about plants and their role in sustainability. Despite the positive feedback, the analysis of the qualitative data revealed a discrepancy in the participants' conceptual focus. More participants concentrated on plant-focused content (50%) compared to people-focused (28%) or planet-oriented content (22%). Another area for improvement emerged when analyzing the participants' ability to reflect on their learning experiences. Only slightly over half of the participants (55%) were able to consistently reflect on what they had learned.

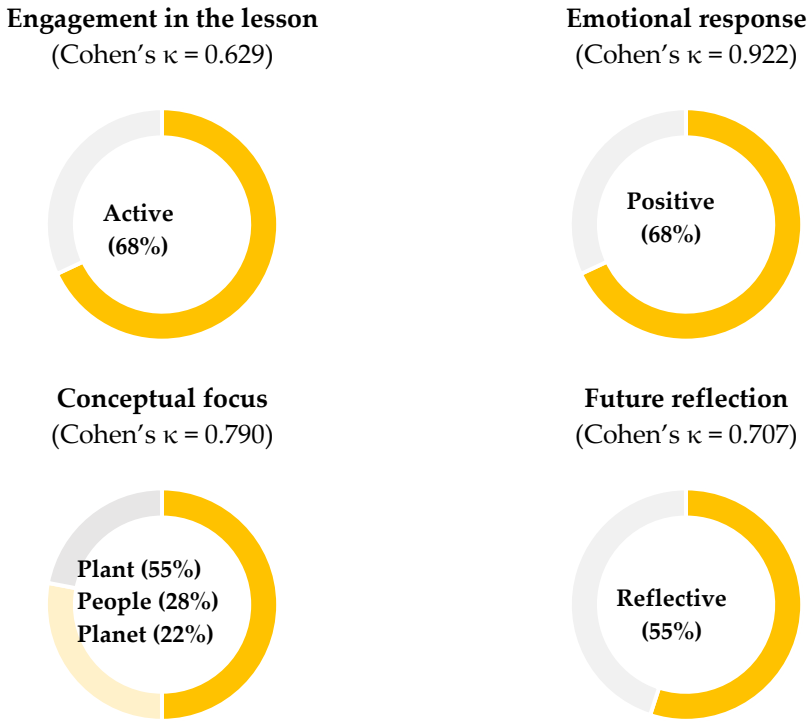

Figure 3. Content analysis result of the reflective journal entries.

3.3. Focus Group Interview

The focus group interviews were conducted to provide additional insights into the participants' experiences with the sustainability-oriented botanical lessons, as well as to further elaborate on the findings from both the survey and the reflective journal entries. The participants shared their experiences and opinions on various aspects of the botanical lessons, including the effectiveness of the lessons, specific activities they found engaging, and their thoughts on the overall impact on their plant awareness.

3.3.1. Excerpts Supporting Survey Results

The focus group interviews provided insights into the participants' experiences, elaborating on the survey results related to attention and attitude towards plants, relative interest in plants, and self-efficacy. The participants attributed the positive outcomes to the engaging content and thought-provoking activities of the lessons.

- Regarding attention and attitude, Interviewee 6 shared, "The lecture on ecosystem services really opened my eyes to how interconnected everything is in nature. I now appreciate how important plants are for the well-being of the entire ecosystem. The classroom activity where we drew invasive alien species and discussed their impact on native ecosystems further solidified this understanding".
- Regarding relative interest in plants, Interviewee 4 mentioned, "I was particularly intrigued by the topic of controversial issues related to plants, such as deforestation and monoculture farming. The classroom discussion allowed us to critically analyze the complexities and trade-offs associated with these issues. This thought-provoking experience sparked my interest in learning more about the real-life challenges faced by ecosystems and the role of plants in addressing them".
- Regarding self-efficacy to teach about plants, Interviewee 5 stated, "The lessons has definitely increased my confidence in teaching plant-related topics. The hands-on activities and the collaborative learning environment gave me the tools and experience necessary to effectively engage students in learning about plants and their role in sustainability".

The focus group interviews provided additional insights into the participants' experiences, expanding on the survey results related to attention and attitude towards plants, relative interest in plants, and self-efficacy. The participants attributed the positive outcomes to the engaging content and thought-provoking activities throughout the lessons. For example, Interviewee 6 mentioned that the lecture on ecosystem services helped them understand the interconnectedness of nature and the importance of plants in the well-being of the ecosystem. Interviewee 4 expressed their curiosity about controversial issues related to plants, such as deforestation and monoculture farming, and how the classroom discussion allowed for critical analyses of these complexities. Interviewee 5 noted that the lessons increased their confidence in teaching plant-related topics through hands-on activities and collaborative learning. These excerpts demonstrate how the engaging content and activities in the lessons fostered positive changes in attention and attitude, interest, and self-efficacy among the participants.

3.3.2. Excerpts Supporting Content Analysis of Reflective Journals

The focus group interviews offered additional insights that elaborated on the findings from the reflective journals, providing a more comprehensive understanding of the participants' experiences.

- Regarding engagement with the lesson, Interviewee 3 shared, "The reflective journal entries really allowed me to process my thoughts about each lesson. I remember how the lecture on the role of plants in mitigating climate change got me hooked, and I found myself more engaged with the sustainability-oriented botanical lessons than I initially expected, especially during the hands-on activities and group discussions".
- Concerning emotional response, Interviewee 1 mentioned, "When I look back at my reflective journal entries, I can see how my enthusiasm for the lessons grew over time. I didn't expect to feel so connected to the topic of invasive species, but the case studies and interactive approach made the learning experience truly enjoyable and memorable".
- Regarding conceptual focus, Interviewee 5 stated, "I realized, through the reflective journal exercise, that I tended to focus more on plant-focused content, like the adaptations of desert plants, than on people- or planet-oriented content. Lecture during the final session of the lessons helped me understand the need to broaden my perspective and make connections between these areas, such as considering the cultural importance of plants to local communities".
- Regarding future reflection, Interviewee 4 elaborated, "As I reviewed my journal entries before final submission, I noticed that my ability to reflect on my learning experiences improved over time. I became more aware of the importance of reflecting on how the knowledge I gained about the controversies surrounding low genetic diversity in banana and the soil pollution caused by pesticide could be applied in my future teaching practice, sparking discussions with my students about the ethical dimensions of plant-related issues".

The focus group interviews provided more comprehensive insights into the participants' experiences, elaborating on the findings from the reflective journals. For instance, Interviewee 3 expressed how the reflective journal entries helped them process their thoughts about each lesson and how they became more engaged with the intervention unit than expected, particularly during the hands-on activities and group discussions. Interviewee 1 reflected on how their enthusiasm for the lessons grew over time, especially regarding the topic of invasive species. Interviewee 5 realized, through the reflective journal exercise, their tendency to focus more on plant-focused content and how the final lecture of the lessons broadened their perspective. Finally, Interviewee 4 noted how their ability to reflect on their learning experiences improved over time, particularly regarding the ethical dimensions of plant-related issues. These excerpts from the focus group interviews helped to provide a more complete picture of the participants' engagement, emotional response, conceptual focus, and future reflection.

4. Discussion

4.1. Effect of Integrating ESD Perspectives on Plant Awareness (RQ1)

The findings from the intervention unit, integrating ESD perspectives in botanical lessons, demonstrate the potential of transformative learning [35,36] and the "Plant, People, Planet" (PPP) concept [31,32] in fostering plant awareness among trainee teachers. The results indicate that the intervention positively influenced trainee teachers' attention and attitudes towards plants, as well as their self-efficacy. By adopting the PPP concept, the intervention unit holistically addressed the economic, social, and environmental aspects of plant biodiversity, fostering a comprehensive understanding of the subject matter. Although no significant difference was observed in the knowledge dimension, the positive impacts on students' attitudes and self-efficacy suggest that the intervention effectively nurtured a sense of responsibility and engagement towards plant conservation and sustainable practices. These outcomes can be attributed to the transformative learning facilitated by the narrative-based approach [36,50], which encourages critical reflection, self-examination, and a deep understanding of the interconnectedness between plants, human societies, and the environment.

Mezirow's transformative learning theory [36] posits that learning involves a critical examination of one's pre-existing assumptions and beliefs, resulting in a transformative experience that fundamentally alters one's perspective and worldview. This transformative process involves a shift from a narrow, rigid, and unquestioned understanding of the world to a more open, flexible, and critically reflective one [36]. The process of transformative learning is facilitated by "disorienting dilemmas," which challenge one's existing assumptions and beliefs, prompting a reassessment and reconstruction of one's understanding of the world. The ultimate goal of transformative learning is to promote personal growth, development, and empowerment. In the context of the study's findings, the integration of ESD perspectives into botanical education provided trainee teachers with the opportunity to engage in a transformative learning process, leading to an enhanced awareness of plants' significance in sustaining life and maintaining ecological balance. Through critical self-reflection, trainee teachers reevaluated their preconceived ideas about plants, resulting in a deeper understanding and appreciation of their environmental significance. This transformative experience leads to a shift in attitudes and increased self-efficacy, promoting a sense of responsibility towards plant conservation and sustainability.

Applying the lens of Mezirow's transformative learning theory [36], the study's findings can be further analyzed in terms of the potential for perspective transformation and personal growth. Although the intervention did not yield significant differences in trainee teachers' knowledge of plants or relative interest in animals, it did have a substantial impact on specific aspects of plant awareness. This suggests that the transformative learning experiences may have been more focused on challenging trainee teachers' existing assumptions about plants and their importance, rather than offering a broader understanding of the natural world. Despite this limitation, the transformative learning process still holds considerable value. As trainee teachers confront their "Plant Awareness Disparity" [12] and critically reflect [37] on the role of plants in the environment, they can undergo a process of perspective transformation. This transformation can lead to a shift in values and priorities, emphasizing the importance of plants in the broader context of sustainability. Although the intervention did not significantly increase trainee teachers' knowledge of plants or relative interest in animals, the improved plant awareness components may still contribute to a more environmentally responsible and sustainable mindset.

In light of these findings, it is evident that integrating ESD principles into botany education can lead to transformative learning experiences, challenging trainee teachers' existing assumptions about plants and their importance in the context of sustainability. By fostering improved plant awareness components, this approach contributes to the cultivation of a more environmentally responsible and sustainable mindset among future teachers. Although the intervention's impact may be more focused on specific aspects of plant awareness, the potential for significant perspective transformation and personal

growth among the participants is undeniable. As a result, the integration of perspectives from ESD such as the PPP concept and transformative learning can play a crucial role in the development of a more environmentally conscious and sustainable society by empowering educators and learners to appreciate the vital role plants play in our world.

4.2. Key Features of the Intervention Unit (RQ2)

The intervention unit within this study was designed to be a comprehensive and engaging educational experience, with a primary focus on fostering plant awareness and promoting sustainability-oriented botanical education. Central to this lesson was the PPP concept [31,32]. This concept emphasized the intricate interdependence between plants, humans, and the environment, highlighting the critical role that plants play in maintaining a sustainable future. By incorporating the PPP concept into the educational content, the intervention unit aimed to facilitate the development of a profound understanding of the complex relationship between these three components. This comprehensive perspective allowed the participants to appreciate the myriad ecosystem services that plants provide, including provisioning, regulating, supporting, and cultural services [56]. Through this understanding, the learners could acknowledge the critical importance of plants in achieving sustainability objectives, ultimately contributing to the overall goal of preventing plant blindness by fostering plant awareness [1,12,13]

To deliver the PPP concept effectively, the intervention unit employed a narrative-based approach [50]. Transformative learning emphasizes the importance of critical reflection and the development of new perspectives, fostering both personal and professional growth among trainee teachers. In the context of the intervention unit, transformative learning encouraged the participants to critically examine their assumptions about the role of plants in their lives and the environment, leading them to re-evaluate their understanding and develop new insights. Levinson's interlocking narrative idea [50] was used to synthesize storytelling and critical realism, providing a context for the PPP perspective. Through this method, the participants were exposed to multiple perspectives on the role of plants in achieving sustainability, engaging with the complexities of real-world issues such as the dual role of Water Hyacinth as an attractive ornamental plant and a destructive IAS [57]. By adopting the interlocking narrative framework and transformative learning, the intervention unit enabled the participants to gain a more comprehensive understanding of the trade-offs associated with different plant species and the significance of plants in providing essential ecosystem services.

The narrative-based approach of the intervention unit, grounded in transformative learning, incorporated four key narrative features, as outlined by Glaser et al. [58]:

1. Personalization, consistent with Mezirow's theory, allowed the participants to connect with the material on a personal level, making the content more relatable and memorable. By encouraging the learners to see the relevance of the information to their own lives, the personalization feature fostered critical reflection and facilitated transformative learning experiences.
2. Emotionalization engaged the participants by evoking emotions and making the content more meaningful to them. By tapping into the emotional aspect, the intervention unit not only captured the learners' attention but also fostered a more profound connection with the subject matter, ultimately promoting empathy towards plants and their role in daily life.
3. Fictionalization, another key feature of the narrative-based approach, presented the content in an interesting and engaging manner. By using elements of storytelling and imaginative scenarios, the intervention unit transformed the material into an experience that the participants could connect with and immerse themselves in. This creative method aligned with Mezirow's transformative learning theory by encouraging the learners to engage more deeply with the content and critically reflect on the broader implications of the presented scenarios.

4. Dramatization, the final narrative feature, brought the content to life by using vivid descriptions, lively examples, and dramatic events. This strategy helped to create a more dynamic and captivating learning experience, allowing the participants to visualize and better understand the concepts being taught, fostering transformative learning by engaging the learners in deep reflection and critical thinking.

Incorporating transformative learning into the intervention unit not only enriched the educational content but also empowered the participants to challenge their assumptions and develop new understandings about the interconnectedness of plants, people, and the planet [31,32]. This approach facilitated a deeper level of learning that went beyond the mere acquisition of knowledge, promoting the internalization of the material and inspiring the participants to become agents of change in their personal and professional lives. By fostering a sense of responsibility and commitment towards promoting plant awareness, the transformative learning experiences within the intervention unit had the potential to inspire lasting change in the participants' attitudes and behaviors.

The broader implications of utilizing transformative learning and the PPP concept in the intervention unit extend beyond the individual level. By incorporating these elements into teacher education programs, future educators can be equipped with an understanding of the central role plants play in maintaining a sustainable future [10]. This knowledge will enable them to educate their students on the importance of plants and the ecosystem services they provide, thus promoting greater awareness of their significance. Furthermore, by fostering transformative learning experiences in their classrooms, teachers can inspire their students to become active participants in addressing sustainability challenges and promoting a healthier relationship between people and the environment.

Overall, the intervention unit, which was centered on preventing plant blindness by fostering plant awareness as the primary goal, utilized the PPP concept as the educational content and implemented transformative learning through a narrative-based approach, specifically the interlocking narrative framework, as the educational strategy. Grounded in Mezirow's transformative learning theory [36,37], this comprehensive approach sought to provide a holistic and engaging learning experience that contributes to the promotion of sustainability-oriented botanical education. By encouraging critical reflection, challenging assumptions, and inspiring new perspectives, the intervention unit facilitated transformative learning experiences that not only enhanced trainee science teachers' understanding of the significance of plants but also empowered them to become agents of change in promoting sustainability and plant awareness.

4.3. Changes in Participants' Experiences and Perceptions (RQ3)

The triangulation of the data from the reflective journals and focus group interviews provided a more comprehensive understanding of the trainee teachers' experiences and learning processes. These triangulated findings demonstrated the interconnectedness of their engagement, emotional responses, conceptual focus, and future reflection. The participants reported active engagement with the ESD-integrated intervention unit and expressed satisfaction and appreciation for the learning experience. The reflective journals and focus group interviews indicated a discrepancy in the participants' conceptual focus, with fewer participants focusing on people- or planet-oriented content. However, these reflective exercises helped them realize their inclination to focus on plant-focused content and the need to broaden their perspective. Slightly over half of the participants consistently reflected on what they had learned, with their ability to reflect on their learning experiences improving over time. This improvement was marked by increased awareness of the importance of considering the ethical dimensions of plant-related issues and integrating their new knowledge into their future teaching practices.

From the lens of Mezirow's transformative learning theory [36], the ESD-integrated intervention unit stimulated significant changes in the experiences, perceptions, and learning processes of the trainee teachers. By presenting thought-provoking content and challenging existing knowledge and beliefs, the intervention led the participants to confront disorient-

ing dilemmas and delve deeper into the intervention unit. This transformative learning process involved critical reflection, rational discourse, and the integration of new perspectives. As the participants engaged with the ESD-integrated intervention unit, they entered the critical reflection phase of transformative learning. Through reflective journals and focus group discussions, they examined their prior assumptions, beliefs, and emotional responses to the lesson's content. This critical reflection allowed the learners to identify gaps in their understanding, recognize biases, and develop a more comprehensive perspective [36] that includes people- and planet-oriented aspects. The final stage of transformative learning, involving rational discourse and the integration of new perspectives, was evident in the experiences of the trainee teachers. The ESD-integrated intervention unit facilitated opportunities for the learners to exchange ideas, critically analyze complex issues, and consider alternative viewpoints through classroom discussions, group activities, and focus group interviews. As a result, the participants began to incorporate their newly acquired perspectives on plants and sustainability into their personal and professional lives, demonstrating increased interest in plant-related topics, improved self-efficacy in teaching about plants, and a desire to include sustainability-oriented content in their future teaching practices.

The integration of ESD perspectives, as exemplified in this study, has broad implications for the overall quality of education and the development of future generations of educators. By incorporating sustainability-oriented content and promoting transformative learning experiences, educational institutions can foster a more holistic understanding of the interconnectedness between people, plants, and the planet. This approach not only enhances the knowledge and skills of trainee teachers but also instills in them a sense of responsibility and commitment to incorporating sustainability-oriented content in their future teaching practices. Ultimately, the integration of ESD perspectives contributes to the cultivation of environmentally conscious, ethically aware, and socially responsible educators who are better equipped to inspire and empower future generations to address complex global challenges and work towards a more sustainable future.

4.4. Limitation of the Study

This study presents certain limitations that need to be considered when interpreting the results. One limitation is the generalizability of the findings, as the study's population consisted of third-year science teacher trainees from East Java, Indonesia, with a majority of participants being female, aged 20–24, and from rural areas. This demographic distribution might limit the applicability of the findings to other populations with different cultural, social, and demographic backgrounds. Nevertheless, the study still provides valuable preliminary insights that can inspire future research involving more diverse samples and exploring the effects of similar interventions in various settings. Such research can help develop a more comprehensive understanding of how ESD-integrated lessons may influence plant awareness among different groups and contexts.

Another limitation is the intervention's short duration of six weeks with a limited number of lessons. This might not offer a comprehensive understanding of the long-term effects of the integration of ESD perspectives into botanical education. However, the study's findings contribute to our understanding of the immediate impact of this approach, opening up opportunities for future research to explore longer intervention periods and a greater number of lessons. This would enable potential improvements in teaching practices related to ESD-integrated botanical education.

Regarding assessment tools, the study utilized a Likert scale to evaluate the knowledge component of plant awareness, which might have limited the accuracy of the assessment compared to a concept inventory. Additionally, the presence of confirmatory factor analysis (CFA) to confirm the factor structure of the translated questionnaire could have provided more robust results. Despite these constraints, the Likert scale still offered valuable data to help us understand the initial effects of the intervention. Future research could benefit from incorporating more rigorous assessment tools, such as concept inventories, and conducting

CFA to validate the questionnaire's factor structure. This would not only enhance the depth and accuracy of the findings but also help researchers identify areas in which ESD-integrated lessons may be particularly effective or require improvements. By refining the assessment tools and validation methods, future studies can provide a more detailed and nuanced understanding of the true impact of ESD-integrated lessons on plant awareness and botanical education.

4.5. Recommendations for Future Studies

Based on the findings and limitations of the study, several recommendations are proposed for future research and practice to enhance the generalizability, validity, and practicality of ESD-integrated botanical lessons. To begin with, future studies should broaden the study population by including a more diverse and representative sample of participants, accounting for various social, cultural, and demographic factors. In addition, researchers should strengthen the validity of the instruments by employing more rigorous analytical methods to validate the factor structure of questionnaires and assessment tools. The utilization of more accurate and objective assessment methods, such as concept inventories, instead of subjective measures such as Likert scales, would provide a comprehensive evaluation of participants' knowledge and understanding.

Furthermore, by employing longitudinal study designs and conducting comparative studies, insights into the long-term effects of sustainability-oriented botanical lessons and the effectiveness of different pedagogical strategies can be found. Longitudinal designs would enable the assessment of the sustainability of the observed changes in plant awareness and understanding, as well as the impact of the lessons on teaching practices and students' learning outcomes. Comparative studies can help identify the most effective approaches for enhancing plant awareness and understanding of sustainability perspectives.

Lastly, encouraging cross-disciplinary collaboration between experts in ecology, sociology, and education can contribute to a comprehensive understanding of the complex issues related to plants and sustainability. This cross-disciplinary approach can help develop more effective and well-rounded ESD-integrated lessons. In addition to focusing on pre-service teacher education, professional development opportunities should be offered to in-service teachers to enhance their plant awareness and understanding of sustainability principles. By extending the benefits of ESD-integrated botanical lessons to the broader educational community, it would be possible to create a more significant and lasting impact on both teachers and students.

5. Conclusions

This study demonstrated the effectiveness of integrating ESD perspectives into botanical lessons for teacher trainees. The intervention unit resulted in statistically significant improvements in the participants' attitudes towards plants, interest in plants, and self-efficacy in teaching plant-related topics. The transformative learning experience led to a more comprehensive understanding of plant-related issues and their connection to broader environmental and social concerns. These findings suggest that the integration of ESD perspectives into biodiversity education positively impacts plant awareness. Further research could explore the long-term impact of integrating ESD perspectives into teacher training programs.

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