

Article

Designing a Teaching–Learning Sequence to Cultivate Plant Awareness Through Transformative Learning

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Abstract

Plant awareness, which refers to the ability to notice, value, and understand the importance of plants, has emerged as a significant research field, particularly considering the growing concerns about sustainability and biodiversity loss. Acknowledging the crucial role of plants in sustaining life on Earth and human well-being, several studies highlight the need for educational interventions that can meaningfully enhance plant awareness. In this context, the present study aims to design, implement, and evaluate a Teaching–Learning Sequence (TLS) with university students in a Pedagogical Department. The TLS was grounded in the principles of transformative learning, an educational approach focused not merely on the transmission of knowledge but on fostering deep, personal shifts in learners' perceptions and attitudes. To assess its impact, the Plant Awareness Disparity Index (PAD-I) was used before and after the implementation, supported by systematic observations and focus group discussions. Results indicate that the TLS effectively enhanced specific dimensions of plant awareness, particularly relative interest between plants and animals and attitudes toward plants. These findings position transformative learning as a promising pedagogical framework for promoting plant awareness in higher education and pave the way for its future application in earlier educational levels.

Keywords: plant awareness; plant blindness; teaching–learning sequence; transformative learning

1. Introduction

Plants play a fundamental role in sustaining life on Earth through a variety of ecological functions. By capturing solar energy through photosynthesis, they form the primary energy base for most terrestrial ecosystems. They also provide essential habitats that support the survival and reproduction of countless other organisms, thereby fostering biodiversity (Narango et al., 2017; Tobisch et al., 2023).

Moreover, plants are integral to key biogeochemical cycles: they actively participate in both the water cycle and the carbon cycle, the latter being critically linked to climate regulation (Eckardt et al., 2023). In addition, soil health is closely connected to plant activity; plants contribute to soil formation and stabilization, and their role in the decomposition of organic matter enhances the fertility and structure of terrestrial substrates (Thakur et al., 2021).

While the environmental significance of plants is undeniably profound, their importance becomes even more pronounced when considered from an anthropocentric perspective. Plants are the primary source of human nutrition, as virtually all food consumed by



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humans originates either from plants themselves or through animals that rely on them within the food chain.

In the domain of health, the pharmaceutical industry relies substantially on plant-based compounds; many modern medicines are derived from plant sources or incorporate bioactive substances first identified in plants and later synthesized in laboratories (Hasnain et al., 2022). In traditional medical systems, dependence on plants is even more extensive, with many communities using botanical remedies as their main form of treatment (Gakuya et al., 2020). Beyond physical health, plants also play a pivotal role in psychological and emotional well-being. Exposure to natural environments—such as gardens, forests, or even houseplants—has been associated with reduced levels of stress, anxiety, and depression, as well as enhanced attention, memory, and creativity (Han, 2024; Oh et al., 2020; Yeo, 2021).

The economic importance of plants is equally significant. Agriculture and forestry employ millions of people worldwide and provide essential raw materials such as timber, fibers, and natural dyes, which are integral to industries including construction, textiles, and crafts. Finally, the educational value of plants is increasingly recognized through initiatives like forest schools (Garden & Downes, 2023), school gardens (Chan et al., 2022; Strgar et al., 2025), and environmental education programs that emphasize outdoor learning (Pirchio et al., 2021).

Based on the preceding discussion, it is evident that plants play a crucial role in both environmental health and human development. These two domains are also central goals of sustainable development, provided they are pursued through genuinely sustainable means. This connection between plants and sustainability has been emphasized in the literature (Amprazis & Papadopoulou, 2020; Lawrence & Calvo, 2023; Sharrock & Jackson, 2017) and should, therefore, be considered a key element of contemporary sustainability policies. As Thomas et al. (2022) argue, efforts toward sustainability become paradoxically unsustainable when plants are overlooked or undervalued. Notably, an emerging body of research situates education for plants within the broader framework of education for sustainability (Akpınarlı & Köseoğlu, 2025; Amprazis & Papadopoulou, 2024a; Compan et al., 2025; Fiel'ardh et al., 2023).

1.1. Plant Awareness

Considering the extensive contributions of plants to ecosystems, and more specifically to human well-being, one might expect a strong public awareness and appreciation of plant life. However, this is often not the case. An increasing number of studies indicate that plants are frequently underappreciated, overlooked, and neglected in everyday life. This pattern of disregard has been well documented in the literature under terms such as plant blindness (Batke et al., 2020; Kaasinen, 2019; Pedrera et al., 2021), lack of plant awareness (Dünser et al., 2024; Pany et al., 2024; D. Sanders et al., 2024) and plant awareness disparity (Hall et al., 2025; Mendes et al., 2023; Mercadé et al., 2025; Prokop et al., 2025).

The first documentation of the phenomenon dates back to the beginning of the 21st century, when American researchers Wandersee and Schussler (1999, 2001) introduced the concept of plant blindness. They defined it as a cognitive bias in which individuals (a) fail to notice plants in their everyday surroundings, (b) perceive plants primarily as supporting the animal kingdom, (c) do not recognize the ecological and societal importance of plants, (d) lack direct, hands-on experiences with plants, (e) possess limited factual knowledge about them, and (f) are insensitive to their aesthetic qualities.

This foundational work by Wandersee and Schussler established a critical line of research into the human–plant relationship and laid the groundwork for what has since evolved into a significant area of scholarly inquiry. The research that followed the work of Wandersee and Schussler can be broadly divided into two periods. The first spans from

the early 2000s to 2019, during which the initial exploratory studies were conducted and published. These studies provided foundational insights into the phenomenon (Bebbington, 2005; Gagliano, 2013; Nyberg & Sanders, 2014; D. L. Sanders, 2007) and proposed strategies to mitigate its impact, often through educational interventions (Cil, 2015; Fančovičová & Prokop, 2011; Pany, 2014; Strgar, 2007).

The second period refers to the last five years, during which there has been a notable increase in published research on this subject, along with important developments in the field. One of the key changes is a shift in terminology. The original term plant blindness has gradually fallen out of frequent use, and alternative terms have emerged. Parsley (2020) was the first to introduce the term plant awareness disparity, which was later adopted by other researchers (Prokop & Fančovičová, 2023; Linderwell et al., 2024; Park & Kim, 2025). In addition, some scholars have been using the broader term plant awareness (Ford, 2025; D. Sanders et al., 2025; Schunko et al., 2025; Söukand et al., 2025), where plant blindness is understood as a lack of plant awareness.

While an increasing number of recent studies tend to adopt the term plant awareness disparity or refer more generally to lack of plant awareness, the term plant blindness still appears in current publications (Blue et al., 2023; Ferreira & Simões, 2024; King, 2025; Novaković, 2025; da Silva, 2025; Tessartz & Scheersoi, 2025). Recognizing this ongoing transitional phase, this manuscript will primarily use the term plant awareness disparity, while acknowledging that plant blindness and the broader framing of plant awareness are employed in the literature to describe the same underlying phenomenon.

Another important change is that there has not only been a shift in terminology, but also in the definition of the phenomenon. The understanding of plant blindness has evolved from the long list of symptoms originally described by Wandersee and Schussler (2001) to a more structured framework based on core components or dimensions. Specifically, plant awareness disparity is now understood to include four main components (Parsley, 2020; Parsley et al., 2022). These are attention, which refers to the limited perception of plants; attitudes, which reflect general indifference toward plants; relative interest, which indicates a greater enthusiasm for animals compared to plants; and knowledge, which refers to cognitive gaps related to plants.

Similarly, the dimensions of plant awareness (Dünser et al., 2025; Pany et al., 2024) include attention, which again concerns the perception of plants; attitudes, which reflect humans' dispositions toward plants; and understanding, which involves recognizing the needs of plants and their role in planetary and human well-being. According to Dünser et al. (2025), the dimension of interest serves as a supportive element of plant awareness but is not considered a core dimension.

1.1.1. Causes of Plant Awareness Disparity

The causes of plant awareness disparity appear to be multifaceted, since there does not seem to be a single explanation. One important factor is the way the human brain functions. From the early stages of research in this field, scholars have suggested that the human brain does not effectively process stimuli from plants (Balas & Momsen, 2014; Wandersee & Schussler, 2001). These findings have been further supported by more recent studies (Achurra, 2022; Guerra et al., 2024; Zani & Low, 2022), which highlight the role of human biology and explain why it should be considered when developing strategies to enhance plant awareness.

Education is also considered one of the main contributing factors to the phenomenon. Within educational institutions, plant organisms are often underrepresented as a subject of study, either in terms of quantity (Brownlee et al., 2021; Chen & Zhai, 2025; Park & Kim,

2024) or in terms of quality, since they are frequently addressed in a superficial manner that does not promote scientific understanding (Pedrera et al., 2025a).

It is also important to note that appreciation and understanding of plants appear to be limited even among educators (Bobo-Pinilla et al., 2023; Kletečki et al., 2023). This limited engagement with plants, particularly among teachers in compulsory education, warrants attention because it may reduce their students' interest and understanding of plant life and, in turn, perpetuate plant awareness disparity (Torres-Porras et al., 2024).

Cultural background is also being explored as a potential contributing factor to plant awareness disparity. Some studies suggest that the phenomenon is more prevalent in the Global North, where people tend to be less connected to nature and often live in urban environments (Stagg & Dillon, 2022; Balding & Williams, 2016). However, other studies indicate that phenomenon exists regardless of society's historical development or urbanization (Linderwell et al., 2024; Walton et al., 2023; Busmann et al., 2025). Consequently, understanding the role of limited human connection with nature as a possible cause of plant awareness disparity remains a relevant and promising area for future research.

1.1.2. Assessing and Enhancing Plant Awareness

Assessing plant awareness disparity presents a particular challenge, especially when considering its complex definition and diverse causes that have been analyzed before. Over the first two decades of research into this phenomenon, scholars have employed a variety of methodological approaches to evaluate it. These include the use of self-developed questionnaires (Amprazis et al., 2021; Bobo-Pinilla et al., 2023; Colon et al., 2020; Söukand et al., 2025), content analysis of participants' drawings (Comeau et al., 2019; Pany et al., 2025), and observational methods (Krosnick et al., 2018; Nyberg et al., 2021). Each approach provides a different lens through which plant awareness disparity can be understood, reflecting the multidimensional nature of the phenomenon.

Some of the questionnaires that have been developed over time to assess the human relationship with plants have been validated and tested for reliability, making them available in the literature as standardized instruments for research purposes (Akpınarlı & Köseoğlu, 2025; Fančovičová & Prokop, 2010). Among these, the most significant is the instrument designed and published by Parsley et al. (2022), as it is the only one that evaluates all four components defined within the concept of plant awareness disparity, rather than addressing only a subset of them. This questionnaire, known as the Plant Awareness Disparity Index (PAD-I), was developed at the University of Memphis. Notably, Elisabeth Schussler, one of the pioneers in the field, contributed to its development (Parsley et al., 2022).

Moreover, several of these questionnaires have also been used as key methodological options for assessing the impact of educational interventions aimed at enhancing plant awareness through pre- and post-implementation designs. Such interventions began to appear more systematically in the literature in the mid-2000s. Examples of these early studies involved indoor activities intended to capture students' attention, increase familiarity with plants and stimulate interest (Strgar, 2007), or focused on outdoor learning experiences, emphasizing sustained contact with natural environments and encouraging direct, hands-on engagement with plants to support observation and exploration (Lindemann-Matthies, 2005).

Entering the decade 2010–2020, interventions continued to employ a range of indoor and outdoor strategies. These included hands-on outdoor activities in which students planted trees with experts and investigated meadow ecosystems using botanical keys and field diaries (Fančovičová & Prokop, 2011); thematic interdisciplinary approaches integrating botany, chemistry and art through activities utilizing microscopes, cameras and laboratory equipment (Cil, 2015); experiential activities using unidentified seeds and

cultivation kits to support sustained engagement with plant life cycles (Krosnick et al., 2018); and guided outdoor exploration supported by first-person botanical descriptions to identify local plant species in their natural environments (Borsos, 2019).

In the recent years, outdoor learning has remained a prominent instructional approach for enhancing plant awareness in the literature. Examples of contemporary suggested educational interventions include hands-on propagation workshops, field identification tasks and lectures delivered by plant researchers (Azevedo et al., 2022); school-based scientific investigations and gardening activities (Tessartz & Scheersoi, 2025); immersive field trips to botanical gardens that used living plant collections to explore ethnobotanical themes (Colon et al., 2020); and the integration of botanical-garden-based learning principles into the design of urban educational spaces (Daniel et al., 2023).

Technology has also become an increasingly important component of plant awareness education. Technology-enhanced interventions include open-source digital games and analogue e-books that combine storytelling with botanical data visualization to promote active learning (de Almeida Souza et al., 2024); project-based learning integrated with digital storytelling, using structured worksheets and media tools to guide students in producing narrative videos about flower-related concepts and plant development (Anggarani et al., 2025); the creation of virtual plant collections supported by a custom-developed mobile application (Ceylan & Altiparmak Karakus, 2024); a Students-as-Partners model used to co-develop a mobile application and interactive botanical map to enhance botanical literacy (Dimon et al., 2019); and the use of nature documentary series as instructional resources, employing mass-media storytelling and high-quality visual imagery to stimulate interest and encourage online information-seeking about specific plant species (Kacprzyk et al., 2023).

Further recent contributions have examined how artistic practices can support the development of plant awareness. These interventions include the use of celebrity music videos as advance organizers, paired with prompting questions and guided discussions to link pop-culture visual cues with botanical concepts (da Silva, 2025), and interdisciplinary workshop activities employing dried plant specimens, cardstock and sewing materials to combine scientific mounting of local flora with the creative composition of short poems as a strategy to counter plant awareness disparity (Prüse et al., 2025).

The robust methodologies and strong statistical rigor employed across the studies described above have collectively established a solid foundation for understanding the role of educational interventions in enhancing plant awareness. Although these interventions demonstrate promising outcomes, they are typically implemented as isolated activities or short-term modules rather than as structured instructional sequences grounded in explicit pedagogical reasoning. In the broader literature, plant awareness is conceptualized as a complex construct that is resistant to change, making it a conceptually rich topic that requires focused and systematic instruction when teaching about plants (Södervik et al., 2021).

A systematic approach that integrates scientific content with pedagogical design principles can be provided by Teaching–Learning Sequences (TLS). Nevertheless, despite their extensive application in various domains of science education (Marshman & Singh, 2022; Rodriguez et al., 2020), no studies to date have employed TLS to promote plant awareness or address plant awareness disparity. Existing TLS research has predominantly concentrated on physics (Carli, 2024; Mandrikas et al., 2021; Peikos et al., 2022), with comparatively fewer contributions in biology education (Pedrera et al., 2025b) and environmental education (Toffaletti et al., 2022).

1.2. Transformative Learning

All the studies mentioned above contribute to a robust theoretical foundation for the development of educational strategies aimed at enhancing plant awareness. However,

despite the demonstrated effectiveness of these interventions, teaching about plants remains a challenging task. Recent studies continue to report low scores in several dimensions of plant awareness (Marcos-Walias et al., 2023; Pany et al., 2024; Wulandari et al., 2023). According to teachers, instruction about plants poses several difficulties (Kletečki et al., 2023; Kováčik & Vydra, 2023; Maskour et al., 2022).

These challenges are further compounded by the presence of alternative conceptions related to plant organisms (Backscheider et al., 1993; Brulé et al., 2014; Sobieszczuk-Nowicka et al., 2018; Stavy & Wax, 1989; Torres-Porras & Alcántara-Manzanares, 2021) or by the inherent complexity of certain plant physiology topics (Messig & Groß, 2018). Collectively, these studies suggest that plant education remains a field with significant potential for further exploration. Additional research would be beneficial to identify and evaluate effective educational strategies for enhancing plant awareness through instruction. Within this context, transformative learning emerges as a promising pedagogical approach deserving empirical investigation.

Transformative learning is an educational theory that emphasizes how individuals can shift their understanding of themselves and the world by critically reflecting on and revising their beliefs and assumptions. Mezirow (1997) originally defined it as a process that extends beyond the mere transmission of knowledge, aiming instead to foster deep changes in perspective and meaning-making (Kitchenham, 2008; Mezirow, 2006). The core principles of transformative learning include critical reflection, contextual awareness, rational discourse, the centrality of experience, and the integration of new perspectives (Schnepfleitner & Ferreira, 2021).

Together, these elements contribute to the transformation of the learner and support action that is aligned with newly constructed meaning (O'Sullivan et al., 2002; Taylor & Cranton, 2012). To apply these principles in educational practice, classroom instruction may incorporate activities such as self-examination of personal values and biases, disorienting dilemmas, structured debates, dialogic learning, and opportunities for integration of the new perspectives (Cranton, 2016; Nohl, 2015). These practices are most effective when implemented within an inclusive, safe, and empowering learning environment (Taylor, 2011).

Transformative learning is already highly valued in the field of education for sustainable development (Boström et al., 2018; Rodríguez Aboytes & Barth, 2020). Its significance is evident not only in the academic literature but also in policy documents published by major international organizations. In a policy paper published by UNESCO, Rieckmann (2018) outlines why education for sustainable development draws heavily on transformative learning theory, particularly in its focus on reflecting on personal values and worldviews, shifting perspectives through learning experiences, and empowering learners to enact social change. In essence, education for sustainable development echoes Mezirow's theory by aiming to cultivate learners' capacity for critical reflection and to support the reframing of assumptions in response to sustainability challenges (Singer-Brodowski, 2025).

Building on the acknowledged role of transformative learning in education for sustainable development, its potential contribution to enhancing plant awareness can also be considered. Similar to the goals of education for sustainable development, the aim in fostering plant awareness is not solely to transmit knowledge, but the facilitation of deeper transformation in the learner. While knowledge remains an essential component, the goal extends beyond addressing an informational gap (Hodkinson, 2025). The intention is to cultivate learners who demonstrate more positive attitudes toward plants, assign greater value to flora, notice plants more often in their surroundings, and exhibit increased interest in plant life.

As a result, the educational emphasis is redirected from the plants themselves to the learner (Amprazis & Papadopoulou, 2024b). This involves encouraging individuals to

critically examine their preconceptions about plants, their level of attention to them, and the assumptions and values that inform their perceptions and actions (Stagg & Dillon, 2023). Achieving such a transformation requires engaging learners in processes such as self-reflection on social and personal norms, critical thinking, rational discourse, and consideration of the cultural and historical contexts that influence their relationship with the plant world. These elements align with the core principles of transformative learning as defined by Mezirow (2006) and discussed earlier in this paper. Therefore, transformative learning could be explored as a promising pedagogical approach for enhancing plant awareness and addressing the persistence of plant awareness disparity.

1.3. Research Aim

Based on the theoretical background presented thus far, the aim of this study is to design, implement, and evaluate a TLS for university students in a pedagogical department grounded in transformative learning principles and intended to enhance plant awareness. By doing so, the study contributes to the existing body of strategies addressing the disparity in plant awareness and positions transformative learning as a viable pedagogical approach within the broader landscape of educational methods aimed at fostering plant awareness. Additionally, the present study therefore contributes to both the pedagogical and research dimensions of TLS development by extending this approach to an underexplored thematic area.

To address this aim, the study was guided by the following research questions:

- (1) To what extent does the designed TLS enhance university students' plant awareness?
- (2) How do students experience and interpret the learning process fostered through the TLS?

2. Materials and Methods

2.1. Teaching Learning Sequences

In recent decades, TLSs have become an important tool for designing coherent and purposeful learning experiences in science education. According to Psillos and Kariotoglou (2016), TLSs can be particularly well-suited for teaching and multifaceted scientific concepts, addressing misconceptions, and fostering conceptual understanding through a structured and iterative process. Rather than functioning merely as a teaching strategy, TLSs constitute a systematically designed instructional model that integrates scientific content with pedagogical reasoning (Méheut & Psillos, 2004). The pedagogical aspects include teacher-student interactions, motivation, and learner engagement, while the epistemic dimensions involve the organization of scientific content, the use of modeling, and the development of problem-solving processes.

A key feature of TLSs is its emphasis on aligning intended teaching with expected student learning (Buty et al., 2004). The design of the TLSs is grounded in multiple theoretical and methodological frameworks, including constructivism, design-based research, educational reconstruction, content-specific theories, and socio-cultural perspectives. Through these lenses, the TLSs design seeks to achieve a balance between scientific content integrity, diverse student learning trajectories, and pedagogical or contextual constraints (Psillos & Kariotoglou, 2016).

The evaluation of TLSs effectiveness involves both quantitative and qualitative methods (Vázquez-Alonso et al., 2016). Pre- and post-tests are commonly used to assess learning gains, while qualitative approaches trace students' conceptual development and compare expected learning paths with actual outcomes. Thus, TLSs serve as educational products tailored for practical classroom application, and at the same time, they function as research instruments to test hypotheses about teaching and learning in science education (Guisasola

et al., 2017). This dual role underscores their purpose not only to guide instruction but also to generate empirical insights into learning processes.

While TLSs can function as research instruments within specific classroom studies, they also constitute a broader research and development domain in science education. TLS research has become a dynamic field in which scholars refine theoretical models, improve design methodologies, and expand pedagogical applications (Grimalt-Álvaro et al., 2025; Muñoz-Campos et al., 2020). Previous and current research extends beyond the design and assessment of TLSs for specific subject areas to also explore how the field itself can evolve, be updated, and enriched with new directions (Guisasola et al., 2023). Through this ongoing process, TLSs are grounded in theoretical frameworks that are continually informed and strengthened by research (Fazio et al., 2023).

2.1.1. Design of the Plant Awareness TLS

The TLS implemented in this study comprised six thematic units delivered over eight instructional hours. Each unit was centered on one or more components of plant awareness, as defined by the theoretical construct of plant awareness disparity: (a) attention, (b) attitude, (c) relative interest, and (d) knowledge (Parsley, 2020; Parsley et al., 2022). The purpose of each unit was to foster development in one or more plant awareness components, and the corresponding learning outcomes were formulated to reflect this intent. Specifically, the learning outcomes aimed (a) to enhance participants attention to plants, (b) to cultivate more positive attitudes to plants, (c) to increase interest in plants relative to animals, and (d) to deepen participants' knowledge about plant life.

The TLS was theoretically grounded in Transformative Learning Theory (Kitchenham, 2008; Mezirow, 2006). Accordingly, the learning experiences were designed to encourage participants to question prior knowledge, attitudes, and taken-for-granted assumptions. Structured discussions supported engagement with disorienting dilemmas, critical debate, justification of viewpoints, and the exploration of alternative perspectives through open and respectful dialogue. Opportunities for conceptual synthesis were intentionally embedded throughout the sequence, enabling learners to reframe their understanding and develop new insights. Throughout the process, a supportive, inclusive, and non-coercive classroom climate was systematically maintained.

Beyond its theoretical grounding, the TLS design incorporated several pedagogical principles. Constructivist and socio-constructivist perspectives (Bada & Olusegun, 2015) shaped the participatory and collaborative structure of learning, positioning knowledge construction as an active and social process involving interaction, dialogue, and reflection (Saleem et al., 2021). Educational reconstruction (Duit et al., 2012; Niebert & Gropengiesser, 2013) provided a systematic framework for translating scientific concepts into teachable content by integrating subject-matter analysis with learners' preconceptions and pedagogical considerations. Dialogic (Lysaker & Furuness, 2011; Teo, 2019) and participatory pedagogy (Barrett, 2008) also guided the design of the Plant Awareness TLS, as plenary discussions, debates, and collective reflection were integrated throughout the instructional process. Moreover, principles of education for sustainability and environmental ethics (Nasibulina, 2015) were embedded in the sequence, particularly through the emphasis on moving beyond anthropocentric perspectives to foster appreciation of plants and the natural world (Kopnina, 2014).

Another essential component of the TLS designed in this study was the integration of the free version of the educational tool Poll Everywhere (version 2.0). This tool allowed students to use their mobile phones to respond to instructor-posed questions, with aggregated results and response percentages displayed in real time on a shared screen. Poll Everywhere! has been recognized as an effective digital resource in higher education, as it

promotes active student engagement and participation in the learning process (Kappers & Cutler, 2015).

In addition to Poll Everywhere, other instructional materials and media included personal computers, a projector, PowerPoint presentations, and student worksheets. Participants engaged in a variety of instructional formats: they worked individually, in small groups, and in plenary sessions.

The TLS was collaboratively developed through a co-design process involving the two authors, who served as the principal researchers, one university instructor specializing in biology education, and an expert in structured instructional design. Informal consultations were also held with teaching assistants, whose classroom experience provided practical insights into activity feasibility and sequencing. In addition, feedback from students enrolled in previous science education courses informed the revision of selected materials and prompts. The current study constitutes the first full implementation of the TLS in a higher education setting.

A brief description of each thematic unit is provided below, accompanied by a table outlining the following elements for each unit: (a) the number of instructional hours allocated, (b) the expected learning outcomes, (c) the implemented learning activities, (d) the targeted components of plant awareness, and (e) the unit's alignment with the core principles of transformative learning (Table 1).

Table 1. Main Characteristics of the Plant Awareness TLS Thematic Units.

Thematic Unit	Class Hours	Expected Learning Outcomes	Participants' Activities	Targeted Components of Plant Awareness Disparity	Alignment with Transformative Learning Principles
1. Being “blind” to plants	1 × 45 min	Awareness of how plants are often overlooked in everyday life	Individually use Poll Everywhere Work collaboratively on the worksheets Presentation of their work to the plenary session Participation in the discussion	Attention	Critical reflection on assumptions Perspective transformation Dialectical discourse Self-examination on values and biases
2. Plant life in human life	2 × 45 min	Recognize the inter-connection between plants and human life Notice plant-derived products and all plants, not just edible ones	Individually use Poll Everywhere Work collaboratively on the worksheets Presentation of their work to the plenary session Participation in the discussion	Attention Attitude	Perspective transformation Context awareness Disorienting dilemmas Integration of new perspectives
3. Grasping importance and confronting misconceptions	1 × 45 min	Evaluate the necessity and the importance of plants Addressing mis-conceptions about plants	Work collaboratively on the worksheets Presentation of their work to the plenary session Participation in the discussion	Attitude Knowledge	Critical reflection on assumptions Perspective transformation Dialectical discourse Integration of new perspectives

Table 1. Cont.

Thematic Unit	Class Hours	Expected Learning Outcomes	Participants' Activities	Targeted Components of Plant Awareness Disparity	Alignment with Transformative Learning Principles
4. Plants shaping our history	1 × 45 min	Evaluate how plants essentially shaped human history	Individually use Poll Everywhere Work collaboratively on the worksheets Presentation of their work to the plenary session Participation in the discussion	Attitude Knowledge	Perspective transformation Context awareness Disorienting dilemmas Dialectical discourse
5. Embrace plants without being human	2 × 45 min	Perceive plants without zoocentric or anthropo-centric perspective Compare plants and animals without zoocentric or anthropo-centric perspective	Watch video Work collaboratively on the worksheets Presentation of their work to the plenary session Participation in the discussion	Relative interest	Critical reflection on assumptions Perspective transformation Self-examination on values and biases Inclusive, non-coercive and empowering learning environment
6. Plants' intrinsic value as a path to rights	1 × 45 min	Evaluate the intrinsic value of plants beyond zoocentrism	Individually use Poll Everywhere Work collaboratively on the worksheets Presentation of their work to the plenary session Participation in the discussion	Relative interest	Self-examination on values and biases Disorienting dilemmas Dialectical discourse Integration of new perspectives Inclusive, non-coercive and empowering learning environment

Thematic Unit 1: Being “Blind” to Plants

The first thematic unit introduces students to the phenomenon of plant awareness disparity, emphasizing the tendency to overlook plants in everyday environments and the underlying attitudes that contribute to this perceptual bias. Participants are invited to reflect and respond to questions posed through the Poll Everywhere tool, such as “*Did you notice any plants on your way to the university?*” and “*As you move through your daily life, what are the things you pay the most attention to?*”.

Following this activity, students work collaboratively in groups using worksheets designed to guide them in analyzing and interpreting why individuals often fail to notice plants. The unit continues with a plenary session during which students present their group findings. This is followed by an instructor-led introduction to the theoretical background of plant awareness disparity and an open discussion.

Thematic Unit 2: Plant Life in Human Life

The second thematic unit aims to underscore the pervasive yet often underappreciated presence of plants in human life. During the first instructional hour of this unit, students investigate the contributions of plants to the advancement of various sectors of human

society. The second hour shifts focus toward the identification of products that are wholly or partially derived from plants.

Participants are invited to reflect on and respond to questions presented via the Poll Everywhere platform. Example prompts include: *“What percentage of currently available pharmaceutical products worldwide contain a substance originally derived from plants or first discovered in plants and later synthesized in laboratories?”* and *“How many people globally rely primarily on plant-based foods due to dietary preferences, economic constraints, religious beliefs, or health considerations?”*. In addition, participants are shown a series of products on screen and asked to determine whether each is fully or partially derived from plants, submitting their responses in real time through the Poll Everywhere tool.

The collaborative group work component includes worksheets designed for participants to engage in self-reflection on plant-derived products they consider essential to their daily lives. Participants are also encouraged to identify non-edible plants that play a significant role in their lives and to articulate the nature of their relationship with these plants. During the plenary session, participants present the outcomes of their worksheet activities, engage in a facilitated discussion aimed at perspective transformation and conclude with a recap highlighting the multifaceted contributions of plants to human life.

Thematic Unit 3: Grasping Importance and Confronting Misconceptions

Initially, participants are introduced to foundational knowledge concerning the significance and necessity of plants for life, evolution, and sustainable development. This thematic unit advances the discussion to a higher and subtler level, stepping up from the previous one which focused primarily on a human-centered and utilitarian perspective.

Subsequently, participants are presented with empirical research findings and statistical data derived from the science education literature, originating from both international and Greek studies. These sources specifically highlight common misconceptions related to the importance of plants (Fernández-Díaz, 2022), as well as fundamental misunderstandings in plant biology, including the documented tendency of students (Amprazis et al., 2021) and adults (Torres-Porras & Alcántara-Manzanares, 2021) to not spontaneously recall plants as living organisms.

Following this, participants engage in group work using a structured worksheet. They are asked to reflect on and identify the role of compulsory education teachers in three key areas: (a) clarifying the importance of plants, (b) shaping students’ broader perceptions of plants, and (c) understanding how misconceptions about plants are formed in both students and adults.

The activity concludes with a plenary presentation of the results, followed by a dialogic learning session. This session focuses on practical and instructional strategies for more effective teaching of plant-related topics, with the goal of emphasizing the importance of plants and reducing the formation of misconceptions.

Thematic Unit 4: Plants Shaping Our History

Drawing on the work of Manetas (2012, 2019), the fourth thematic unit explores the ways in which plants have influenced and shaped human history, emphasizing their profound cultural, economic, and political significance. Participants are invited to reflect on and respond to questions presented through the Poll Everywhere tool, such as: *“Which plant led to the transportation of 10–12 million Africans as slaves to plantations in the United States?”* *“Which plant altered the course of global trade and triggered two wars?”* and *“Which plant significantly influenced the history of medicine, with its derivative now consumed at an estimated rate of 40,000 tons annually (equivalent to 50–120 billion tablets)?”*. Following each response, the correct answer is revealed, accompanied by a brief explanation of the specific plant and

its historical impact. After this activity, participants complete worksheets in which they are asked to identify and document non-plant-related factors that they believe have had a comparable influence on human history. The session concludes with a plenary discussion, during which participants present their findings and engage in collective reflection.

Thematic Unit 5: Embrace Plants Without Being Human

The fifth thematic unit focuses on challenging the anthropocentric perspectives through which plants are typically viewed, both in scientific discourse and educational contexts. The unit is grounded in the work of Marder (2013, 2024), who advocates for re-evaluating plants as beings with distinct modes of existence, temporal rhythms, and forms of interaction with the world. In this context, participants watch selected science videos that present plant processes resembling functions like vision, sound production, and memory, which are known from the human and animal world. After each screening, a presentation of the relevant scientific data follows, along with a discussion about mechanisms that plants possess but are often misunderstood or dismissed when evaluated exclusively through the prism of human experience.

This highlights key changes in how plants are understood, such as: (a) abandoning the traditional view of plants as “inferior” or “passive” organisms, (b) recognizing that they are living beings with their own ways of perceiving, and relating to the environment, and (c) moving away from anthropocentric patterns of thought and science when interpreting plant life, in order to form new beliefs. Given that abandoning anthropocentric perspectives represents a significant conceptual shift, this thematic unit may evoke feelings of unfamiliarity, uncertainty, or even slight discomfort among participants. For this reason, creating an inclusive and non-coercive learning environment was a central priority of this thematic unit.

The unit concludes with participants working in groups to “transcribe” an imaginary conversation with a plant, envisioning how it might respond to questions if it were given a “voice.” The results are then presented in a plenary session and serve as a starting point for further exchange of views, critical reflection, and perspective transformation.

Thematic Unit 6: Plants’ Intrinsic Value as a Path to Rights

The sixth and final thematic unit centers on the concept of the intrinsic value of plants and the rights that may arise from this recognition. Participants are first invited to vote via the Poll Everywhere platform in response to the question of whether plants should be acknowledged as bearers of rights. They then work in groups to develop arguments supporting the position they selected. These arguments are presented in a structured plenary debate, where groups in favor and against plant rights engage in dialogue. The use of debate within the context of transformative learning is a deliberate and widely adopted pedagogical strategy.

Following the debate, participants are introduced to official positions held by various states and international organizations on the concept of plant rights, as well as selected theoretical frameworks. These include: (a) phyto-centric ethics, which evaluates plant rights not on the basis of consciousness or sentience, but in relation to the subjective reality of plants; (b) a view of rights based on the ability of plants to grow, reproduce, and interact with their environment; and (c) symbiotic ethics, which promotes a mutually respectful relationship in which humans regard plants not as exploitable resources, but as co-inhabitants of the planet.

A dialectical discourse on the above topics follows, aiming to challenge and transform perspectives on plants, particularly regarding how their intrinsic value is often diminished by the greater interest directed toward animals.

As this was the first comprehensive implementation of the Plant Awareness TLS, the design should be viewed as part of an iterative development process. The outcomes of this study will inform subsequent refinements to the sequence, particularly regarding the duration of specific activities and the integration of additional multimodal materials to support perception-related learning. Future iterations will also aim to test the TLS in different educational contexts and with diverse student populations, thereby strengthening its generalizability and further aligning it with the cyclical nature of design-based research.

2.2. Participants

The participants of the study were 84 undergraduate students from a Teacher Education Department at a university of Northern Greece. A convenience sampling strategy was implemented, as the participants were students at the same institution where the study was conducted. The majority of students in this department come from regions of Northern Greece.

This department was selected for the study due to its lack of specialization in a particular subject area and its emphasis on broad, general education. As a result, students' knowledge and perceptions may reflect, to some extent, those of the general population. Furthermore, as pre-service teachers prepare to work in compulsory education settings, their views and attitudes toward plant awareness are particularly relevant for informing educational practices at these levels.

Of the total sample, 84.7% of participants were between 18 and 22 years of age, while 15.3% were between 23 and 48 years. Regarding gender, 95.3% identified as female and 4.7% as male.

Ethical approval for the implementation of the educational intervention was obtained from the Research Ethics Committee of the University (Approval No. 147/2024).

2.3. Data Collection

The evaluation of the TLS in this study was carried out using data collected from three sources: the implementation of the research instrument, in-class observations, and a focus group conducted after the TLS implementation. To ensure the validity and depth of the findings, a triangulation strategy was employed, combining quantitative data from the research instrument with qualitative insights derived from the systematic classroom observations and the post-intervention focus group discussion. This multi-method approach enabled a comprehensive examination of participants' measurable outcomes, potential subjective transformations in their plant awareness, and their perceptions of the TLS as an educational process.

2.4. Research Instrument

The primary research instrument employed to evaluate the TLS was the Plant Awareness Disparity Index (PAD-I), which was used both before and after the implementation to collect pre- and post-intervention data. The PAD-I is a validated questionnaire developed at the University of Memphis (United States) and thoroughly described by [Parsley et al. \(2022\)](#). It assesses plant awareness disparity through four key components: "attention", "knowledge", "relative interest", and "attitudes".

The PAD-I comprises six factors, each of which corresponds to one or more of the four components mentioned above. These six factors are "Attention Toward Plants," which forms the component attention; "Necessity or Importance of Plants," which forms the component "knowledge"; "Plants Better Than Animals" and "Animals Better Than Plants," which together constitute the component "relative interest"; and "Positive Affect Toward Plants" and "Caring for or Investment in Plants," which together constitute the component "attitudes". Each factor includes closed-ended items measured on a four-point Likert

scale, with response options ranging from “strongly disagree” to “strongly agree.” The questionnaire consists of a total of 25 items.

The Greek version of the PAD-I research instrument was developed following procedures outlined in the international literature and includes some differences from the original tool. This validated version has been formally published (Amprazis et al., 2025) and is available for use in Greek educational and research settings. The translation process adhered to cross-cultural adaptation principles, including initial translation, reconciliation of discrepancies between versions, and back-translation of the questionnaire.

Following the translation, cognitive interviews and a pilot administration of the questionnaire were conducted. The final version was validated through both exploratory and confirmatory factor analyses, and its reliability was assessed using Cronbach’s alpha. During the exploratory factor analysis, a series of iterative tests were performed in which items were gradually removed and the analysis repeated, with the aim of improving the clarity and structure of the final factor solution. Specifically, three items from the original version were excluded due to significant cross-loadings above the 0.300 threshold on more than one factor.

As a result, the final solution of the Greek version of the PAD-I included 22 items across five distinct factors, with all retained items loading cleanly onto a single factor. This solution explained 51.74% of the total variance and was used in all subsequent analyses. The five-factor model that emerged from the exploratory factor analysis was tested through confirmatory factor analysis (CFA) using EQS software (version 6.1) (Bentler & Wu, 2003). This model demonstrated a good fit to the data, as indicated by the fit indices: $\chi^2(203) = 250.27$, $p = 0.013$, CFI = 0.965, NNFI = 0.961, and RMSEA = 0.030, with a 90% confidence interval [0.014, 0.041]. The combination of a high CFI and a low RMSEA confirmed the conclusion that the model demonstrated good overall fit.

A notable outcome of both the exploratory and confirmatory factor analyses in the present study was the consistent emergence of two distinct factors within the broader construct of relative interest, namely “Plants Better than Animals” and “Animals Better than Plants.” Although these two sets of items seem to represent opposite poles of the same construct, they did not load on a single factor. This finding directly replicates the structure reported in the original development of the PAD-I (Parsley et al., 2022), where the same two subscales also emerged as psychometrically distinct despite their conceptual relationship.

At first glance this result may appear counterintuitive. However, psychometric research indicates that reverse coded items do not always function as simple mirrors of positively worded items (DiStefano & Motl, 2006; Woods, 2006). Respondents often interpret semantically opposite items differently at both cognitive and affective levels, with reverse coded items capturing nuances related to reasoning, salience, or identity linked preferences rather than merely the inverse of the corresponding positive statement (Weijters et al., 2013). Consequently, items that appear to be conceptual mirrors may behave as empirically distinct indicators.

This distinction becomes particularly relevant when the statements concern entities that do not carry equal cultural meaning, such as plants and animals. As highlighted in the plant awareness literature, the statement “animals are more interesting than plants” derives from several factors, including educational experiences (Chen & Zhai, 2025; Kletečki et al., 2023), human perceptual and cognitive biology (Achurra, 2022; Guerra et al., 2024), and the fact that humans biologically belong to the animal kingdom (Wandersee & Schussler, 2001). Hence, this belief about the more interesting animals frequently operates automatically and with little reflective effort.

By contrast, the statement “plants are more interesting than animals” requires respondents to challenge the dominant preference for animals. Agreeing with such an item

often involves deliberate cognitive work, self-reflection, a reordering of value, and an intentional elevation of plants to a position that contradicts common experience (Amprazis & Papadopoulou, 2024a; Dünser et al., 2024). Psychologically, the two statements therefore do not represent equivalent but opposite positions. Instead, they appear to index different underlying mechanisms.

In the same context, it is important to note that several scholars argue that framing the issue as a symmetrical contrast between plants and animals is conceptually limiting (Dünser et al., 2025; Pany et al., 2024). According to this perspective, the phenomenon of plant blindness is not a balanced comparison between two biological groups but rather the systematic undervaluation of plants independently of what people think of animals. For this reason, the two statements should not be understood as opposite positions on a single continuum. Instead, they reflect an underlying asymmetry in cultural meaning, educational emphasis, and cognitive accessibility.

Even in Parsley et al. (2022), although the PAD-I items regarding relative interest may initially appear to present a simple “plants versus animals” comparison, a closer reading of their reasoning reveals that this contrast is not intended to establish a symmetrical evaluative scale. Instead, it serves to demonstrate that humans are often more interested in organisms other than plants. In this sense, the comparison functions as a diagnostic tool that highlights a pervasive disadvantage for plants in human cognition and attention. This interpretive framework further supports the idea that the construct of relative interest in the PAD I is multidimensional rather than bipolar.

Elaborating even more on the factor structure of the Greek version of the PAD-I, the reduction in the original six to five factors was driven by the empirical results of the exploratory factor analysis, in which items from the “Positive Affect Toward Plants” factor loaded strongly and exclusively on the same factor as items from the “Attention Toward Plants” factor. From a theoretical standpoint, this merger reflects the close relationship between noticing an object and valuing it. As noted by Parsley et al. (2022), visual attention and emotional attitude are likely related, since “intentional visual attention can cause an increase in intensity of emotions” (p. 4).

Furthermore, the original development of the PAD-I employed direct oblimin rotation in the factor analyses, a methodological choice that allows the underlying factors to correlate rather than treating them as orthogonal. In the present study, this covariance between “Attention” and “Positive Affect” was sufficiently strong for the items to cluster into a single factor. This suggests that, for the participants in our sample, attending to plants is not experienced as a neutral sensory act but is intrinsically linked to positive emotional responses.

It is also noteworthy that the other attitudinal factor, “Caring for or Investment in Plants,” remained distinct. This separation likely reflects the fact that “Caring” describes an active, behavioral dimension (for example, watering or gardening), whereas “Attention” and “Positive Affect” represent more internal cognitive and emotional states.

Finally, cultural factors may have further contributed to this structural consolidation. In Mediterranean contexts such as Greece, where the natural landscape and outdoor experiences are deeply integrated into everyday life and cultural identity (Mikusiński et al., 2023; Otamendi-Urroz et al., 2023), observing plants is often directly associated with enjoyment and personal meaning. Consequently, the final factor “Attention and Positive Affect Toward Plants” in the Greek version of the PAD-I reflects the interwoven cognitive and emotional dimensions of plant related experience within this specific sample.

Regarding reliability, the Cronbach’s alpha value for the overall Greek version of the PAD-I was 0.823, which is considered satisfactory (Watkins, 2021).

An overview of the factors and the item structure of the Greek version of the PAD-I is presented in Table 2.

Table 2. Factor Structure and Item Distribution of the PAD-I in the Greek Context.

Plant Awareness Disparity Components	Five (5) Factors	22 Total Items
Attitudes	Caring for/investment in plants	3
Attention	Attention and positive affect toward plants	8
Knowledge	Necessity or Importance of Plants	5
Relative interest	Plants Better than Animals	3
	Animals Better than Plants	3

Observation & Focus Groups

Unstructured classroom observation was undertaken by a second researcher acting as a non-participant observer (Mulhall, 2003). The observation covered the entire TLS and was carried out without predefined coding schemes or rigid observational protocols. This approach was chosen to capture the complexity and spontaneity of students' engagement with plant-related topics and their participation in TLS activities, thereby avoiding the limitations of predefined coding that might have excluded unexpected yet relevant behaviors. The observer's role focused on documenting participants' spontaneous reactions, statements, questions, shifts in attention, and general classroom behavior related to plant-focused content and the TLS process. This form of unstructured observation served as an additional evaluative component of the TLS, enabling the triangulation of questionnaire data with qualitative insights into how students' awareness and dispositions toward plants evolved in authentic classroom contexts (Creswell & Creswell, 2017).

In addition to the above, a post-TLS focus group was conducted with a subset of participants to gain deeper insight into the questionnaire and observation data. A total of nine students participated in the focus group, selected through purposive sampling to reflect diverse engagement levels. Engagement levels were defined based on the observational data collected during the TLS implementation, focusing on students' frequency of participation, contribution to discussions, and involvement in TLS activities.

The aim was to explore participants' relationships with plants and to gather their overall evaluations of the TLS as an educational intervention. The discussion followed a semi-structured format, guided by prompts that encouraged participants to elaborate on each component of the plant awareness disparity framework, as well as their general reflections on the TLS. Data was collected through detailed note-taking during the discussion, as no audio or video recordings were made. The focus group was conducted immediately following the completion of the post-test by all participants.

2.5. Data Analysis

After completing the PAD-I questionnaire at the end of the educational intervention, the data collected from both before and after the TLS were entered into SPSS software (version 25). Appropriate statistical tests were conducted to assess the normality of the sample and to identify any potential differences in participants' scores before and after the educational intervention. Statistically significant differences related to the independent variables of gender and age were not examined, as the vast majority of participants belonged to the same age group (18–22 years) and gender (female). Consequently, there were not sufficient or balanced groupings by gender or age to allow for a methodologically valid comparison.

In addition to the quantitative analysis, qualitative data from classroom observation and the focus group were also examined. The observation notes were analyzed through

a qualitative content analysis using descriptive coding to identify emerging themes and specific behavioral indicators. Engagement, interest, and motivation were assessed qualitatively based on established indicators in educational research.

Engagement was identified through observable behaviors such as active participation in group work, sustained attention to tasks, and frequency of verbal contributions. Interest was inferred from cognitive and affective cues, including spontaneous questions, expressions of curiosity, reflective comments, and voluntary collaboration on plant-related activities. Motivation was identified through persistence in addressing challenges, positive emotional responses (e.g., excitement, satisfaction) during task completion, and shifts from off-task to on-task behavior. These behavioral and affective indicators were used collectively to interpret students' participation in the TLS and the enhancement of plant awareness.

The focus group data were analyzed using thematic analysis (Braun & Clarke, 2006). Participants' responses were documented through detailed notes taken during the session, which were subsequently expanded and annotated to include contextual details and preliminary analytic reflections. Codes were developed inductively to capture recurring patterns and emergent themes. Two researchers independently coded the expanded notes, generating initial codes through a data-driven approach. Examples of initial codes included "expressing curiosity," "seeking information about plants," "valuing plant life equally to animals," "acknowledging the historical importance of plants," "broadening appreciation beyond flowering plants," "reframing prior assumptions about plants," and "expressing intention to care for plants."

These codes were then organized into broader themes through an iterative process of comparison, refinement, and conceptual grouping. Among the themes generated through this process, those presented in the Section 3 ("Rethinking Comparative Value," "Deepening Understanding of Plant Significance," and "Emerging Care and Responsibility Toward Plants") correspond to the PAD-I factors that showed statistically significant change. A comparative analysis was then undertaken to reconcile discrepancies and establish a shared coding framework. Inter-rater agreement, calculated during the initial coding phase using percentage agreement, yielded a value of 84%, indicating a high level of coding consistency.

This multi-source analytic process enhanced the trustworthiness and credibility of the findings, allowing the qualitative evidence to meaningfully complement the quantitative results and provide a comprehensive evaluation of the effectiveness of the TLS.

3. Results

3.1. Quantitative Analysis

To determine whether parametric or non-parametric statistical tests were appropriate for evaluating the TLS, normality was assessed using the Kolmogorov–Smirnov and Shapiro–Wilk tests (Table 3). For the Kolmogorov–Smirnov test, results indicated that PAD-I questionnaire scores were normally distributed both before the educational intervention, $D(85) = 0.04$, $p = 0.20$, and after the intervention, $D(85) = 0.084$, $p = 0.20$. Similarly, the Shapiro–Wilk test confirmed normality for both pre-intervention values, $W(85) = 0.99$, $p = 0.97$, and post-intervention values, $W(85) = 0.99$, $p = 0.84$. Additional normality checks, including analysis of skewness, kurtosis, and histograms, further supported the assumption of normal distribution.

Based on the normality results, paired samples *t*-tests were conducted on the overall PAD-I questionnaire scores as well as on the five factors of the Greek version of the research instrument: (a) Attention and positive affect toward plants, (b) Animals better than plants, (c) Plants better than animals, (d) Necessity/importance of plants, and (e) Caring for/investment in plants (Table 4). Cohen's *d* values were also calculated to estimate the effect sizes for each of the paired comparisons.

Table 3. Kolmogorov–Smirnov and Shapiro–Wilk Tests for Normality of PAD-I Scores Before and After the TLS.

Statistical Test	Time Point	D/W Value	df	<i>p</i>
Kolmogorov–Smirnov	Pre-intervention	D = 0.04	85	0.20
Kolmogorov–Smirnov	Post-intervention	D = 0.084	85	0.20
Shapiro–Wilk	Pre-intervention	W = 0.99	85	0.97
Shapiro–Wilk	Post-intervention	W = 0.99	85	0.84

Table 4. Paired Samples *t*-Test Results for Each Factor and the Overall PAD-I Instrument.

Factors of the Greek Version of PAD-I		N	Mean	<i>t</i>	df	<i>p</i>
Attention and positive affect toward plants	Pre	85	3.27	0.32	84	0.744
	Post	85	3.25			
Animals Better than Plants	Pre	85	1.53	−11.05	84	<i>p</i> < 0.001 *
	Post	85	2.43			
Plants Better than Animals	Pre	85	1.47	−13.02	84	<i>p</i> < 0.001
	Post	85	2.51			
Necessity/importance of plants	Pre	85	3.79	−1.94	84	0.055
	Post	85	3.85			
Caring for/investment in plants	Pre	85	2.30	−13.27	84	<i>p</i> < 0.001
	Post	85	3.21			
Total PAD I score	Pre	85	2.47	−15.85	84	<i>p</i> < 0.001
	Post	85	3.05			

* Note. Higher scores in the *Animals Better Than Plants* factor reflect a lower level of perceived animal superiority, as this factor includes reverse-coded items.

For the Attention and positive affect toward plants factor, no statistically significant difference was found between participants' scores before ($M = 3.27$, $SD = 0.47$) and after the TLS ($M = 3.25$, $SD = 0.43$), $t(84) = 0.32$, $p = 0.744$, $d = 0.036$.

In the Animals better than plants factor, a statistically significant difference was recorded, with scores increasing from $M = 1.53$ ($SD = 0.53$) pre-intervention to $M = 2.43$ ($SD = 0.60$) post-intervention, $t(84) = -11.05$, $p < 0.001$, $d = 1.19$, indicating a large effect size. It is important to note that an increase in this factor's score does not indicate a more favorable view of animals. According to the research team that developed the PAD-I instrument (Parsley et al., 2022), this factor includes reverse-coded items, meaning that higher scores reflect a decrease in the perception that animals are superior to plants.

Likewise, the Plants better than animals factor also showed a significant increase from $M = 1.47$ ($SD = 0.46$) to $M = 2.51$ ($SD = 0.53$), $t(84) = -13.02$, $p < 0.001$, $d = 1.41$, indicating a large effect size.

For the Necessity/importance of plants factor, no statistically significant change was found, with pre-intervention scores at $M = 3.79$ ($SD = 0.23$) and post-intervention scores at $M = 3.85$ ($SD = 0.21$), $t(84) = -1.94$, $p = 0.055$, $d = 0.21$.

A statistically significant increase was recorded in the Caring for/investment in plants factor, with scores rising from $M = 2.30$ ($SD = 0.49$) to $M = 3.21$ ($SD = 0.45$), $t(84) = -13.27$, $p < 0.001$, $d = 1.44$, indicating a large effect size.

Finally, analysis of the overall PAD-I score revealed a statistically significant increase from $M = 2.47$ ($SD = 0.25$) before the TLS to $M = 3.05$ ($SD = 0.26$) after the intervention, $t(84) = -15.85$, $p < 0.001$, $d = 1.69$, indicating a large effect.

In summary, the results indicate statistically significant increases in the PAD-I scores for the factors animals better than plants, plants better than animals, and caring for/investment in plants. A statistically significant increase was also recorded in the total PAD-I score following the intervention.

3.2. Qualitative Findings

With respect to the qualitative findings from the classroom observations and focus group discussions, several noteworthy insights emerged concerning both the implementation of the TLS and the enhancement of participants' plant awareness. Regarding the observation, participants appeared to be actively engaged throughout the educational intervention, demonstrating interest, motivation, and consistent collaboration, without exhibiting signs of fatigue or disengagement. Their response to the use of the digital tool Poll Everywhere was particularly positive; this was confirmed both through observation and the focus group, during which participants described it as an immersive and innovative component of the instructional process. This interactive element played a critical role in sustaining their engagement and stimulating participation.

Additionally, during focus group many participants reported feeling surprised by the information presented and acknowledged that they had revised their prior perceptions of plants. This element of surprise played also a key role in deepening their involvement throughout the learning experience, as reflected in their discussions and responses. Participants also seemed to adopt new perspectives on issues they had previously taken for granted, recognizing the need to shift their attitudes toward plants. These qualitative findings, together with the statistical results, support the conclusion that the TLS appears to have contributed meaningfully, at least to some extent, to learners' conceptual restructuring and increased awareness of plant organisms.

Table 5 presents the results of the triangulation procedure, focusing specifically on the components of plant awareness that demonstrated change. The first column displays the questionnaire factors that exhibited statistically significant differences following the implementation of the TLS. The corresponding columns summarize the observational notes and focus group themes that align with and further support these quantitative findings.

Table 5. Triangulation of Quantitative and Qualitative Data: PAD-I Factors With Statistically Significant Differences Supported by Observation Notes and Focus Group Themes.

PAD-I Factors (Greek Version) Demonstrating Statistically Significant Change	Observation Notes	Focus Group Themes
Animals Better than Plants	Participants initially made comparisons that favored animals, but these decreased over time Increased frequency of classroom comments valuing plant life equally to animal life	Rethinking Comparative Value (<i>"Plants can be impressive too", "I still love animals, but maybe plants too"</i>)
Plants Better than Animals	Participants actively engaged in discussions that framed plants as more fundamental to life than animals Some participants initiated plant-focused questions without prompting	Deepening Understanding of Plant Significance (<i>"Plants have shaped human history more than animals", "Where can I find information about these plants?"</i>)
Caring for/investment in plants	Participants began asking for information about non flowering/non fruit-bearing plants Participants discussed plants in their city that they could care for or help maintain	Emerging Care and Responsibility Toward Plants (<i>"I used to only care about flowering and fruit-bearing plants", "I will see what I can do for the plants in my region"</i>)

Note. Focus group themes were derived from inductively generated codes. Illustrative quotes represent typical student expressions within each theme.

4. Discussion

This study highlighted the potential of transformative learning as an instructional framework for enhancing plant awareness. Based on the results, it is proposed that this approach should be included among the effective educational approaches identified in the literature for addressing this issue. While the TLS in this study undoubtedly provided some information about plants, its primary objective was to cultivate deeper interest, greater appreciation, heightened perceptual awareness, and more positive attitudes toward the plant world. In this context, the findings of the present study are consistent with those of Fiel'ardh et al. (2023), who also integrated elements of transformative learning into their intervention and observed improvements in participants' attitudes, interest, and self-efficacy in engaging with plant-related content.

The findings indicated that, following a specially designed TLS, positive changes were observed in the factors of relative interest and caring for/investment in plants. The absence of a statistically significant change in the factor related to the recognition of the necessity or importance of plants may be attributed to participants' initially high scores in this area prior to the intervention.

Regarding the factor of attention and positive affect toward plants, the lack of significant change is likely due to the need for more long-term and systematic educational interventions. These could involve direct contact with the natural environment (Park & Kim, 2025) or the integration of visual methods in learning and assessment (D. Sanders et al., 2024). More broadly, as suggested by recent literature reviews (Brković et al., 2025; Stagg et al., 2025), enhancing perception appears to be one of the most challenging plant awareness dimensions to influence. This difficulty may, in part, stem from the role of human physiology, which does not favor plant perception as a default or easily activated cognitive process (Achurra, 2022; Guerra et al., 2024).

The data collected through classroom observation and the focus group not only supported the statistically significant changes observed in the three factors discussed above but also revealed participants' positive emotional responses, voluntary engagement, and a general interest in the TLS process. The above elements are particularly significant for educational interventions related to plant awareness, as studies have documented low levels of student interest in plants within the broader context of plant awareness disparity (Amprazis et al., 2021; Marcos-Walias et al., 2023; Strgar, 2007; Wandersee & Schussler, 2001).

In addition, other research reports that students often perceive botany lessons as unengaging or boring (Batke et al., 2020; Kletečki et al., 2023; Kubiak et al., 2021; Maskour et al., 2019). Moreover, the effective use of the digital tool Poll Everywhere provides additional evidence that technology can play a significant role in enhancing plant awareness. This finding aligns with previous research that has utilized information and communication technologies to support plant awareness initiatives (de Almeida Souza et al., 2024; Ceylan & Altıparmak Karakus, 2024; Dimon et al., 2019; Kacprzyk et al., 2023; Lampert et al., 2023; Novaković, 2025).

4.1. Educational Implications

By equipping teachers with both knowledge and pedagogical tools to highlight the significance of plants, educational institutions not only transform teacher preparation programs but also help shape the values and attitudes of future generations. Therefore, it is critical that such directions be prioritized by educators and curriculum designers, particularly in departments of early childhood and primary education, which play a foundational role in shaping learners during compulsory schooling years.

A TLS based on transformative learning principles can be effectively deployed in pedagogical university departments, particularly within biology didactics and environ-

mental education courses. In addition, since the TLS developed in this study integrates perspectives from rights, history, culture, and other related domains, it holds potential for adaptation to a wider range of courses beyond biology and environmental science.

This broad applicability offers an additional benefit: it highlights the inherently interdisciplinary nature of plant-related issues and emphasizes that plants are deeply interconnected with multiple dimensions of human development. As such, it supports the view that the significance of plants extends far beyond the narrow perspective traditionally held as a result of plant awareness disparity.

Introducing transformative learning as a pedagogical approach to enhancing plant awareness among university students can also serve as a foundation for applying this, or similar methods in their future classrooms. Although transformative (Kitchenham, 2008) or transgressive (Macintyre et al., 2020) learning approaches were originally developed for adult education, their core principles—such as critical questioning, challenging taken-for-granted assumptions, envisioning alternatives, and emphasizing the centrality of experience—can be meaningfully adapted for younger learners through age-appropriate and playful strategies. These principles can foster children's critical and creative engagement with plants and ultimately support the development of plant awareness from an early age. Thus, embedding such approaches in pre-service teacher education not only enriches future teaching practices but also moves beyond the limited strategy of merely increasing botanical knowledge in biology classes.

Importantly, the implications extend beyond pre-service education. Raising plant awareness should also be a priority for in-service teachers. Professional development opportunities, such as training programs, workshops, or information sessions, can incorporate TLS models like the one presented in this study. These initiatives can support perspective transformation, promote critical reflection on plant-related values, and foster more inclusive and accurate representations of the plant world. As previously noted, transformative learning is particularly well suited to contexts such as higher education, adult learning, and lifelong education, where it facilitates the questioning of norms, the disruption of unsustainable practices, and engagement in collective agency toward a more plant-aware perspective.

Above all, the TLS developed and examined in this study aligns closely with the vision of modern educational institutions committed to sustainability. Transformative learning has already been recognized as a promising approach within education for sustainable development (Balsiger et al., 2017). Given that plant awareness is increasingly linked to sustainability goals (Amprazis & Papadopoulou, 2020; Lawrence & Calvo, 2023; Thomas et al., 2022), a TLS grounded in transformative learning emerges as an effective vehicle for fostering plant awareness in both universities and schools with sustainability-oriented agendas. In such institutions, sustainability extends beyond infrastructure, governance, or strategic planning; it is also embedded in curriculum design and pedagogical practices (Lee & Louis, 2019; Lukman & Glavič, 2007). Therefore, innovative and reflective educational strategies like the TLS presented here can play a pivotal role in promoting plant awareness. They should be prioritized by institutions that recognize the fundamental contribution of plants to achieving broader sustainability goals.

4.2. Limitations and Future Inquiry Directions

Although the results of the present study are encouraging, several limitations should be acknowledged. The research instrument was applied immediately before and immediately after the TLS implementation. Consequently, no follow-up assessment was conducted to examine whether the statistically significant differences observed in the post-test were

retained over time. This is particularly important for a multidimensional construct such as plant awareness and therefore constitutes a key limitation of the study.

Another limitation concerns the characteristics of the PAD-I itself, which was used in this study to assess the impact of the TLS. The affective dimension of the instrument is measured exclusively through positively framed items that capture enjoyment, interest, or positive emotional responses toward plants. As a result, the PAD-I does not explicitly capture possible negative attitudes, such as discomfort, aversion, or biophobia (Soga & Evans, 2024). This constraint means that the instrument provides a partial picture of students' affective relationship with plants, focusing solely on the presence or absence of positive affect. Consequently, the conclusions drawn regarding changes in attitudes toward plants should be interpreted with awareness of this limitation, as the instrument cannot reflect shifts across the full spectrum of plant-related affect.

A further methodological consideration relates to the way the PAD-I assesses the component of Attention. In this instrument, attention toward plants is measured through self-reported noticing behaviors, such as whether individuals perceive or identify plants when they are outdoors. While this approach is common and provides a practical way to capture perceived attentiveness, it offers only an indirect indication of actual attentional processes. Self-reported noticing may be influenced by subjective memory or interpretation, and it may not always correspond to a person's real-time attentional engagement, even for individuals who are generally plant aware.

Consequently, the Attention subscale may only partially reflect the complexity and situational variability of attention toward plants. This consideration is particularly relevant in the context of our findings, as no statistically significant changes were observed in this dimension. Therefore, together with the points already discussed in the Section 4, interpretations related to attention should be made with an awareness of how this component is operationalized within the PAD-I.

With regard to the study's demographics, the sample consisted predominantly of women, which may restrict the generalizability of the findings. Moreover, the research was conducted at a single university, specifically within one Teacher Education Department, which further restricts the diversity of the sample. The selection of pre-service teachers from this department was based on the broader scope of their academic discipline, which is generally less specialized compared to other academic fields. However, implementing the TLS more broadly, for example in departments that prepare instructors across various scientific disciplines, could yield findings that are both more comprehensive and generalizable.

Additionally, although the geographical location of the university where the study was implemented may not be as critical as gender or academic discipline in shaping the findings, it remains a relevant factor. Greece is a country with a rich and diverse flora, as well as a culturally embedded relationship with plants. The university involved in this study is located in the mountainous northern region of Greece; therefore, future implementations of the TLS in pedagogical departments situated in southern Greece, including the islands, could provide additional data and contribute to a more robust generalization of the results.

These latter limitations also serve as a foundation for proposing directions for future research. Specifically, it is recommended that the implementation of the TLS be tested on a larger sample, with a more balanced gender distribution and with students from a wider range of education departments beyond teacher education.

Furthermore, it is advisable that the study be replicated in universities located in other geographical regions of Greece, thereby introducing greater variation in the independent variable of location. Undoubtedly, implementing the TLS in countries beyond Greece could also yield valuable comparative data and further refine both the TLS itself and the broader transformative learning approach as a viable means of enhancing plant awareness.

5. Conclusions

This study contributes to educational practice by presenting, for the first time, a specially designed educational intervention for enhancing plant awareness based on the principles of transformative learning. Although further research is required to establish transformative learning within the field of plant awareness to the same extent as it has been established in sustainability education, the findings of this study provide a solid foundation for future exploration. Education for sustainability and education for plant awareness can progress together in an interconnected way, drawing on and exchanging effective strategies.

Additionally, the present study contributes to the literature on TLSs, as it represents the first application of them to the field of plant awareness, thereby expanding the TLS research into an underexplored thematic area. In this sense, it introduces TLS design as a viable pedagogical option for addressing a pressing educational challenge, namely the lack of plant awareness.

The study provides a replicable framework for designing TLS that integrates transformative learning principles into plant awareness education, a domain in which TLS-based approaches have been particularly limited. Moreover, it bridges the gap between transformative learning theory and design-based educational research by demonstrating how abstract transformative processes such as critical reflection and perspective transformation can be purposefully embedded within structured teaching sequences.

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