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Science and Plant Interest in Outdoor Learning: Evaluating Prospective Teachers' Experiences with a Botanical Inquiry Trail

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ABSTRACT

This study explores the influence of science and plant interest, alongside emotional responses, on the learning experiences of prospective primary education teachers during a botanical inquiry trail. Conducted at the University of Extremadura (Spain), the research involved 137 participants and valued their science and plant interest, knowledge acquisition, and emotional reactions before and after the trail. Results indicate that participants with higher interest in science and plants demonstrated greater knowledge gains and a more positive evaluation of the activity. Emotional responses, particularly reduced nervousness and increased enjoyment, further contributed to their engagement with botanical learning. The findings highlight the importance of encouraging interest in science and plants in teacher training programs to enhance environmental literacy and promote effective science education. This research underscores the importance of experiential learning strategies like botanical inquiry trails in motivating future educators to integrate active, inquiry-based approaches in their teaching practices.

KEY WORDS: Botanical inquiry trail; Experiential learning; Environmental literacy; Teacher training; Plant science education

INTRODUCTION

Botanical Teaching and Learning Challenges

Botanical knowledge is essential for understanding various scientific disciplines but is often neglected in education, leading to student disinterest (Kletečki et al., 2023; Stagg and Dillon, 2022; Wandersee and Schussler, 2001). Promoting environmental literacy through botanical education is necessary, as plants are foundational to ecosystems and vital for addressing global challenges such as biodiversity loss and climate change (Amprazis and Papadopoulou, 2020; Uno, 2009). However, engaging students and educators in plant science remains a challenge, partly due to the focus on animal biology in curricula (Comeau et al., 2019; Strgar, 2010). The lack of botanical training and hands-on resources among educators further contributes to the neglect of botany (Borsos et al., 2023; Kissi and Dreesmann, 2018).

One result of this neglect is plant blindness, where individuals fail to appreciate plants' ecological significance (Balding and Williams, 2016; Parsley, 2020). Plant blindness limits understanding of ecological processes and hinders efforts toward environmental literacy and sustainability (Parsley et al., 2022; Stroud et al., 2022). Addressing this issue is critical, especially in teacher training, as future educators play a key role in promoting plant awareness (Fiel'ardh et al., 2023; Pany et al., 2022). Research suggests that teacher engagement with plant sciences is often influenced by their prior experiences and intrinsic interest in the subject, which in turn affects their ability to engage students effectively (Vydra and Kováčik, 2025). Experiential learning, such as botanical inquiry trails, can promote student and teacher engagement with plant science, enhancing environmental literacy and motivating sustainable practices (Colon et al., 2020; Hiatt et al., 2021; Stagg and Verde, 2019). Studies indicate that teachers who participate in hands-on botanical learning experiences demonstrate higher confidence in teaching plant-related topics and better student outcomes (Borsos et al., 2023; Vydra and Kováčik, 2025).

Although these strategies are promising, they have had limited impact in educational settings, indicating the need for greater efforts, particularly in teacher training (Kletečki et al., 2023). Engaging both prospective teachers and students in science, especially plant science, requires developing positive attitudes and strong interests, as these are linked to deeper engagement and better learning outcomes (Osborne et al., 2003; Potvin and Hasni, 2014). For prospective teachers, developing a positive attitude toward science is crucial, as it directly influences their future teaching effectiveness (Burić and Moè, 2020; Minner et al., 2010). Conversely, negative attitudes can perpetuate a cycle of disinterest in science education (Bandura, 2000; Bleicher, 2004). Vydra and Kováčik (2025) highlight those teachers with stronger engagement in plant science use more practical activities and laboratory-based approaches, which significantly enhance students' understanding of plant biology. Improving science interest among future educators is essential for advancing science literacy and ensuring students receive engaging, high-quality science education (Avraamidou, 2020; De Jong and Taber, 2007; Hodson, 2014). Ultimately, encouraging a more science-literate society is necessary to address complex environmental and scientific challenges (Osborne and Dillon, 2008).

Aims and Objectives

Despite the well-documented benefits of outdoor learning in improving science literacy (Stagg and Verde, 2019), research on its specific impact on prospective primary education teachers remains scarce. While previous studies have explored the role of experiential learning in student engagement with plant sciences (Borsos et al., 2021), far less attention has been given to how these experiences shape the knowledge, attitudes, and teaching confidence of future educators. In addition, little is known about how intrinsic factors, such as participants' interest in science and plants, influence engagement, self-efficacy, and learning outcomes in botanical education (Vydra and Kováčik, 2025). Without a clearer understanding of these relationships, teacher education programs may fail to provide the necessary support and strategies to effectively prepare educators for plant-focused instruction. Addressing these gaps is essential for developing targeted educational interventions that enhance both content knowledge and motivation among prospective teachers, ultimately strengthening botanical literacy in primary education.

Therefore, the present study aims to address these gaps by exploring how interest in science and plants, along with emotional responses, influence prospective primary education teachers' engagement, self-efficacy, and learning outcomes in a botanical inquiry-based activity. By investigating how these factors shape knowledge acquisition and activity evaluation, this study provides insights into the role of experiential botanical learning in teacher preparation. The findings may inform the development of more effective teacher training programs, ensuring that future educators are better equipped to integrate plant science into their teaching and raise botanical literacy among students.

To achieve these aims, the study is guided by the following research questions: (1) To what extent does interest in science influence prospective teachers' evaluation of the botanical inquiry trail?; (2) How does interest in plants affect the participants' evaluation of the activity?; (3) What role does science interest play in botanical knowledge acquisition?; (4) How do emotional responses to the trial impact learning outcomes?.

MATERIALS AND METHODS

Sample

This research took place at the University of Extremadura (Spain), involving 137 prospective primary education teachers (81 % females, average age 22). The participants were deliberately selected from the 4th-year students participating in a botanical inquiry trail activity integrated in a "Knowledge of the Natural Environment in Primary Education" course during 2021–2022 and 2022–2023. This group of prospective teachers was chosen for convenience, as they willingly participated in a survey focusing on their science and plant interest, emotions, and scientific knowledge about botany. All participants were informed about the confidentiality of their responses, the purpose of the research, and the use of their data. Their participation was formalized through written informed consent, adhering to the ethical standards set by the Bioethics and Biosafety Committee of the University of Extremadura (Spain).

Methods

This study measured five key constructs: Science interest, plant interest, botanical learning, evaluation of the activity, and the emotional domain. Each construct was defined and assessed through questionnaires with distinct separate validated subscales to ensure conceptual clarity and minimize overlap. Science interest refers to participants' curiosity and enthusiasm for engaging with science-related topics and activities, crucial for promoting motivation and deep learning in scientific domains (Potvin and Hasni, 2014). Plant interest was defined as the participants' specific interest in plants and botanical topics, reflecting their willingness to engage with activities or learning that focuses on plant biology and ecology (Fančovičová and Prokop, 2011). Botanical learning measured the participants' knowledge acquisition in plant science, focusing on both factual and conceptual understanding of botanical topics gained during the activity (Kletečki et al., 2023). The evaluation of the activity assessed participants' perceptions of the botanical inquiry trail in terms of engagement, usefulness, and satisfaction, providing insight into the effectiveness of the learning experience (Savi et al., 2010). Finally, the emotional domain involved participants' emotional responses, both positive (e.g., enjoyment, interest) and negative (e.g., anxiety, frustration), before and after the activity, as emotions significantly impact motivation and learning outcomes (Pekrun et al., 2002).

Therefore, the pre-test questionnaire (Supplementary 1) addressed (a) sociodemographic data (age, gender, and previous studies); (b) emotional domain; (c) science interest; (d) plant interest; and (e) test of botany knowledge related to the activity. The post-test questionnaire (Supplementary 2) covered (a) emotional domain; (b) evaluation of the activity; and (c) test of knowledge of botany contents related to the activity.

The participants' science interest was assessed using: (a) Questions *How much do you like science subjects?* and *How intensely do you study science?,* in which participants rated their responses on a scale of 1–10 and (b) a series of statements, where participants rated their agreement with them on a Likert scale from 1 to 5 (Table 1) (Brígido Mero, 2014; Hernández-Barco et al., 2024; Hernández-Barco, 2023). The statements covered multiple dimensions of science education, including the importance and value of science (e.g., S1, S2, S5, S18), learning and teaching science (e.g., S6, S11, S14-17, S19), and personal competence and experience in science (e.g., S7, S9, S10). This science interest scale demonstrated acceptable reliability, with McDonald's $\omega = 0.727$ and Cronbach's $\alpha = 0.714$.

Table 1: Science attitude questionnaire

No.	Item
S1	Science and technology are essential to understand the world we live in.
S2	I like to propose activities in which my students get involved in the environmental improvement of their school and their surroundings.
S3	It makes me anxious to think that I am going to have to explain scientific content in class.
S4	If there were a scientific itinerary in the degree, I would choose that one.
S5	Science education is essential for the cognitive development of students.
S6	In general, more time should be devoted to science subjects.
S7	I have sufficient skills in resources and material for designing and delivering activities and preparing good science lessons.
S8	Science is difficult to learn
S9	The science I have learned throughout my training is interesting.
S10	I think I am good at science
S11	The best way to learn science is through inquiry, experimentation, manipulation, etc.
S12	When I was a child, science was more exciting to me than it is now.
S13	My experience as a student has been detrimental to my view of science.
S14	The education system fosters scientific vocations.
S15	Applying scientific methodologies in the classroom would increase my motivation.
S16	Understanding science content requires effort, perseverance, and patience.
S17	School failures in science are usually due to teachers
S18	The science I have learned throughout my schooling will be useful in my work.
S19	I feel more confident when the teacher teaches science classes in a theoretical way, following the textbook or a traditional methodology.

Plant interest was analyzed through: (a) Question Rate, from 1 to 10, your ability to teach content related to plants (Corbacho-Cuello et al., 2024) and (b) a nine-item Likert-scale questionnaire based on the plant attitude scale (PAS) (Fančovičová and Prokop, 2011). The PAS contains four categories (importance, urban trees, interest, and utilization); however, for this study, only the items from the "Interest" category were used (Table 2). The internal consistency of the plant interest scale was robust, with McDonald's $\omega = 0.827$ and Cronbach's $\alpha = 0.816$.

The botanical learning outcomes were assessed using a series of ten questions designed to measure students' knowledge of the topics addressed during the activity (Supplementary 1 and 2) (Corbacho-Cuello et al., 2024). The emotional domain was assessed by asking participants to indicate their emotions across several dimensions at different moments in the study (Hernández-Barco et al., 2024). They were presented with a list of emotions – *joy, confidence, fun, enthusiasm, satisfaction, surprise, boredom, anxiety, fear, nervousness, worry,* and *rejection* – and were asked to indicate which of these emotions

Table 2. Plant interest questionnaire

No.	Item
PL1	I like to read about plants
PL2	I would like to grow plants
PL3	I like to visit parks, botanical gardens, etc., where I can see lots of plants
PL4	I like to spend part of my free time enjoying nature
PL5	I would like to have a small garden
PL6	I like plants
PL7	We should have learned more about the importance of plants at school
PL8	I like to watch videos or programs about plants
PL9	I like to walk in the forest/countryside

they felt in relation to specific contexts: About science in general (pre-test), about the activity expectation (pre-test), after completing the activity (post-test). In addition, participants were asked to indicate the emotions they usually felt about plants before (pre-test) and after the activity (post-test). This comprehensive emotional assessment allowed for an analysis of changes in emotional responses related to both science and plant-related activities, as well as an evaluation of how the botanical inquiry trail influenced participants' emotional engagement.

Finally, the evaluation of the activity was carried out using a 22-item questionnaire in the post-test (Corbacho-Cuello et al., 2024; De Carvalho et al., 2018; Savi et al., 2010). These items were divided into nine categories across three dimensions: (1) Motivation – covering attention, relevance, reliability, and satisfaction; (2) experience – covering immersion, challenge, social interaction, and fun; and (3) knowledge acquisition (Savi et al., 2010). Participants rated their agreement with each statement on a Likert scale from 1 to 5. The internal consistency of this questionnaire was high, with McDonald's $\omega = 0.849$ and Cronbach's $\alpha = 0.843$.

Both the pre- and post-test questionnaires were validated by five experts in the Didactics of Experimental Sciences to ensure content validity and appropriateness for the target population.

Data Analysis

First, the Kolmogorov–Smirnov normality test was performed to establish whether the data were normally distributed or not, with the result that the data were not normally distributed. Therefore, Spearman's correlation coefficient was calculated to determine the existence of correlations. Wilcoxon signed-rank test was used for knowledge analysis. For nominal variables, Chi-square was used. All the analysis was carried out with the JASP statistical program version 0.19.0 (JASP Team, 2024). Confidence levels are indicated accordingly in the results section.

Botanical Inquiry Trail

The botanical inquiry trail is an outdoor, experiential learning activity designed to engage prospective teachers in the study of local vegetation (Corbacho-Cuello et al., 2024). Participants are guided along a designated trail that includes multiple stops, where they complete various tasks such as plant identification, information retrieval using provided materials, and exploring the practical uses of local plant species. At each stop, participants are encouraged to observe plant life, collect data, and engage in critical thinking exercises about the role of plants in ecosystems. The activity integrates hands-on exploration with inquiry-based learning, allowing participants to connect theoretical knowledge with real-world applications. By immersing themselves in nature, prospective teachers gain not only botanical knowledge but also experience in active learning strategies that they can apply in their future teaching careers.

RESULTS

Science and Plant Interest

Participants demonstrated a generally positive attitude toward science (mean [M] = 6.8, standard deviation [SD] = 2.0). However, their intensity of science study (M = 8.2, SD = 1.4) was not significantly correlated with their science enjoyment ($\rho = 0.126$, $P > 0.05$), suggesting that enjoyment alone does not necessarily drive study habits. The results further revealed that participants held positive views about the importance and value of science (Table 3). Participants generally held positive views about the importance and value of science, as reflected in high mean scores for items related to the significance of science in understanding the world (S1: M = 4.50, SD = 0.77; S2: M = 4.43, SD = 0.66; S5: M = 4.16, SD = 0.84; S18: M = 2.89, SD = 1.20). This suggests strong enthusiasm for scientific inquiry and environmental improvement efforts as described in prior research (Houseal et al., 2014; Potvin and Hasni, 2014). However, responses to items about the challenges of learning and teaching science were more mixed: Participants expressed mixed responses regarding the challenges of learning and teaching science. While high scores for S11 (M = 4.50, SD = 0.76) and S16 (M = 4.17, SD = 0.77) suggest a preference for hands-on, inquiry-based learning methods and recognition of the effort required to learn science, moderate scores for S6 (M = 3.75, SD = 0.88), S17 (M = 3.42, SD = 0.92), and S15 (M = 3.78, SD = 0.87) indicate skepticism about the effectiveness of current educational practices and the role of teachers in addressing science education failures, aligning with previous works (Potvin and Hasni, 2014; Wang and Degol, 2014).

Table 3: Science interest

Item	Mean
S1	4.50±0.77
S2	4.43±0.66
S3	2.68±1.30
S4	2.73±1.28
S5	4.16±0.84
S6	3.75±0.88
S7	2.84±0.90
S8	3.19±1.00
S9	3.36±1.03
S10	2.78±1.16
S11	4.50±0.76
S12	2.92±1.24
S13	3.29±1.34
S14	2.61±1.11
S15	3.78±0.87
S16	4.17±0.77
S17	3.42±0.92
S18	2.89±1.20
S19	2.30±1.14

Participants also exhibited skepticism about the promotion of scientific vocations (S14: M = 2.61, SD = 1.11) and the effectiveness of traditional teaching methods in promoting student interest in science (S19: M = 2.30, SD = 1.14) (Kanter and Konstantopoulos, 2010; Vedder-Weiss and Fortus, 2011), as indicated by their lower scores on these items. Furthermore, some participants reported a lack of confidence in their own scientific abilities, as indicated by moderate to low scores on items such as S7 and S10, highlighting a perceived gap in personal competence when it comes to teaching science (Hu et al., 2022). This ambivalence toward personal competence may affect participants' motivation and engagement with science content, as suggested by the moderate score on item S9 (Edelson, 2001; Penuel et al., 2022).

Science was perceived as somewhat challenging (S8: M = 3.19, SD = 1.00), which may contribute to mixed feelings toward science over time. Many participants reported that science was more engaging during their childhood (S12: M = 2.92, SD = 1.24), highlighting a potential decline in enthusiasm with age (Tytler et al., 2008). The data also revealed that negative experiences in formal science education may have impacted participants' current attitudes toward science, as shown by the moderate score for S13 (Hanuscin et al., 2011). Anxiety or discomfort around teaching science was reflected in lower scores for item S3, reinforcing the idea that confidence and experience in teaching science are often lacking (Bleicher, 2007).

Concerning plant interest, participants demonstrated a relatively neutral level of plant interest (M = 3.6, SD = 0.7), suggesting neither a strong affinity for nor aversion to plant-related topics (Table 4). This finding is consistent with previous studies, which have shown that plant interest tends to be lower than interest in other scientific topics, especially compared

Table 4: Interest toward plants

Item	Mean
PL1	2.57±1.05
PL2	3.27±1.13
PL3	3.61±1.07
PL4	4.02±0.93
PL5	3.98±1.05
PL6	3.50±1.21
PL7	4.22±0.83
PL8	2.46±1.11
PL9	4.46±0.81

to perceived utility or importance (Fančovičová and Prokop, 2011). However, notable exceptions were found in activities such as walking in natural environments (PL9), which scored highly, indicating that participants enjoy outdoor activities involving plants. In addition, participants strongly agreed with the importance of plant education in schools (PL7), suggesting an awareness of their own limited knowledge about plants and the need for improvement in botanical education (Hiatt et al., 2021; Iri and Çil, 2020).

Although participants responded positively to nature-based activities, they showed relatively low personal interest in plant-related content, as indicated by their lower scores for reading about plants (PL1: M = 2.57, SD = 1.05) and watching plant-related media (PL8: M = 2.46, SD = 1.11). This aligns with previous findings on "plant blindness," where individuals underappreciate or overlook the importance of plants in the environment (Kubiatko et al., 2021; Strgar, 2010). Interest in plant-related activities varied depending on the level of engagement required. Participants showed the highest interest in maintaining a small garden (PL5: M = 3.98, SD = 1.05), suggesting that they may be more inclined to engage with botanical content when it involves hands-on tasks. Moderate interest levels were found for items PL2 and PL6, which relate to learning about plants and participating in plant-related educational activities.

Regarding the question rate, from 1 to 10, your ability to teach content related to plants, participants reported relatively high self-efficacy in teaching plant-related content (M = 7.0, SD = 1.7) when asked to rate their ability on a scale from 1 to 10, indicating a moderate to high level of confidence in their ability to teach botanical topics. This suggests that while plant interest may be moderate, prospective teachers feel relatively confident in their ability to teach botanical content. This finding is consistent with literature suggesting that prospective teachers often feel more confident in teaching biological and geological subjects than in physical sciences (Hernández-Barco, et al., 2024). Self-efficacy is a significant predictor of teaching behavior and classroom management, and participants' reported confidence in teaching plant content could have positive implications for their future teaching practices (Künsting et al., 2016). High self-efficacy has been shown to correlate with a willingness to take risks in teaching methods, leading to more dynamic and engaging classroom environments (Brígido et al., 2013). This suggests that teachers who feel competent in teaching plants are more likely to implement active, inquiry-based approaches to botanical education. However, despite the generally positive levels of self-efficacy in teaching plants, previous research has highlighted the challenges teachers face in teaching science, often due to a lack of confidence and negative experiences during their own education (Menon and Sadler, 2016). Literature reviews have found that prospective teachers tend to exhibit lower self-efficacy when it comes to teaching science in general, particularly in areas where they have had less exposure or training, which is often accompanied by high levels of anxiety and other negative emotions (Brígido et al., 2013).

Science and Plant Interest Effects on Activity Evaluation

The botanical inquiry activity received an overall positive evaluation (M = 3.98, SD = 0.41), as shown in Table 5. Among its three subcategories, user experience received the highest rating (M = 4.16, SD = 0.45), followed by knowledge acquisition (M = 4.06, SD = 0.74) and motivation (M = 3.79, SD = 0.44) (Corbacho-Cuello et al., 2024). This evaluation was further broken down into three categories – motivation, user experience, and knowledge acquisition – each of which received similar ratings (De Carvalho et al., 2018; Savi et al., 2010). The motivation category had the lowest average score, but still reflected a respectable level of participant engagement.

Spearman's rho correlations were used to examine the relationship between science interest and activity evaluation. A statistically significant, moderate positive correlation was found between participants' liking of science and their overall evaluation of the activity ($\rho = 0.209$, $p < 0.05$) (Table 6). However, no significant correlation was found between participants' reported effort in science and their evaluation of the activity ($\rho = 0.130$, $P > 0.05$), suggesting that intrinsic enjoyment of science, rather than study effort, plays a greater role in determining how positively the activity was perceived. A similar correlation was found between participants' attitudes toward science and their evaluation of the activity. However, no significant correlation was found between participants' reported effort in science and their evaluation of the activity, suggesting that participants' personal enjoyment and positive attitudes toward science, rather than the amount of effort they typically put into science studies, influenced how they assessed the botanical inquiry trail.

Participants' liking of science was significantly correlated with their motivation during the botanical inquiry activity ($\rho = 0.208$, $p < 0.05$), suggesting that those with a stronger affinity for science were more engaged in the experience. The strongest correlation was observed between participants'

Table 5: Activity evaluation

Categories	Mean scores
Total	3.98±0.41
Motivation	3.79±0.44
User experience	4.16±0.45
Knowledge	4.06±0.74

Table 6. Correlations between science interest and activity evaluation

Categories	Like	Effort	Interest
	ρ	ρ	ρ
Total	0.209*	0.130	0.386***
Motivation	0.208*	0.148	0.444***
User experience	0.155	0.129	0.313***
Knowledge	0.134	0.056	0.15

*p<0.05; **p<0.01; ***p<0.001

science interest and their perceived usefulness and relevance of the activity ($\rho = 0.444$, $p < 0.001$), further reinforcing the role of prior interest in shaping motivation. The relationship between attitudes toward science and activity evaluation, particularly in relation to motivation and user experience, suggests that participants who hold positive attitudes toward science are more likely to engage deeply with educational activities and assess them favorably (Table 6).

User experience also contributed significantly to participants' overall evaluation. A moderate positive correlation was found between science interest and user experience ($\rho = 0.313$, $p < 0.001$), indicating that those with a greater enthusiasm for science reported a higher level of enjoyment and engagement in the activity. These findings indicate that pre-existing positive attitudes toward science can enhance how participants perceive the value of educational activities (Díez-Palomar et al., 2020), further reinforcing the importance of aligning educational content with participants' interests and attitudes to boost motivation and engagement (Hidi and Renninger, 2006; Krapp, 2005).

The relationship between plant interest and activity evaluation was also assessed using Spearman's rho correlations. A moderate positive correlation was found between participants' plant interest and their overall evaluation of the activity ($\rho = 0.217$, $p < 0.05$) (Table 7). In addition, participants' self-efficacy in teaching plant-related content was strongly correlated with their perception of the activity ($\rho = 0.304$, $p < 0.001$), suggesting that those who felt more confident in plant-related knowledge were more engaged and rated the experience more favorably. Participants who reported higher self-efficacy in plant-related tasks and greater enthusiasm for plants were more likely to evaluate the botanical inquiry trail positively.

These findings indicate that higher plant self-efficacy leads to deeper engagement with botanical activities. Participants with greater confidence in their ability to understand and teach plant-related topics rated the botanical inquiry trail more favorably. The strong correlation between plant self-efficacy and knowledge acquisition ($\rho = 0.418$, $p < 0.001$) reinforces the idea that confidence plays a key role in effective learning and positive educational experiences (Bandura, 2000). In addition, participants who had a greater liking for plants tended to enjoy the activity more, as interest and enthusiasm are known to drive deeper engagement and positive emotional responses to learning experiences (Krapp, 2002).

Science and Plant Interest Effects on Knowledge

As previously reported (Corbacho-Cuello et al., 2024), the botanical inquiry activity had a significant impact on participants' botanical knowledge. A Wilcoxon signed-rank test indicated that post-test correct answers ($M = 54.2\%$, $SD = 20.3$) were significantly higher than pre-test correct answers ($M = 23.2\%$, $SD = 14.4$), $W = 94$, $p < 0.001$, with a large effect size ($r_B = -0.974$), reflecting a 31.0% increase in correct responses.

As shown in Table 8, a moderate positive correlation was found between participants' liking of science and their botanical learning gains ($\rho = 0.267$, $p < 0.01$), suggesting that those with higher enthusiasm for science performed better on the botanical knowledge assessments. In addition, science enjoyment was significantly correlated with post-test scores ($\rho = 0.267$, $p < 0.01$) but had no strong effect on pre-test performance ($\rho = 0.261$, $p < 0.05$), indicating that engagement with the activity played a role in knowledge improvement. The significant correlation between science interest and learning outcomes supports the idea that intrinsic motivation influences cognitive engagement and retention. The pre-post score difference ($\Delta M = 28.6\%$) was significantly higher for participants with strong science interest ($\rho = 0.224$, $p < 0.05$), reinforcing the notion that enthusiasm for science promotes better comprehension and recall of botanical concepts (Hidi and Renninger, 2006).

Participants with positive attitudes toward science achieved significantly greater knowledge gains, as indicated by the correlation between science interest and pre-post improvement ($\rho = 0.224$, $p < 0.05$). This suggests that enhancing positive perceptions of science in teacher training may directly impact knowledge acquisition and educational outcomes (Osborne et al., 2003). Finally, a significant positive correlation was observed between participants' plant interest and their post-test scores ($\rho = 0.242$, $p < 0.01$), indicating that those with a greater affinity for plants engaged more effectively with the botanical inquiry activity. However, plant interest alone did not strongly predict knowledge gains ($\rho = 0.058$, $P > 0.05$), suggesting that other factors, such as self-efficacy and prior exposure to botanical content, may play a more substantial role in learning outcomes. Interest in botanical topics was moderately correlated with knowledge retention ($\rho = 0.242$, $p < 0.01$), reinforcing the role of engagement in enhancing memory recall and conceptual understanding. However, self-

Table 7: Correlations between plants interest and activity evaluation

Categories	Plant liking	Plant self-efficacy
	ρ	ρ
Total	0.217*	0.304***
Motivation	0.243**	0.276**
User experience	0.126	0.236**
Knowledge	0.149	0.418***

*p<0.05; **p<0.01; ***p<0.001

Table 8: Science and plants interest correlations with knowledge

Scores	Science			Plant	
	Like	Effort	Interest	Plant liking	Plant self-efficacy
	ρ	ρ	ρ	ρ	ρ
Pretest score	0.261**	0.145	0.070	0.237**	0.168
Posttest score	0.267**	0.163	0.264**	0.242**	0.133
Score Δ	0.114	0.044	0.224*	0.058	0.050

*p<0.05; **p<0.01; ***p<0.001

efficacy in plant-related education was more strongly correlated with knowledge acquisition ($\rho = 0.418$, $p < 0.001$) than interest alone, indicating that confidence in teaching botanical content is a critical factor in knowledge retention (Krapp, 2002).

Emotional Domain

The analysis of the emotional domain provided valuable insights into participants' emotional responses toward science, the botanical inquiry activity, and plants at different time points (pre- and post-test) (Figure 1). Chi-square (χ^2) tests of independence were used to examine whether significant shifts in emotional responses occurred after participation in the activity. Before the activity, participants reported predominantly negative emotions toward science, with nervousness (53%) and worry (43%) being the most common. A Chi-square test of independence revealed a significant association between pre- and post-activity nervousness levels ($\chi^2 = 6.84$, df = 1, $p < 0.05$), indicating that participation in the botanical inquiry trail significantly reduced science-related anxiety. When anticipating the botanical inquiry trail, participants reported predominantly positive emotions, with fun (74%) and enthusiasm (63%) being the most frequently reported feelings, followed by joy and surprise (53% each). Chi-square analysis confirmed a significant shift toward positive emotions pre-activity ($\chi^2 = 9.76$, df = 1, $p < 0.01$), suggesting that the experiential nature of the activity generated excitement and engagement. Post-activity assessments showed significant reductions in nervousness ($\chi^2 = 7.21$, df = 1, $p < 0.05$) and surprise ($\chi^2 = 4.89$, df = 1, $p < 0.05$), indicating that participants felt more at ease and more comfortable with botanical learning after completing the trail.

In contrast, participants' emotions toward plants remained largely positive both before and after the activity, with fun (50%) and enthusiasm (40%) being the most common pre-activity responses. However, a significant reduction in plant-related nervousness was observed post-activity ($\chi^2 = 5.42$, df = 1, $p < 0.05$), suggesting that participants became more confident and comfortable engaging with botanical topics after the experience. Despite these changes in emotional responses, Chi-square tests found no significant association between participants' emotional shifts and knowledge acquisition ($\chi^2 = 2.15$, df = 1, $P > 0.05$) or activity evaluation ($\chi^2 = 1.73$, df = 1, $P > 0.05$). This suggests that while positive emotions contribute to engagement and motivation, they may not directly predict cognitive outcomes such as retention of botanical knowledge or perception of the learning experience.

DISCUSSION

Science and Plant Interest

Participants exhibited a generally positive attitude toward science, reflecting their enthusiasm for science-related topics. However, the lack of a significant correlation between science enjoyment and study intensity suggests that interest alone may not drive engagement, as factors like external pressures and career goals also play a role (Rieger et al., 2022; Ruiz-Alfonso et al., 2020). Our findings align with previous research (Osborne et al., 2003; Potvin and Hasni, 2014), which suggests that intrinsic interest in science is a key driver of engagement and improved learning outcomes. However, unlike these studies, our results indicate that science interest alone does not fully explain knowledge acquisition. This suggests that additional variables, such as self-efficacy and active participation, may play a more substantial role in determining learning success.

Participants scored highly on the importance of science in society, aligning with research indicating that those who see science as critical to global issues tend to engage more deeply (Potvin and Hasni, 2014). Nonetheless, mixed responses regarding teaching confidence suggest a lack of preparedness to fully engage with complex scientific topics, particularly in areas like scientific methodology and vocational promotion (Kanter and Konstantopoulos, 2010; Vedder-Weiss and Fortus, 2011).

Students also reported moderate challenges with science, indicating that many find it difficult, which can lead to disengagement (Collins and Osborne, 2000). Some reflected that science was more engaging in childhood, suggesting the need for more interactive learning to retain this enthusiasm (Tytler et al., 2008). Anxiety about teaching science was also reported, reinforcing the need to address self-efficacy to ensure educators feel equipped to teach effectively,

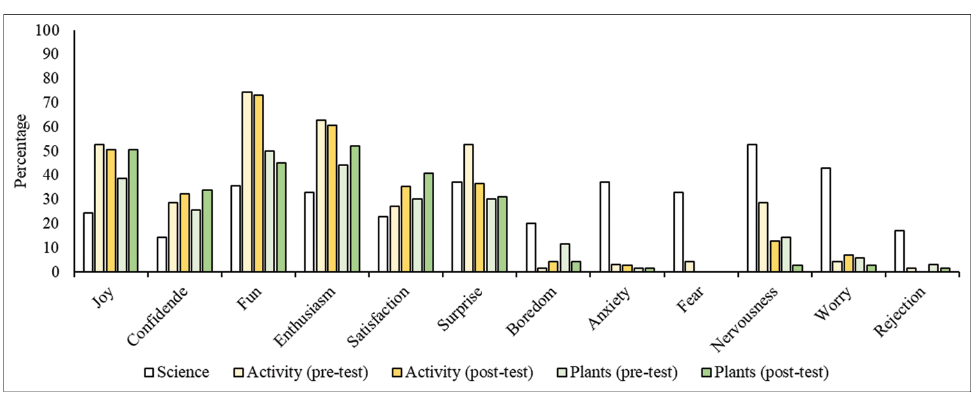

Figure 1: Emotions toward science, the activity, and plants

especially using inquiry-based methods (Bleicher, 2007; Brígido et al., 2013).

In contrast, plant interest levels were neutral, consistent with plant blindness (Fančovičová and Prokop, 2011). Previous studies (Fančovičová and Prokop, 2011) suggested that plant interest is a strong predictor of botanical knowledge acquisition. However, our findings indicate that plant self-efficacy, rather than interest alone, was a more significant factor in learning outcomes. This suggests that while fostering interest is important, building confidence in teaching botanical content may be crucial for improving botanical literacy, as also emphasized in recent research (Borsos et al., 2023).

However, participants expressed strong interest in nature-related activities like walking in natural environments and recognized the importance of plant education in schools (Hiatt et al., 2021). The low scores for passive activities like reading about plants suggest that hands-on engagement is a key to develop a deeper connection with botany (Kubiatko et al., 2021; Strgar, 2010). This aligns with Borsos et al. (2023), who found that teacher trainees with outdoor education experience exhibited significantly better plant identification skills than those without, reinforcing the importance of experiential learning. Similarly, Vydra and Kováčik (2025) emphasize that teachers who actively incorporate practical activities, such as botanical experiments, tend to raise stronger student engagement and improve conceptual understanding. High interest in practical activities such as gardening indicates that experiential learning strategies, like the botanical inquiry trail, may be effective in increasing engagement with plant science. Participants also showed strong agreement on the importance of plant education, reflecting a growing awareness of the role plants play in sustainability and education (Iri and Çil, 2020).

Relatively high self-efficacy in teaching plant-related content self-efficacy was reported, suggesting they feel confident delivering botanical education, contrasting with the anxiety seen in teaching science (Hernández-Barco et al., 2024). Self-efficacy strongly correlates with teaching performance, and teachers with higher self-efficacy are more likely to adopt innovative, inquiry-based methods (Brígido et al., 2013; Künsting et al., 2016). However, self-efficacy may vary depending on the subject, with lower confidence reported in teaching more complex topics such as physics or chemistry (Menon and Sadler, 2016). Addressing these imbalances is important to ensure prospective teachers are equally prepared across all scientific disciplines.

Science and Plant Interest Effects on Activity Evaluation

The positive correlation between participants' liking of science and their evaluation of the botanical inquiry activity highlights the influence of pre-existing attitudes on how educational experiences are perceived. Participants who enjoyed science were more likely to find the activity engaging and meaningful, supporting research that links personal interest to motivation and deeper engagement (Hidi and Renninger, 2006; Krapp, 2005). When educational activities align with students' interests, they tend to produce more immediate learning outcomes and sustain long-term interest (Inkinen et al., 2020). The findings also reveal that effort alone does not necessarily result in a more favorable evaluation of the activity. While effort signifies a commitment to studying science, it is intrinsic enjoyment that appears to have a stronger influence on how participants experience educational activities (Pintrich, 2003).

For plant interest, the positive correlation between participants' enthusiasm for plants and their evaluation of the activity demonstrates that personal interest enhances the learning experience. Participants with a stronger interest in plants found the activity more meaningful and enjoyable, supporting the idea that hands-on, experiential learning is most effective when it aligns with students' interests (Ainley and Ainley, 2011; Krapp, 2002). Furthermore, the correlation between plant self-efficacy and the evaluation of the activity highlights the role of confidence in learning. Participants with greater self-efficacy were more likely to persist through challenges and rated the activity more favorably, consistent with Bandura's (2000) theory that higher self-efficacy promotes deeper engagement and a more rewarding learning experience. Building self-efficacy in botanical education could be a crucial strategy for enhancing both student and teacher engagement.

These findings suggest that educators should focus on promoting self-efficacy and interest in science and plants to improve student engagement. By designing interventions that improve confidence and curiosity, educators can enhance students' perceptions of botanical education and cultivate a deeper appreciation for plant science (Díez-Palomar et al., 2020). In addition, addressing motivational factors such as attention, difficulty, and relevance could make science learning more accessible and appealing, potentially altering students' perceptions of science as a challenging subject (Pintrich, 2003).

Science and Plant Interest Effects on Knowledge

The improvement in participants' botanical knowledge showed the effectiveness of experiential learning in enhancing their understanding of botanical science. This supports the idea that active learning strategies, like the botanical inquiry trail, promote better cognitive engagement and improve knowledge retention (Hernández-Barco et al., 2024). Experiential learning strategies, such as the botanical inquiry trail, have been shown to enhance engagement and learning outcomes (Borsos et al., 2023; Stagg and Verde, 2019). Our results align with these studies, demonstrating a significant improvement in botanical knowledge following participation in the activity. However, while our study assessed immediate learning gains, future research should investigate long-term knowledge retention, as suggested by Colon et al. (2020), to determine whether these effects persist over time.

The positive correlation between science interest and learning outcomes highlights the key role of interest in motivating deeper engagement with learning materials. Interest drives more effective information processing, ultimately leading to better learning outcomes (Hidi and Renninger, 2006). This finding reinforces the need for educational strategies that not only deliver content but also cultivate curiosity and enthusiasm for science.

Similarly, the correlation between positive attitudes toward science and learning outcomes emphasizes the importance of developing better views of science to enhance academic success. Students with positive attitudes are more likely to engage deeply and achieve higher learning gains (Osborne et al., 2003). Therefore, educators should focus on creating positive science learning experiences that sustain engagement and long-term success.

The correlation between plant interest and learning outcomes further supports the importance of interest in the subject matter for academic achievement. Participants with greater interest in plants engaged more deeply with the botanical inquiry trail, resulting in improved knowledge acquisition. This aligns with interest-driven learning theories, which suggest that students invest more cognitive resources in subjects they find personally engaging (Krapp, 2002). Addressing plant blindness is extremely important, as Borsos et al. (2023) found that teacher trainees often lack plant identification skills due to limited direct interaction with plants. Similarly, Vydra and Kováčik (2025) showed that teachers with greater awareness of plant education are more engaged in teaching botany, reducing student knowledge gaps. These findings emphasize the need for hands-on, outdoor learning strategies to foster plant appreciation and improve botanical understanding.

Emotional Domain

Participants' high levels of nervousness and worry toward science reflect the common anxiety associated with scientific subjects, often stemming from negative past experiences (Pekrun et al., 2002). Pekrun et al. (2002) proposed that emotions play a critical role in shaping learning outcomes, with positive emotions enhancing engagement and knowledge retention. Our findings partially support this, as we observed a significant reduction in science-related anxiety and an increase in enjoyment after the activity. However, unlike Pekrun's theory, we did not find a strong correlation between emotional responses and knowledge acquisition. This suggests that while emotional engagement may facilitate motivation, structured learning activities and self-efficacy might be stronger determinants of actual knowledge gains (Immordino-Yang and Damasio, 2007).

However, the shift to positive emotions – such as fun and enthusiasm – when anticipating the botanical inquiry trail highlights the potential of inquiry-based learning to reduce anxiety and boost excitement for learning. The significant reductions in nervousness and surprise after the activity further supports the idea that experiential learning can alleviate anxiety by providing a structured and engaging environment. These findings suggest that botanical inquiry trails can serve as effective tools for easing students' anxiety toward science and fostering more positive emotional associations with learning.

In contrast, participants consistently expressed positive emotions toward plants, with significant reductions in nervousness after the activity. This highlights the potential of nature-based activities to adopt positive emotional responses, as outdoor experiences are known to reduce stress and enhance well-being (Hiatt et al., 2021).

Interestingly, no significant relationship was found between emotional responses and knowledge acquisition or activity evaluation, aligning with research that shows while emotions are crucial for motivation and engagement, their direct impact on cognitive outcomes may be limited (Immordino-Yang and Damasio, 2007). While emotions create a positive learning environment, cognitive outcomes such as knowledge retention may depend more on factors such as interest, attitudes, and self-efficacy.

CONCLUSION

This study investigated the influence of science and plant interest, self-efficacy, and emotional responses on prospective teachers' engagement and learning outcomes during a botanical inquiry trail. Our findings demonstrate that while plant interest contributed to engagement, it alone was not a strong predictor of botanical knowledge acquisition, contrasting with previous research (Fančovičová and Prokop, 2011). Instead, self-efficacy played a more important role, indicating that confidence in applying botanical knowledge may be more important than mere interest. In addition, while our results support the emotional engagement benefits described by Pekrun et al. (2002), we did not find a direct link between emotions and knowledge outcomes. This suggests that motivation and structured learning activities may be stronger drivers of knowledge retention, reinforcing the need for experiential, inquiry-based educational strategies to foster both interest and self-efficacy in future educators.

These findings have important implications for teacher education. Since self-efficacy emerged as the strongest predictor of botanical knowledge acquisition, teacher training programs should prioritize activities that enhance confidence in teaching plant science, such as hands-on inquiry-based learning and real-world application of botanical concepts. Our results also emphasize the need for educational strategies that translate plant interest into practical teaching competence, rather than assuming that interest alone will drive knowledge retention. Field-based learning experiences, where prospective teachers actively engage with botanical content, could be particularly effective in achieving these goals.

Based on these findings, we propose the following recommendations for improving science and environmental literacy in teacher education: (a) Integrate hands-on botanical activities in teacher training curricula to enhance self-efficacy and active engagement in plant science education; (b) Incorporate emotional engagement strategies to reduce science-related anxiety and make scientific content more approachable for future educators; (c) Provide continuous professional development opportunities for educators, ensuring they have access to experiential learning methodologies that reinforce both content knowledge and pedagogical confidence; (d) Encourage educational policies that promote environmental literacy, embedding plant science and field-based education more deeply into broader science education frameworks.

By implementing these strategies, teacher education programs can cultivate a generation of educators who are not only knowledgeable about plant science but also confident in teaching it. This, in turn, can contribute to a more scientifically literate and environmentally conscious society.

While this study provides valuable insights into the role of self-efficacy and experiential learning in teacher education, further research is needed to: (a) Examine long-term knowledge retention following inquiry-based botanical learning experiences; (b) Investigate how different teaching strategies (e.g., active learning vs. traditional methods) affect both engagement and confidence in science education; and (c) Explore the integration of digital and outdoor learning to maximize student motivation and knowledge acquisition.

Strengthening botanical literacy in teacher training is critical for equipping future educators with the skills and confidence needed to inspire scientific curiosity in students. Future research should focus on developing and assessing sustainable educational interventions that bridge the gap between interest, self-efficacy, and effective teaching practices in plant science education.

CONFLICTS OF INTEREST

The authors confirm that there are no known conflicts of interest associated with this publication.

ETHICS STATEMENT

This research was approved by the Bioethics Committee of the University of Extremadura (reference number: 154/2003). All participants were informed about the purpose of the study, and their participation was voluntary. Written informed consent was obtained from all participants in accordance with institutional and national research ethics guidelines.

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