

THE ROLE OF BOTANICAL GARDENS IN TEACHER TRAINING WITHIN THE CONTEXT OF CLIMATE CHANGE AND EDUCATION FOR SUSTAINABILITY

El papel de los jardines botánicos en la formación del profesorado ante el cambio climático y la educación para la sostenibilidad

Raquel DE RIVAS*, Amparo VILCHES** and Olga MAYORAL*

* *Universitat de València. Jardí Botànic UV. España.*

raquel.rivas@uv.es; amparo.vilches@uv.es

<https://orcid.org/0000-0002-8936-0146>; <https://orcid.org/0000-0001-5308-2714>

** *Universitat de València. España.*

olga.mayoral@uv.es

<https://orcid.org/0000-0003-2340-4676>

Date received: 27/10/2025

Date accepted: 22/12/2025

Online publication date: 23/06/2026

How to cite this article / Cómo citar este artículo: De Rivas, R., Vilches, A. & Mayoral, O. (2026). The Role of Botanical Gardens in Teacher Training within the Context of Climate Change and Education for Sustainability [El papel de los jardines botánicos en la formación del profesorado ante el cambio climático y la educación para la sostenibilidad]. *Teoría de la Educación. Revista Interuniversitaria*, 38(2), 107-126. <https://doi.org/10.14201/teri.32933>

ABSTRACT

The current socio-environmental crisis, characterised, among other things, by the collapse of biodiversity, climate change, and an increasing symbolic and educational disconnection from the natural world, requires profound transformation across all areas, especially education. In this context, university botanical gardens emerge as

key infrastructures for promoting meaningful, contextualised, and interdisciplinary education for sustainability. This study analyses the potential of the Botanical Garden of the University of Valencia as a teaching resource for the professional development of secondary school teachers.

The research is structured around the design, implementation, and evaluation of an intensive course on sustainability and climate change, carried out in 2022 and 2023. Teachers from different subject areas participated, working collaboratively to create teaching proposals applicable to their respective subjects, aligned with the curriculum and the Sustainable Development Goals. Throughout the sessions, theoretical reflections were combined with practical outdoor experiences, thus fostering active learning, an emotional connection to nature, and practical classroom application.

The results show a high appreciation of the course and the garden as an educational space. The activities carried out demonstrated the potential of an interdisciplinary approach to address environmental issues from different perspectives. The proposals ranged from estimating CO₂ sequestration to the recovery of plant cultural heritage. The teachers expressed their intention to implement these ideas, thereby reinforcing their commitment to educational transformation.

This study concludes that integrating green spaces, such as botanical gardens, into teacher training fosters a reconnection with natural systems and contributes to the development of key competencies for addressing the socio-environmental challenges of the 21st century.

Keywords: botanical gardens; teacher training; education for sustainability; climate change; SDGs; global crisis.

RESUMEN

La actual crisis socioambiental, caracterizada entre otras cosas por el colapso de la biodiversidad, el cambio climático y la desconexión simbólica y educativa con el mundo natural, requiere una transformación profunda en todos los ámbitos, especialmente en el educativo. En este contexto, los jardines botánicos universitarios se revelan como infraestructuras clave para promover una educación para la sostenibilidad significativa, contextualizada e interdisciplinar. Este estudio analiza el potencial del Jardí Botànic de la Universitat de València como recurso didáctico en la formación continua del profesorado de secundaria.

La investigación se articula a través del diseño, implementación y evaluación de un curso intensivo sobre sostenibilidad y cambio climático, desarrollado en 2022 y 2023. Participaron docentes de distintas especialidades, que trabajaron de forma colaborativa para generar propuestas didácticas aplicables a sus respectivas materias, vinculadas al currículo y a los Objetivos de Desarrollo Sostenible. A lo largo de las sesiones, se combinaron reflexiones teóricas con experiencias prácticas al aire libre, promoviendo el aprendizaje activo, la conexión emocional con la naturaleza y la aplicación concreta en el aula.

Los resultados muestran una alta valoración del curso y del jardín como espacio formativo. Las actividades desarrolladas evidenciaron el potencial del enfoque

interdisciplinar para abordar problemáticas ambientales desde diversas áreas. Las propuestas incluyeron desde estimaciones de captura de CO₂ hasta la recuperación del patrimonio cultural vegetal. El profesorado manifestó su intención de implementar estas ideas, reforzando el compromiso con la transformación educativa.

Este trabajo concluye que integrar espacios verdes como los jardines botánicos en la formación docente fomenta una reconexión con los sistemas naturales y contribuye a desarrollar competencias clave para enfrentar los desafíos socioambientales del siglo XXI.

Palabras clave: jardines botánicos; formación del profesorado; educación para la sostenibilidad; cambio climático; ODS; crisis global.

1. INTRODUCTION

The socio-environmental situation currently faced by humanity poses an unprecedented crisis in which numerous serious intertwining problems converge to create a highly complex scenario. Described and substantiated for several decades now, with broad consensus amongst experts and scientific institutions, a profound transformation is required in response to this scenario across every layer of society and in diverse fields. One of the most relevant frameworks that can help guide this transformation is the 2030 Agenda and the Sustainable Development Goals (SDG).

The global crisis cannot be understood in terms of a single cause nor can it be addressed with fragmented solutions. It is shaped by a web of mutually exacerbating issues: biodiversity loss, resource depletion, collapsing ecosystems, fresh water shortages, widespread pollution, climate change, food insecurity, social inequality, geopolitical tensions and the erosion of cultural diversity, among other factors. These closely related elements are all rooted in a deeply dysfunctional model of the relationship between humanity and nature. Scientific concern about the increasing disconnection from the nature systems that sustain us has grown in recent years. This disconnection is not just physical, but also symbolic, cultural and educational. Çakar et al. (2021) and Chu (2022) note that this missing link to the natural world has been so decisive that the biophysical foundations of life are at risk. From an educational perspective, this break calls for a 'glocal' approach and training in planetary citizenship capable of constructing scales and responsibilities (Murga-Menoyo and Novo, 2017).

As indicated by Rockström et al. (2024), these issues are pushing us dangerously close to the so-called planetary boundaries, and even beyond them in some cases, such as concentrations of carbon dioxide in the atmosphere, species extinction rates and loss of biodiversity. This set of thresholds defines a framework in which humanity can safely survive (Folke, 2013).

In light of this complex situation, education emerges as an essential tool, with teachers playing a key role in any strategy drawn up, given their potential for

generating a profound cultural change. Educational transformation must focus on regaining an understanding of the inter-dependence between humans and ecosystems, integrating and fostering this scientific knowledge in basic curricula at every educational level. The aim is to cultivate not only cognitive, but also ethical and emotional, skills that will enable younger generations to correct the aforementioned dysfunctions and exercise citizenship with an awareness of our dependence on the natural world.

Therefore, resources such as botanical gardens are essential additions to educational interventions designed to amplify and improve the impact and efficacy of education for sustainability (ES). While botanical gardens cannot be considered natural spaces, they are green spaces that offer a wide range of opportunities for research, conservation and education in locations with limited space but featuring lush biodiversity. It is striking that, despite the extensive progress seen in terms of the potential of plants in general and of botanical gardens in particular (De Rivas et al., 2024; Mayoral, 2019), they remain underused as a didactic resource in settings like that described above. The aggravation of the planet's problems, in which the loss of biodiversity has a particularly revealing weight, has led to the emergence of new challenges for conservation and education which these spaces are uniquely positioned to address. There is also a historical and structural dimension worth highlighting: a good number of botanical gardens belong to higher education institutions and were created primarily for teaching purposes within formal education settings (botany, medicine, pharmacology). These university roots naturally position them as ideal academic infrastructures for teaching and for scholarly research, in addition to making them essential tools for ES among students at diverse educational levels.

In a region such as the Mediterranean, long recognised as one of the main hotspots for biodiversity worldwide (Hewitt, 2011; Myers et al., 2000) and, at the same time, one of the regions most prone to climate change and other pressures of global change (Cramer et al., 2020), botanical gardens represent an especially relevant educational tool. These spaces are not only home to a valuable sampling of local and regional flora, but they also enable students and teachers to experience a direct connection with the environment closest to them, thus facilitating so-called *place-based solutions* that promote meaningful, contextualised learning (UNESCO, 2017). This connection to the region raises ecological awareness, fostering a deep understanding of impacts already seen at a local level, such as the loss of endemic species, gradual aridification, the problems of the rural world and changes in water cycles (Díaz et al., 2019).

Based on this approach, research was conducted at the Jardí Botànic de la Universitat de València (JBUV) as part of a broader intervention involving secondary school teachers and their students at diverse schools across the province (De Rivas et al., 2025). The university botanical garden was created as a space for teaching

and research in botanical studies and has since extended its aims and usage to other fields. The aim of the study is two-fold, and it is designed in assessable terms. Firstly, the botanical garden is defined as an educational tool with wide-ranging potential in diverse areas of knowledge, particularly in teacher training. Secondly, and most importantly, the active engagement of secondary school teachers is sought, thus building their skills and interest in ES through the use of highly motivating contexts and themes.

To this end, the climate change-biodiversity dichotomy, and the educational approach to it, is reviewed and discussed, later focusing on and specifically addressing the teacher training required in response to the numerous calls for their participation, within the framework of the JBUV. There follows a description of the methodology used, including the experimental designs created for this purpose (an *ad-hoc* course and an evaluation thereof), and some of the findings gathered to date are presented and analysed. Finally, conclusions are formulated and estimates made, indicating future lines of research and innovation in education, focusing on the necessary involvement of teachers in ES settings.

The magnitude of the socio-environmental challenge described above forces us to move beyond fragmented visions of the issue in order to progress toward a new paradigm based on respect for the planet's boundaries and social equity. As Bybee (1991) remarked, sustainability continues to be "the most necessary unifying concept" of our time. Now more than ever, this word embodies the possibility of repairing our relationship with nature and constructing, in the present, a hospitable future together.

2. BIODIVERSITY AND CLIMATE CHANGE EDUCATION IN THE CONTEXT OF A BOTANICAL GARDEN

Climate change is dramatically transforming the planet's ecosystems, impacting both land and water resources. These changes have already prompted a massive loss of species, leading to an overall decline in planetary health. One of the most critical issues is the reduction in essential ecosystem services such as carbon capture, flood control, water and air purification, soil fertility and pollination. When natural systems are destabilised, they cease to provide these services, resulting in severe ecological, social and cultural impacts, leaving human livelihoods increasingly vulnerable. The collapse of biodiversity is recognised as one of the planetary boundaries that has already been significantly breached, and climate change is deemed the main factor in this decline, as confirmed by a large-scale international study published recently (IUCN, 2023), among other sources.

As is the case with socio-environmental issues as a whole, the relationship between biodiversity and climate change is profoundly interdependent and reciprocal: while climate change represents one of the primary threats to biodiversity,

the loss of biodiversity, in turn, fuels global warming. Increasing temperatures, changes in precipitation patterns, the acidification of the oceans and extreme weather events are driving habitat deterioration, displacement of species and local extinctions (Beery et al., 2020), contributing to the withdrawal from rural settings and growing inequality, among numerous other social problems. At the same time, the destruction of natural ecosystems like forests, wetlands, prairies and marine systems disrupts key processes such as carbon capture and storage, reducing the planet's capacity to regulate climate. In this context, biodiversity conservation and restoration represent key strategies for mitigating—but also for adapting to—climate change. Diverse, healthy ecosystems act as natural barriers against climate disasters: protecting coastal regions, cooling the environment, regulating water flows and keeping soil fertile, while at the same time effectively capturing carbon in a lasting way. Furthermore, biodiversity affords resilience; the greater the variety of species and ecological functions within an ecosystem, the better equipped it will be to adapt to changing conditions without reaching a breaking point. Investing in biodiversity is not merely an environmental action, but a strategic response to climate change with a powerful social impact (Seddon et al., 2020). Such an investment is crucial for the survival of all living beings in order to restore the balances upon which our own species depends, thus avoiding serious consequences like pandemics, and to acknowledge our reliance on the system services provided by the biodiversity to which we belong (Gil Pérez and Vilches, 2023).

Based on this assessment, the research deliberately incorporates the JBUV as a cornerstone of the proposed actions to be implemented for sustainability and climate change, strengthening and encouraging its use as an element of ES.

These experiences also promote education in values such as social justice, human rights, knowledge about other cultures and respect for diverse opinions and ways of life (Gil Pérez and Vilches, 2017). Specifically, education outside the classroom in green spaces offers numerous interesting opportunities to explore and develop holistic, cross-disciplinary, experiential and action-oriented approaches (Amórtegui et al., 2017). Furthermore, working with specific environmental impacts provides a powerful means of literacy-building and ethical 'awakening' (Puig i Baguer and Casas-Jericó, 2017), which botanical gardens can facilitate through a situated approach.

Botanical gardens encourage open, active learning by participants, positively influence students' socio-environmental knowledge and attitudes, and facilitate comprehension of subjects specifically related to nature and climate change (Eberbach and Crowley, 2017; Sellmann, 2014; Sellmann and Bogner, 2013; Williams et al., 2015). For this reason, efforts are being stepped up to expand and enhance educational programmes (Dodd and Jones, 2010; Suárez-López and Eugenio, 2018) in these spaces, which can include wide-ranging, interrelated themes such as the climate emergency, biodiversity conservation, sustainable

gardening, improving food security, and exchanges of personal experiences about the value of biodiversity for local communities, to name a few (Vergou and Willison, 2016).

For these undertakings to be successful, teachers, leaders and educational institutions require training and engagement capable of driving the change of cultural and educational paradigm that needs to be seen (Lugg, 2007). In fact, the LOMLOE [the Spanish law regulating the educational system], for example, specifically mentions the need for education focused on sustainability and the threats of climate change, explicitly noting that the educational system must foster 'students' contact with green spaces.

In light of the complex systemic challenges posed by climate change, such as the accelerated loss of biodiversity and the aforementioned deterioration of essential ecosystem services, there is an unquestionable need to incorporate relational, emotional and ethical perspectives in education.

The inclusion of the JBUV in ES proposals is an illustrative example of how these educational spaces can facilitate comprehensive learning. In addition to academic knowledge, these spaces promote emotional experience, ethical reflection and a connection to values that nurture care for the planet. This reinforces the idea that transformative education must combine scientific knowledge with critical skills, social sensitivity and engagement, thus contributing to the formation of citizens capable of understanding and coping with the threats of today and tomorrow from a holistic, committed viewpoint.

Botanical gardens have unique features that make them privileged spaces for the development of educational proposals not easily replicated in other settings, including their global presence and the diversity of the living plant collections they are home to. This idiosyncrasy offers highly valuable teaching-learning opportunities for addressing complex issues like the effects of climate change in a tangible way. Moreover, many of these gardens are host to exceptional historical archives —herbaria and gene banks— that comprise valuable scientific and teaching resources rarely found in other educational settings. In recent years, this potential has increased thanks to the growing involvement of botanical gardens in citizen science initiatives and collaborative projects linked to the current planetary crisis (Miller and Derewnicka, 2019).

This is compounded by a strategic argument about including work sessions in green spaces in ES programmes: conservation of the plant world is an undeniable requirement on the path to meeting the Sustainable Development Goals (Amprazis and Papadopoulou, 2020). The issue reflects a key paradox that emphasises the very essence of the concept of sustainability: without plants, life on Earth would not be possible.

In 2018, the Climate Change Alliance of Botanic Gardens signed an international agreement acknowledging the urgency and unprecedented magnitude of the climate crisis. The founding statement highlights the key role of botanical

gardens as custodians of scientific and horticultural knowledge and as inspirational, educational spaces for driving social change. The Alliance underscores the need to act collectively to protect living botanical collections, landscapes and life on the planet, promoting the creation of resilient environments. In a joint statement, gardeners from around the world declared that the time to act is now.

In sum, botanical gardens are miniature depictions of nature (Heyd, 2006), a resource that can be used for educational purposes to influence visitors' experience, their connection to nature, their understanding of biodiversity and its connection to other issues such as the threats of the climate crisis (Zelenika et al., 2018) and the socio-environmental problems that are emerging. Therefore, it must be noted that botanical gardens afford a tremendous opportunity: to reconnect communities and the natural world (De Rivas, 2024).

3. TEACHER TRAINING ABOUT CLIMATE CHANGE AND SUSTAINABILITY

Given the growing relevance and urgency of socio-environmental issues, a broad, widespread commitment by teachers is a crucial step toward student involvement in the measures that must be taken (Buchanan, 2012; Geli and Terradellas, 2019; Medir et al., 2014; Summers et al., 2005; Vilches and Gil Pérez, 2012). However, numerous studies coincide in pointing out that most teachers do not feel prepared to discuss these contents, leading to insufficient or fragmented teaching about sustainability (Evans, 2020; Timm and Barth, 2021). The shortcomings found are related not only to a limited understanding of the contents linked to this matter, but also to a lack of specific tools for effectively integrating them into their daily work. Questions about how to teach these subjects, in addition to a perceived failure to achieve the desired learning objectives, generate insecurity among teachers and highlight the urgent need for better training and institutional support (Geli et al., 2005; Vilches and Gil Pérez, 2012; Waltner et al., 2020). This lack of training can even lead to an imbalanced view of the magnitude and urgency of the global socio-environmental crisis (García-González et al., 2020; López-Fernández et al., 2024).

Work must be done from diverse perspectives to address such a situation. One key way of doing this consists in bolstering initial training for teachers, so that they receive training in ES that prepares them to act in such a specific social context before joining the workforce. In addition to this training, which directly concerns university institutions responsible for educating future teachers, it is also necessary to include in this goal those who currently need to meet these ES demands but likely did not receive adequate training to do so during their educational years (Corney and Reid, 2007). It should be noted that little research has been done in which teachers are included for the purpose of assessing specific activities performed; however, excluding their vision obviously limits

the scope of these studies (Chalkley and Sterling, 2011; Holm et al., 2015; Solís and Valderrama, 2015). On the other hand, field work in teacher training on sustainability has shown that there is a need for active teacher participation in research/innovation processes, indicating that this contributes to their active involvement in educating responsible citizens in relation to this global issue (Cebrián and Junyent, 2015; Collazo and Geli, 2017; Vilches and Gil Pérez, 2012).

One aspect that fosters effective integration of sustainability in teacher training is its cross-disciplinary focus. The challenge is not merely to strengthen competence in sustainability, but to specify how to teach it in real settings. Therefore, there is a need to develop competence, knowledge and skills, in addition to didactic experience and appropriate attitudes towards this approach.

The competency-based curriculum prevalent in the Spanish educational system assigns a key role to establishing coherent frameworks of reference that guide educational actions and proposals and help clearly define the specific training needs of the teaching staff responsible for implementing programmes. In today's context, sustainability emerges as an especially relevant cornerstone for guiding any intervention taking place inside or out of the classroom. The regulatory strength of this approach has long been recognised, consolidating it as the predominant model in the field of education (Werler and Tahirsylaj, 2022). The global crisis has aided in redefining the types of knowledge considered truly meaningful and necessary, guiding the necessary reflections on 'why we teach' and what types of knowledge are worth prioritising. Teaching and learning against the backdrop of a planetary emergency are no simple endeavours. Within this scenario, rigorous, systematic research must be done to address the specific challenges that are emerging. In order to bring about meaningful, lasting changes in teaching practice, it is crucial to have a sound, coherent body of knowledge to back those changes, thus avoiding the danger of innovative but isolated or one-off proposals. It is essential not only to boost this kind of research, but also to actively engage teachers, with a view to offering specific responses to the difficulties they face in their everyday work.

The creation of a critical body of teachers equipped to interpret diverse academic situations and integrate conclusions stemming from a collective reflection process has emerged as a highly beneficial practice for the ongoing improvement of everyone involved in education (Tilbury, 2007).

In light of the above, including botanical gardens in teacher training at every stage of education and across all fields of study could represent an especially relevant strategy. These spaces not only offer a direct, multisensory experience with natural systems, but they also afford an opportunity to develop curricular contents through a cross-disciplinary approach, encouraging collaboration. Their didactic potential is particularly valuable for teacher career development, encouraging critical reflection on the methodologies used and stimulating educational

innovation (Collazo and Geli, 2017). As advocated in the 2030 Agenda, teachers are called upon to lead educational processes that are aligned with the realities of the world today.

4. METHODOLOGY

Based on the arguments described, this research focuses on the design, implementation and assessment of ES training courses at the JBUV geared towards teachers from diverse schools in the province of Valencia and created as part of a broader intervention (De Rivas et al., 2025).

An active methodology was adopted in the course sessions, in which the teachers were divided into collaborative teams for the construction of knowledge about climate change and sustainability, as well as strengthening positive attitudes towards teaching these concepts. This entailed a discussion about the potential interest and relevance of the issues to be studied, raising questions, making educated guesses, preparing and implementing problem-solving strategies and instruments, formulating proposals, etc. The methodology coincided with that applied by the teachers and their students throughout the school year, with guidance from the research team.

Cooperation in the classroom is viewed as a crucial instrument for achieving meaningful learning outcomes and a growing interest in the content to be discussed, thus helping create a suitable working environment by involving participants in a shared task and to enhance the learning outcomes for all types of teaching activities and contents at any educational level, particularly in teacher training (Vilches and Gil Pérez, 2012) for engagement in ES, in this case.

As noted above, in this study the important role that education outside the classroom in green spaces such as botanical gardens can and should play in formal education and in initial and ongoing teacher training is analysed and showcased, using the JBUV as a superb educational resource and also showing how this approach can be useful for a number of subjects, in line with the cross-disciplinary nature of ES.

4.1. *Course design*

It is worth noting that these training courses offered an opportunity to expand and strengthen a proposal implemented in several school years now, in which they served as a support mechanism and driving force of a line of work taking place at the schools involved and their teachers (De Rivas et al., 2025). The specific intention is to generate concrete learning proposals in which teachers can make use of the JBUV.

Both editions of the course, bearing the title: “The Role of Botanical Gardens in Teacher Training within the Context of Climate Change and Education for

Sustainability”, were carried out at the JBUV, one in late June 2022 and the other in early July 2023, lasting approximately five hours.

To sum up, the course was designed with the following aims: (i) to increase teachers’ understanding of the relationships between biodiversity, climate change and sustainability; (ii) to prepare teachers to include these contents in their programmes through cross-disciplinary proposals; and (iii) to foster the use of the JBUV as a didactic resource for developing competencies linked to contextualised, experiential education. The courses gradually introduced contents on the current socio-environmental crisis, the scientific foundations of climate change, the relevance of biodiversity and ecosystem services, and the didactic potential of green spaces in secondary education. In line with these aims, the methodology combined sessions for reflection, group dynamics and a path for learning in the garden, where applied activities took place, such as estimating the biomass of a tree, analysing species or interpreting heritage features, geared towards the promotion of meaningful learning that can be transferred to the classroom. The course was assessed by means of a survey containing quantitative and qualitative items to evaluate the perceived usefulness, comprehension of the contents, the pertinence of the activities and the garden’s potential as an educational resource. The relationship between methodology, activities and expected learning outcomes was explicitly defined in the design, so that each phase of the course would contribute to the development of teaching skills for the contextualisation of teaching, designing cross-disciplinary proposals and boosting the students’ literacy.

First, a reflection on the aims and contents of the course is given (point 2). Next, a discussion is held for the purpose of reviewing the topics dealt with in the activities carried out during each school year in relation to sustainability and climate change (point 3), in addition to introducing the JBUV as an educational resource in ES. The teacher is expected to discern the numerous opportunities offered in the different subjects of the secondary school curriculum, to focus on a specific project outside the classroom in the proposed setting. The visit (point 5) is conducted on a path that focuses on some of the ideas considered most important for understanding the climate crisis, its causes and consequences. The subsequent teamwork aims to encourage the participants to gradually note and remark on the contents that can be applied in the subjects they teach, linked to specific locations and integrated into a complete activity. Finally (point 6), the work done is shared and assessed in the classroom.

During the group work, the participants break up into collaborative teams of teachers working in the same general disciplines.

4.2. *Sample*

Over the two editions of the course, a total of 57 working teachers (36 women and 21 men) with 15 years of professional experience on average

participated. The participating teachers were selected out of convenience, as members of a group of teachers taking part in a research project on climate change and ES those years, involving 14 secondary schools with an interest in socio-environmental issues.

The subjects they teach are: Biology and Geology, Physics and Chemistry, Mathematics, Latin, Geography and History, Music, Physical Education, Technology, Art, Philosophy, English, Spanish Language and Literature, Classical Culture, Valencian Language, Scientific Literacy and Greek.

4.3. *Instrument and data collection*

To assess the course, a survey validated by experts was used, consisting of three closed response items on a Likert scale (1-10) aimed at evaluating the perceived usefulness, the pertinence of the activities and the suitability of the methodology, in addition to an open-ended question for the purpose of gathering qualitative remarks about the experience. The survey was taken anonymously at the end of each edition of the course by means of an online form, thus ensuring a high response rate. To analyse the data, the quantitative assessments were processed by means of simple descriptive statistics (frequencies and percentages), while the open-ended responses were classified by topic according to the applicability of the proposals, the value of the JBUV as an educational resource, the relevance of the contents and suggested improvements. This procedure served to supplement the numerical data, giving a richer, more nuanced view of the teachers' perceptions.

Survey

The survey below addresses diverse aspects of the course in which you have participated. We appreciate your collaboration, as your opinion will be very helpful for enhancing and redirecting the activities, where necessary. Give reasons for all of your responses.

1. Rate the course overall from 1 to 10 (where 1: I did not like it at all, and 10: I liked it very much)
2. Rate the methodology used
3. Rate the usefulness of the course for understanding the role of the Botanical Garden and nature spaces in general in the study of climate change and citizen education for sustainability
4. Remarks justifying your responses and suggestions

5. RESULTS

The discussion of the course aims at the start of the session (point 2) showed that it is a useful tool because it expands on the preliminary work done by the teachers previously in their schools (De Rivas et al., 2025), with shared experiences and opinions about the proposal. This contextualisation highlights the importance of being linked to projects featuring a research team available for orientation and guidance while at the same time ensuring that the participating teachers' perspectives and interests are integrated from the start through their active central role.

The following session (point 3) allowed the teachers to discover the wealth of opportunities that exist for defining a specific project outside the classroom in the proposed setting, aware of the fact that preliminary preparation and subsequent follow-up sessions would be required. Examples shared include using trigonometry to calculate the height of the trees and the mass and quantity of carbon they contain; the importance of using texts that discuss matters related to botanical gardens was also noted, in addition to their importance in citizen education and their evolution throughout history, to name a few.

In the next session (point 5), group work was done in the outdoor garden in which the participants and the research team agreed on a route designed to address important aspects of climate change while also reflecting on the need to conserve and protect plant biodiversity, exploring the topic of humans' utter dependence on healthy, balanced ecosystems (De Rivas, 2024). At each stop along the way, the contents that could be discussed and the subjects they could be linked to were outlined. It became clear that the range of contents was broad and cross-disciplinary in nature, and each teacher, depending on the department they worked in and the subjects taught, could adapt and discuss them from the perspective best suited to and aligned with the curriculum. This framework facilitated the more in-depth, precise work done by the teams afterwards.

The group work culminated in the preparation of an ES and climate change project proposal revolving around a visit to the garden or other green spaces available to the schools. Following a reflection period, each team presented their proposal to the other participants in an enriching debate that revealed the possibilities and opportunities of using these spaces to discuss the global crisis. For example, one group of science teachers proposed an activity for the subject of Physics and Chemistry in 3rd-year Compulsory Secondary Education aimed at estimating how many botanical gardens would be needed to absorb all the CO₂ generated by the city of Valencia. Another group, involving language teachers, proposed an activity geared towards 1st-year Compulsory Secondary Education students for connecting plant biodiversity conservation to the restoration of cultural heritage in villages and communities. At the end of the session, several participants expressed a commitment to implement their proposals during the 2023-2024 school year.

The last part of the course was devoted to systematising the main ideas and conclusions reached throughout the session; overall, the pertinence and need to include intervention proposals such as those mentioned here in formal education was confirmed, preferably outside the classroom and also in other green spaces, such as school gardens, as motivational didactic resources that help generate useful learning environments for the implementation of active methodologies for building competency in sustainability. These proposals must be assessed after implementation, as part of a process of reflection, research and innovation aimed at providing an appropriate response to the training needs of teachers and the teaching-learning process in which they intend to add value.

The aforementioned survey was conducted at the end of the course in order to assess the usefulness of the proposed training activity and to gather possible suggestions for improvement or redirection. Table 1 shows the scores of the first three items (scale of 1-10).

Item 4, for collecting the participants' open responses and suggestions, confirms these positive numerical scores. As an illustrative example, some of the remarks are shown below:

'Providing teachers with resources for classroom work on climate change in different departments/subjects is essential if we want to generate a change in our society through our students. I found the training course to be very interesting and it should take place each year, expanding the contents and further exploring key matters for mitigating the climate emergency'.

'I think the garden is an unbeatable resource for working in any subject area. Infinite projects could be done there'.

'I found the information to be precise and useful. The experts managed to catch our attention completely and the group work was spot on'.

'I found the group work to be interesting for developing the ideas we came up with earlier and to foster the use of the Garden and the contents on climate change in different subjects. It was also highly gratifying to listen to the responses of the other groups, especially with such wide-ranging subjects'.

TABLE 1
RESULTS FOR ITEMS 1, 2 AND 3 OF THE ASSESSMENT SURVEY

N = 57	7	8	9	10
1. Rate the course overall from 1 to 10		10 %	30 %	60 %
2. Rate the methodology used	10 %	10 %	10 %	70 %
3. Rate the usefulness of the course for understanding the role of the Botanical Garden		5 %	15 %	80 %

Source: Prepared by the authors

6. CONCLUSIONS AND OUTLOOK

The findings of this research show the opportunities and potential of the JBUV as a key educational resource in ES with secondary school teachers. The integration of green spaces like this in training processes not only promotes a cross-disciplinary approach to urgent issues but also contributes to a meaningful, transformative educational experience. Teachers' participation in the construction of specific didactic proposals linked to their respective subjects has been shown to foster the development of new perspectives and didactic approaches focused on the connection to the environment and the natural world.

The fact that the participating teachers rated the course highly, in addition to the wealth and variety of proposals created, leads to the conclusion that this type of training interventions can contribute significantly to the strengthening of teachers' professional competence in sustainability. Furthermore, as indicated by the participants, the active, collaborative and contextualised methodology has shown to help generate engagement, motivation and commitment to the educational transformation needed in response to today's global crisis. It should be noted that the participating teachers logically had vastly different motivation and interests, which occasionally led to difficulties and posed a challenge for the work being done in the courses. However, the lack of previous training experiences in this field remains an obstacle, thus reinforcing the need to expand and follow up on this type of initiatives in both initial and ongoing teacher training.

One of the most relevant contributions of this proposal lies precisely in its capacity to facilitate a deep reconnection with the natural world. Direct experience in a space like a botanical garden transcends theoretical comprehension of the contents discussed and at the same time nurtures emotional ties to the ecosystems that we live in and depend on.

As a whole, this combination of theory and practice strengthens the coherence of the study, evidencing the way in which the conceptual basis guides and sustains each component of the training experience.

Looking towards the future, this study opens up several avenues of action and research. The first is the advisability of systematising and following up on the proposals developed by the teams of teachers after the course in order to assess the implementation at schools and the impact on students. Secondly, it is crucial to generate networks of collaboration between botanical gardens, universities, education authorities and schools in order to build a culture conducive to using these spaces as learning environments. It would also be highly beneficial to incorporate the students' perspective in future research in order to assess their perception and experience in relation to this type of approach.

In sum, this research bolsters the idea that botanical gardens are not just reservoirs of biodiversity or spaces for contemplation, but that they can and must

become strategic allies in education in the 21st century. Their inclusion in teacher training programmes poses an undeniable opportunity to progress towards a concept of schools committed to the challenges of today, integrating SDGs and curricular contents from a transformative, situated perspective.

FUNDING

Grant “Educación para el Cambio Climático y la Sostenibilidad, un estudio longitudinal de aprendizaje intergeneracional” PID2020-114358RB-I00 funded by MCIN/AEI/10.13039/501100011033 ERDF and “Educación ambiental, cambio climático y sostenibilidad” RED2024-153630-T funded by Ministerio de Ciencia, Innovación y Universidades.

REFERENCES

- Amórtégui, E., Mayoral, O., & Gavidia, V. (2017). Aportaciones de las Prácticas de Campo en la formación del profesorado de Biología: un problema de investigación y una revisión documental. *Didáctica de las Ciencias Experimentales y Sociales*, 32, 153–169. <https://doi.org/10.7203/dces.32.9940>
- Amprazis, A., & Papadopoulou, P. (2020). Plant blindness: a faddish research interest or a substantive impediment to achieve sustainable development goals? *Environmental Education Research*, 26(8), 1065–1087. <https://doi.org/10.1080/13504622.2020.1768225>
- Beery, T., Chawla, L., & Levin, P. (2020). Being and becoming in nature: Defining and measuring connection to nature in young children. *International Journal of Early Childhood Environmental Education*, 7(3), 3–22.
- Buchanan, J. (2012). Sustainability education and teacher education: Finding a natural habitat? *Australian Journal of Environmental Education*, 28(2), 108–124. <https://www.jstor.org/stable/26422799>
- Bybee, R. (1991). Planet Earth in crisis: how should science educators respond? *The American Biology Teacher*, 53(3), 146–153. <https://doi.org/10.2307/4449248>
- Çakar, N. D., Gedikli, A., Erdoğan, S., & Yıldırım, D. Ç. (2021). Exploring the nexus between human capital and environmental degradation: The case of EU countries. *Journal of Environmental Management*, 295, 113057. <https://doi.org/10.1016/j.jenvman.2021.113057>
- Cebrián, G., & Junyent, M. (2015). Competencies in education for sustainable development: Exploring the student teachers views. *Sustainability*, 7(3), 2768–2786. <https://doi.org/10.3390/su7032768>
- Chalkley, B., & Sterling, S. (2011). Hard Times in Higher Education: The Closure of Subject Centres and the Implications for Education for Sustainable Development (ESD). *Sustainability*, 3(4), 666–677. <https://doi.org/10.3390/su3040666>
- Chu, L. K. (2022). Determinants of ecological footprint in OCED countries: do environmental-related technologies reduce environmental degradation? *Environmental Science and Pollution Research*, 29(16), 23779–23793. <https://doi.org/10.1007/s11356-021-17261-4>

- Collazo, L., & Geli, A. M. (2017). Avanzar en la educación para la sostenibilidad. Combinación de metodologías para trabajar el pensamiento crítico y autónomo, la reflexión y la capacidad de transformación del sistema. *Revista Iberoamericana de Educación*, 73, 131–154. <https://doi.org/10.35362/rie730295>
- Corney, G., & Reid, A. (2007). Student teachers' learning about subject matter and pedagogy in education for sustainable development. *Environmental Education Research*, 13(1), 33–54. <https://doi.org/10.1080/13504620601122632>
- Cramer, W., Guiot, J., & Fader, M. (Eds.). (2020). *Climate and Environmental Change in the Mediterranean Basin – Current Situation and Risks for the Future. First Mediterranean Assessment Report (MAR1)*. Union for the Mediterranean, Plan Bleu, UNEP/MAP, MedECC. <https://www.medecc.org/first-mediterranean-assessment-report-mar1/>
- De Rivas, R. (2024). *La Educación Secundaria frente al Cambio Climático y la Sostenibilidad: concepciones del alumnado y propuestas de intervención para la formación del profesorado en el marco de los ODS* [Tesis de doctorado, Universitat de València]. Roderic.
- De Rivas, R., Güemes, J., & Mayoral, O. (2024). Jardines botánicos, recurso didáctico y oportunidad ante la emergencia climática. En R. Borges y E. Martínez-García (Eds.), *Sostenibilidad curricular en ciencias y herramientas desde ingeniería. Las universidades como motor de cambio ecosocial: sostenibilización curricular* (pp. 255–273). Tirant Humanidades.
- De Rivas, R., Vilches, A., & Mayoral, O. (2025). Bridging the Gap: How Researcher-Teacher Collaboration Is Transforming Climate Change Education in Secondary Schools. *Sustainability*, 17(3), 908. <https://doi.org/10.3390/su17030908>
- Díaz, S., Settele, J., Brondizio, E. S., Ngo, H. T., Agard, J., Arneth, A., & Zayas, C. N. (2019). Pervasive human-driven decline of life on Earth points to the need for transformative change. *Science*, 366(6471), eaax3100. <https://doi.org/10.1126/science.aax3100>
- Dodd, J., & Jones, C. (2010). *Redefining the role of botanic gardens: Towards a new social purpose*. Research Centre for Museums and Galleries (RCMG).
- Eberbach, C., & Crowley, K. (2017). From seeing to observing: How parents and children learn to see science in a botanical garden. *Journal of the Learning Sciences*, 26(4), 608–642. <https://doi.org/10.1080/10508406.2017.1308867>
- Evans, N. (2020). What ought to be done to promote Education for Sustainability in teacher education? *Journal of Philosophy of Education*, 54(4), 817–824. <https://doi.org/10.1111/1467-9752.12482>
- Folke, C. (2013). Respetar los límites del planeta y recuperar la conexión con la biosfera. En The Worldwatch Institute (Ed.), *La situación del mundo 2013. ¿Es aún posible lograr la Sostenibilidad?* Icaria.
- García-González, E., Jiménez-Fontana, R., & Azcárate, P. (2020). Education for sustainability and the sustainable development goals: Pre-service teachers' perceptions and knowledge. *Sustainability*, 12(18), 7741. <https://doi.org/10.3390/su12187741>
- Geli, A. M., Junyent, M., & Arbat, E. (2005). La sostenibilidad en la formación inicial del profesorado: aplicación del modelo ACES. *Enseñanza de las Ciencias*, número extra: VII Congreso. <https://www.blues.uab.es/~sice23/>

- Geli, A. M., & Terradellas, M. R. (2019). Formación de maestros mediante aprendizaje basado en retos y procesos de co-creación, en Ruiz-Herrera, N. Guillén-Riquelme, A., Guillot-Valdés, M. (Coords.), *Avances en Ciencias de la Educación y del Desarrollo*. AEPC.
- Gil Pérez, D., & Vilches, A. (2017). Educación para la sostenibilidad y educación en derechos humanos: dos campos que deben vincularse. *Teoría de La Educación. Revista Interuniversitaria*, 29(1), 79–100. <https://dx.doi.org/10.14201/teoredu29179100>
- Gil Pérez, D., & Vilches, A. (2023). Cómo avanzar en la necesaria transición a la Sostenibilidad. *Ciência & Educação*, 23, e23027, <https://doi.org/10.1590/1516-731320230027>
- Hewitt, G. M. (2011). Mediterranean peninsulas: the evolution of hotspots. In *Biodiversity hotspots* (123-147). Springer.
- Heyd, T. (2006). Thinking through botanic gardens. *Environmental Values*, 15(2), 197-212. <https://www.jstor.org/stable/30302159>
- Holm, T., Sammalisto, K., Grindsted, T., & Vuorisalo, T. (2015). Process framework for identifying sustainability aspects in university curricula and integrating education for sustainable development. *Journal of Cleaner Production*, 106, 164-174.
- IUCN. (2023). The IUCN *Red List of Threatened Species*. Version 2023-1. <https://www.iucnredlist.org>
- López-Fernández, C., Paños, E., & Ruiz-Gallardo, J. R. (2024). Responsible consumers are made, not born: a clothing secondhand market experience in two Spanish high schools. *The Journal of Environmental Education*, 1-20. <https://doi.org/10.1080/00958964.2023.2300447>
- Lugg, A. (2007). Developing sustainability-literate citizens through outdoor learning: Possibilities for outdoor education in higher education. *Journal of Adventure Education & Outdoor Learning*, 7(2), 97–112. <https://psycnet.apa.org/doi/10.1080/14729670701609456>
- Mayoral, O. (2019). Las plantas como recurso didáctico. La Botánica en la enseñanza de las Ciencias. *Flora Montiberica*, (73), 93-99.
- Medir, R. M., Heras, R., & Geli, A. M. (2014). Guiding documents for environmental education centers: an analysis in the Spanish context, *Environmental Education Research*, 20(5), 680–694. <https://doi.org/10.1080/13504622.2013.833590>
- Miller, H., & Derewnicka, L. (2019). Citizen science. *Roots*, 16, 4–5.
- Murga-Menoyo, M. Á., & Novo, M. (2017). Sostenibilidad, desarrollo «glocal» y ciudadanía planetaria. Referentes de una pedagogía para el desarrollo sostenible. *Teoría de la Educación. Revista Interuniversitaria*, 29(1), 55–78. <https://doi.org/10.14201/teoredu20172915578>
- Myers, N., Mittermeier, R. A., Mittermeier, C. G., Da Fonseca, G. A., & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature*, 403(6772), 853–858. <https://doi.org/10.1038/35002501>
- Puig i Bager, J., & Casas Jericó, M. (2017). El impacto ambiental: Un despertar ético valioso para la educación. *Teoría de la Educación. Revista Interuniversitaria*, 29(1), 101–128. <https://doi.org/10.14201/teoredu2017291101128>

- Rockström, J., Donges, J. F., Fetzer, I., Martin, M. A., Wang-Erlandsson, L., & Richardson, K. (2024). Planetary Boundaries guide humanity's future on Earth. *Nature Reviews Earth & Environment*, 5(11), 773–788. <https://doi.org/10.1038/s43017-024-00597-z>
- Seddon, N., Chaussou, A., Berry, P., Girardin, C. A., Smith, A., & Turner, B. (2020). Understanding the value and limits of nature-based solutions to climate change and other global challenges. *Philosophical Transactions of the Royal Society B*, 375(1794), 20190120. <https://doi.org/10.1098/rstb.2019.0120>
- Sellmann, D. (2014). Environmental education on climate change in a botanical garden: adolescents' knowledge, attitudes and conceptions. *Environmental Education Research*, 20(2), 286–287. <https://doi.org/10.1080/13504622.2013.870130>
- Sellmann, D., & Bogner, F. X. (2013). Climate change education: Quantitatively assessing the impact of a botanical garden as an informal learning environment. *Environmental Education Research*, 19(4), 415–429. <https://doi.org/10.1080/13504622.2012.700696>
- Solís, C., & Valderrama, R. (2015). La educación para la sostenibilidad en la formación de profesorado. ¿Qué estamos haciendo? *Foro de Educación*, 13(19), 165–192.
- Suárez-López, R., & Eugenio, M. (2018). Wild botanic gardens as valuable resources for innovative environmental education programmes in Latin America. *Environmental Education Research*, 24(8), 1102–1114. <https://doi.org/10.1080/13504622.2018.1469117>
- Summers, M., Childs, A., & Corney, G. (2005). Education for sustainable development in initial teacher training: Issues for interdisciplinary collaboration. *Environmental Education Research*, 11(5), 623–647. <https://doi.org/10.1080/13504620500169841>
- Tilbury, D. (2007). Learning based change for sustainability: perspectives and pathways. In *Social learning towards a sustainable world*. Leiden, The Netherlands: Wageningen Academic, 117–131. https://doi.org/10.3920/9789086865949_009
- Timm, J. M., & Barth, M. (2021). Making education for sustainable development happen in elementary schools: The role of teachers. *Environmental Education Research*, 27(1), 50–66. <https://doi.org/10.1080/13504622.2020.1813256>
- UNESCO. (2017). *Education for sustainable development goals: Learning objectives*. United Nations Educational, Scientific and Cultural Organization. <https://doi.org/10.54675/CGBA9153>
- Vergou, A., & Willison, J. (2016). Relating social inclusion and environmental issues in botanic gardens. *Environmental Education Research*, 22(1), 21–42. <https://doi.org/10.1080/13504622.2014.984161>
- Vilches, A., & Gil Pérez, D. (2012). La educación para la sostenibilidad en la universidad: el reto de la formación del profesorado, *Profesorado*, 16(2), 25–43. <https://www.ugr.es/~recfpro/rev162ART3.pdf>
- Waltner, E. M., Scharenberg, K., Hörsch, C., & Rieß, W. (2020). What teachers think and know about education for sustainable development and how they implement it in class. *Sustainability*, 12(4), 1690. <https://doi.org/10.3390/su12041690>
- Werler, T. C. & Tahirsylaj, A. (2022). Differences in teacher education programmes and their outcomes across Didaktik and curriculum traditions. *European Journal of Teacher Education*, 45(2), 154–172, <https://doi.org/10.1080/02619768.2020.1827388>

- Williams, S. J., Jones, J. P., Gibbons, J. M., & Clubbe, C. (2015). Botanic gardens can positively influence visitors' environmental attitudes. *Biodiversity and conservation*, 24, 1609–1620. <https://doi.org/10.1007/s10531-015-0879-7>
- Zelenika, I., Moreau, T., Lane, O., & Zhao, J. (2018). Sustainability education in a botanical garden promotes environmental knowledge, attitudes and willingness to act. *Environmental Education Research*, 24(11), 1581–1596. <https://doi.org/10.1080/13504622.2018.1492705>