Heliyon 10 (2024) e35301

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Use of aromatic plants and essential oils in the teaching of physics and chemistry to enhance motivation and sustainability awareness among primary education trainee teachers

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A R T I C L E I N F O

Keywords:
Educational innovation
Motivation
Sustainable education
Aromatic plants
Essential oils
Ethnobotany
Future teachers

A B S T R A C T

This work faces the known problem of negative visión among prospective primary teachers regarding science teaching and learning. This is even more acute if gender is taken into account. To overcome this, the use of ethnobotany as a science of proximity is proposed. Specifically, an educational intervention is described that is based on a combination of active methodologies and the use of ethnobotany as a teaching tool for a subject with physics and chemistry contents. Ninety-two university-based primary education trainee teachers participated in the research. By means of questionnaires, information was collected regarding attitudes toward the subject and the use of ethnobotany as a teaching tool, evaluation of the proposal, sustainability awareness, and affective and emotional dimensions. The data indicated a great impact and acceptability. The results show a significant increase in motivation, an improvement in attitudes toward sustainable behavior and a favorable assessment of the proposed didactic tool. This hybrid methodology demonstrates, in the context used, effectiveness in improving the perception of science.

1. Introduction

Universities play a key role in shaping the direction of education [1–3]. The new generations of teachers and future teaching professionals who are being trained will develop their professional work on the basis of the training they have received during their careers as students.

In recent years, there has been a significant transformation in university educational paradigms [4]. The Covid-19 health crisis, coupled with the rise of new academic tools centered around online teaching [5], has underscored their efficacy in fostering both cognitive learning and the development of essential soft skills crucial for successful integration into the workforce. However, amidst these advancements, the enduring question of the university's societal role and the enduring quality of its educational endeavors across centuries remains relevant. It is undeniable that contemporary societies still place value on a predominantly face-to-face educational model, potentially transitioning towards a hybrid approach, which must uphold recognized standards of quality while striving to enhance pedagogical efficacy. Consequently, there is a pressing need for the adoption of novel methodologies, tools, and didactic

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https://doi.org/10.1016/j.heliyon.2024.e35301
Received 12 May 2023; Received in revised form 17 July 2024; Accepted 25 July 2024
Available online 29 July 2024

approaches to surmount the challenges inherent in traditional educational frameworks.

Designing, proposing, and using new didactic tools and methodologies that not only facilitate the learning of future teachers but also facilitate their application in the classroom are tasks that should be carried out at university, especially in the Early Childhood and Primary Education degrees; such tools will also reduce some of the educational problems that the teachers will face and will, in turn, be applicable in the teaching of boys and girls at school.

To reduce the negative views that many future teachers have of the experimental sciences, especially in areas such as physics and chemistry [6], is quite a challenge. The source of this bad opinion ranges from their studies as undergraduate students to the development of their own didactic knowledge of the content [7], that is, the construction of their own way of teaching the subject. These negative views are directly related to their motivation as students and as teachers (when they become teachers) to teach such subjects in the classroom [8].

The preconceived ideas, values, and emotions about science that an individual has in adulthood derive from their experiences in their school years, so it is necessary to have motivated and qualified teachers to prevent the negative views that arise in childhood and increase in adolescence [9]. As the age and educational levels of students increase, a generalized rejection of the study of experimental science subjects, particularly physics and chemistry, develops and stays in adults; it is present in most future teachers [10]. It is even more acute in the case of the female gender, where there is still a gap marked by the very concept they have of their ability to deal with the sciences, requiring a vocational orientation that contributes to breaking this sexist orientation that directly influences the decisions they will make throughout their professional life [11,12].

Therefore, when we talk about teachers in training, alternatives that increase their emotional involvement and learning can be decisive in their future activity in the classroom, and in turn, in reducing the difference between men and women that leads to them "fleeing" from the contents of experimental sciences and limiting their areas of work, especially when the majority of teaching staff, in the pre-school and primary stages, are of the female gender.

We know that a scientific culture is essential for a functional society capable of satisfying personal curiosity [13]. However, in order to achieve a pragmatic appreciation of experimental sciences, a different educational approach to the traditional one is necessary, one that fosters students' motivation [14] and therefore, the link between learning and emotions [15], while at the same time developing the sustainable conscience of citizens [16].

There is a tendency to think that the contents mark or determine emotional involvement and meaningful learning, but there are studies showing that an appropriate methodology can modify this situation [17,18]. We are mainly referring to active methodologies that seek the direct involvement of students, but these can have certain drawbacks.

Many future teachers do not consider themselves sufficiently prepared or do not have enough time to adapt their classes to this type of methodology [19]. In addition, in the case of physics and chemistry, experimental activities often require specific training in certain areas or in laboratory materials and tools, which may not be easily accessible or manageable for non-chemists or physicists.

> It is at this point that the use of a "proximity science" arises [20], based on the immediate environment of future teachers, and in turn that of their future students, which on the one hand is more motivating and facilitates the learning of complex scientific concepts and, on the other hand, does not involve materials, tools, or spaces such as those usually associated with a laboratory, but which are easily applicable in the classroom by any teacher without requiring specialization and can be adapted to any subject or subject.

Specifically, ethnobotany, a branch of botany focused in human interactions with plant biodiversity, is a tool from the immediate environment and which, combined with active methodologies from the student-centered paradigm, according to previous studies, is motivating for students, which can be a promising tool for promoting sustainability and enriching the scientific perspective [21,22]. But can it be a tool that improves the self-efficacy of future teachers? Will it be a methodology that is really sustainable and easy to apply?

2. Objectives

The aim of this work is to assess the impact of the use of ethnobotany as a method for teaching other experimental sciences among second-year undergraduates studying for a degree in Primary Education. The aim is to answer two questions:

a) Is ethnobotany a useful resource for the classroom approach to experimental sciences such as physics and chemistry and what contributions, in terms of motivation and perception of the discipline, can be expected? Are there gender differences?
b) Are there gender differences in this performance?

Specifically, there are two specific goals:

- To determine the views of future teachers about ethnobotany as a didactic tool for the experimental sciences based on their attitudes, personal assessment, and sustainability awareness.
- To analyze the motivation (affective and emotional dimensions) of students toward learning physics and chemistry.

3. Methodology

We describe below the implementation of a didactic proposal based on the use of ethnobotany as an educational tool as part of the programming of a subject in the experimental sciences, composed of a series of practical activities that have aromatic plants and essential oils as a common thread [23], with the intention of improving future teachers' attitudes and learning in relation to physics and chemistry.

The intervention is organized into four stations or activities: Activity 1, "Discovering essential oils"; Activity 2, "Where are essential oils extracted from?"; Activity 3, "Applications of essential oils: soap making"; and Activity 4, "Applications of essential oils: cream making." These follow a logical order, based on Reigeluth's theory [24], the work beginning with a more global vision of the contents and ending with their more detailed development. Specifically, we start with a "Search for information on aromatic plants and essential oils" (Activity 1), continue with "Obtaining essential oils" (Activity 2) and end with the "Practical application of essential oils" (Activities 3 and 4).

The impact produced in the students as a consequence of the educational intervention is evaluated through the use of questionnaires for the collection of information and subsequent analysis of the data.

3.1. Description of the sample and details of the subject in which the proposal is included

A total of 92 university students in their second year of the degree in Primary Education participated in this study. Specifically, the sample is made up of 59 women and 33 men aged between 19 and 44 years. In relation to their previous studies, 75 % came from the humanities, social sciences or arts baccalaureates, 17.39 % from health sciences or science and technology baccalaureates, and 7.61 % from other branches.

This sample was chosen by non-probability convenience sampling [25] of the population of future teachers of primary education students in a general basic science subject. Specifically, the proposal we are dealing with is framed within two of its topics, included in the teaching plan [26] on the basis of which the learning objectives are established (Table 1).

3.2. Description of the intervention

During the practice, the students were divided into four groups of up to eight people and distributed across the four stations established, rotating through them every 35 min. The design of each activity is based on previous works [21]. Each of the activities carried out is detailed below:

Activity 1. "Discovering essential oils"

In order to learn more about the concepts of "aromatic plants," "essential oils," and their "origins," the students had to search for information, smelling, observing, and manipulating a sample of more than 40 plant species classified according to the part of the plant with the highest concentration of oils, some of them already described before [19]. This first activity was suggested as an introduction to the tool that will be used throughout the session for the teaching-learning about the contents of the "Didactics on Matter and Energy" through aromatic plants, their oils, and some of their traditional uses.

Activity 2. "Where are essential oils extracted from?"

Steam distillation is a process that involves work using the concepts of heterogeneous mixtures and sieving (during sample

Table 1
Details of the subject for which the proposed didactic proposal is designed.

Identification and characteristics of the subject	
Grade to which it belongs	Degree in Primary Education
Semester of study	4th
Designation	Didactics on Matter and Energy
Contents or topics covered	• Topic 3: Didactics of the states of matter. • Topic 4: Didactics of matter transformations.
Didactic objectives established	• To know examples of new didactic tools for approaching the topic of the states of matter. • Practical learning about some reactions and changes of state.
Competencies to be worked on	GENERAL SKILLS CG9. Value individual and collective responsibility in achieving a sustainable future. CG10. Reflect on classroom practices to innovate and improve teaching work. Acquire habits and skills for autonomous and cooperative learning and promote such learning among students. TRANSVERSAL COMPETENCIES CT2.2. Efficiently use a set of resources, techniques, and learning strategies that guarantee autonomous, responsible, and continuous lifelong learning. CT2.3. Update knowledge in the socio-educational field through research and know how to analyze future trends. CT2.4. Maintain an attitude of innovation and creativity in the exercise of their profession. SPECIFIC COMPETENCIES CE27. Pose and solve problems associated with the sciences in everyday life. CE28. Value science as a cultural fact. CE29. Recognize the mutual influence between science, society, and technological development, as well as relevant citizenship behaviors, to ensure a sustainable future. CE30. Develop and evaluate curriculum contents through appropriate didactic resources and promote the acquisition of basic competences in students (experimental sciences).

Source: Author's own elaboration based on the teaching plan established at the University of Extremadura [26].

preparation), as well as homogeneous mixtures, distillation, and changes of state (during the separation process).

On this occasion, the students weighed and sieved *Thymus mastichina*, observed the distillation process *in situ,* calculated the yield of the plant used, sampled the odors, and learned how to preserve the oils obtained.

Activity 3. "Applications of essential oils: soap making"

An activity was presented involving an example of a chemical change that matter can undergo: saponification. To this end, a traditional recipe was used to make solid soap, and a subsequent search for information on the reaction that takes place was carried out.

Activity 4. "Applications of essential oils: cream making"

Again, taking as a reference close knowledge associated with essential oils and natural ingredients, such as beeswax and olive oil, a simple ointment was made. During the process, the concepts of homogeneous mixtures, dissolution, fusion, and solidification were worked on.

3.3. Questionnaire design

As a tool for the collection of information, two types of questionnaire, pre-test and post-test, were elaborated, based on those used in previous research [18,27,28]. Both had a similar structure and content and were completed, respectively, before and after the intervention. They are shown in Annexes A1 and A2.

Each consisted of a first part, in which sociodemographic data were collected (age, gender, and background), followed by 30 items grouped into four blocks: attitudes toward the subject and the use of ethnobotany as a teaching tool (1-11), evaluation of the teaching methodology (12–16), sustainability awareness (17–24), and affective and emotional dimensions (25–30). Most items (1-24) were evaluated by Likert-type scales of five alternatives, which increased their reliability [8], while for those corresponding to emotions (25–30), a multi-response table was presented. The subdivision into four blocks directly related to the aspects to be evaluated in this research facilitated the interpretation and discussion of the results.

Prior to completing the pre-test, a brief introduction was given by the teacher on the didactic objectives of the seminar, the methodology, and the contents to be covered. It was believed that this initial explanation was necessary to avoid random responses as a result of decontextualization. This stage did not anticipate or clarify the items of the pre-test.

The pre-test and post-test items are listed below, along with their bidirectional correlation and the method of response assessment.

This is a non-interventional study, and all participants were informed about their assured anonymity, about why the research was being conducted, and how their data were going to be used. Informed consent was obtained from all subjects involved in the study. This study, and its questionnaire, was approved by University of Extremadura Bioethics Commission, registered number REGAGE23e00028517550.

3.3.1. Block 1: Attitudes toward the subject and the use of ethnobotany as a didactic tool

This section included 11 items aimed at evaluating attitudes toward the subject and the use of ethnobotany as a didactic tool, for which a 5-point Likert-type scale was used in which 1 = "Strongly disagree" and 5 = "Strongly agree" (Table 2).

Specifically, items 1–3 had content relating to the general acceptance or valuation of the activity, items 4 and 5 referred to prejudices toward the study and teaching of science, while items 6 and 7 evaluated the influence of the intervention on the evaluation that each individual had of their own abilities (self-efficacy) [29,30] to learn science and apply it on their own in didactic proposals in the classroom with primary school children. Items 8–11 made direct reference to the use of ethnobotanical contents and the attitude this generated in them.

Table 2
Items related to attitudes and use of ethnobotany in the pre-test and post-test.

pre-test	post-test
No. 1. I think I am going to like the activity very much.	No.1. I liked the activity very much.
No.2. Addressing subject matter content in the laboratory can, I believe, facilitate teaching-learning.	No.2. Addressing subject matter content in the laboratory can, I believe, facilitate teaching-learning.
No.3. Applying scientific methodologies in the classroom increases motivation.	No.3. Applying scientific methodologies in the classroom increases motivation.
No.4. I think science is difficult to learn.	No.4. I think science is difficult to learn.
No.5. The states of matter and their transformations are a difficult subject to discuss with primary school students.	No.5. The states of matter and their transformations are a difficult subject to discuss with primary school students.
No.6. What I learn from this activity will be useful in my work.	No.6. What I have learned from this activity will be useful in my work.
No.7. I consider myself prepared to teach science to my future students.	No.7. I consider myself more prepared to teach science to my future students than before the internship.
No.8. I would like to apply methodologies based on ethnobotany in my classes.	No.8. I would like to apply methodologies based on ethnobotany in my classes.
No.9. I believe that using ethnobotany as a didactic tool enhances curiosity.	No.9. I believe that using ethnobotany as a didactic tool enhances curiosity.
No.10. I believe that learning new content is improved by starting from local knowledge.	No.10. I believe that learning new content is improved by starting from local knowledge.
No.11. Promoting the culture of traditional knowledge is useful for educational improvement.	No.11. Promoting the culture of traditional knowledge is useful for educational improvement.

3.3.2. Block 2: Assessment of teaching methodology

Again, a 5-point Likert-type scale was used for the evaluation of items 12–16, ranging from 1 = "I find the method not very useful" to 5 = "I find the method very adequate" (Table 3). The statements were aimed at evaluating the design of the didactic strategy itself from the point of view of future teachers, as well as the "positive" response, if any, that the "ethnobotany" resource provokes in relation to student involvement and participation.

3.3.3. Block 3: Sustainability awareness

The design of this section used the instrument of Marcos-Merino et al. [31], with six items measuring the knowledge, attitudes, behavior, and values of the individual in relation to sustainable development, evaluated using a 5-point Likert-type scale in which 1 = "Strongly disagree" and 5 = "Strongly agree" (Table 4).

3.3.4. Block 4: Affective and emotional dimensions

Ten emotions were presented, classified as "positive" (Confidence, Amusement, Curiosity, Tranquility, Enthusiasm) or "negative" (Worry, Boredom, Rejection, Nervousness, Anxiety) based on works such as those of Mellado et al. and Hernández-Barco et al. [8,32]. The student was required to mark the emotions suggested by six propositions relating to the content of the didactic intervention (Table 5), choosing one or more of them for each item.

3.4. Statistical analysis

The data obtained were collected in spreadsheets according to the content blocks in the pre-test and post-test.

The results were elaborated by comparing the responses collected in pre-test and post-test for each item. Since the parametric fit, normality, and homoscedasticity criteria were not met, the analysis was carried out using nonparametric tests (Mann-Whitney *U* test). A significance level of $\alpha = 95$ % (p-value ≤ 0.05) was adopted. This analysis was carried out with JASP 0.16.1 [33].

4. Results and discussion

4.1. Views of future teachers on ethnobotany as a didactic tool of experimental sciences

A total of 92 pre-tests and 92 post-tests were collected. To determine whether there was a general variation in the data collected, a comparison was made between the values obtained in the responses of both questionnaires. The answers given for items 1–24 and those related to the emotional dimension (25–30) are analyzed separately because the nature of the data is different, since in the first case only one response per item was accepted, while in the second there was the option of marking more than one emotion for each proposed content.

The statistical analysis of items globally 1–24 revealed significant variations in more than 50 % of these items (Table 6), so it can be said that the didactic tool used had an impact on the participants in the study.

If we focus on the attitudes generated, a significant change can be observed for items 1, 6, 7, 8, 9, and 11. The participants' expectations about the activity improved significantly (item 1), as did their predisposition and behavior toward the study of physics and chemistry contents. An improvement is also observable in relation to the concept of self-efficacy [34]. That is, after the intervention, the participants considered themselves more prepared and qualified to teach science as future teachers, thus influencing their future activity in the classroom [8] (items 6 and 7). They were especially positive about the idea of applying this strategy in their classes (item 8), regarding ethnobotany as a useful, accessible, and close didactic tool that would improve not only learning but also curiosity and the dissemination of traditional culture (items 9 and 11). These results support the conclusions drawn by Verde et al. [35], who defended the transversal use in the classroom of knowledge associated with our culture and natural heritage as a way to contribute to its conservation and provide it with new value as a method for improving learning.

Recent works have raised the importance of the methodology used in relation to the contents, so that concepts that might generate rejection or involve great difficulty are pleasant and motivating in relation to their study [18].

In the data obtained in this case regarding students' assessment of the planning and methodology used, a significant variation is observed, produced by an increase in the valuations given for items 12–15, although not for question 16. It can be said that in relation to the proposals for activities, their design, the combination of physics and chemistry contents with close knowledge of plants, programming, and the specific method applied in each case, the majority of the participants considered them of great didactic usefulness.

In terms of sustainability awareness, the items for which significantly different results were obtained related to sustainable

Table 3
Items related to the participatory methodology used (common to the pre-test and post-test).

No.12. The preparation of plant samples by sieving for distillation to achieve the learning of the concepts of "heterogeneous mixtures and the separation of components."
No.13. Viewing of the steam distillation process of essential oils to deal with homogeneous mixtures and the separation of their components.
No.14. Viewing of the steam distillation process of essential oils in order to approach the states of matter (solid, liquid, and gas) and their changes of state (evaporation, condensation …).
No.15. Soap making to work on the chemical transformations of matter.
No.16. The preparation of wax and oil cream to facilitate understanding of the concept of dissolution as an example of homogeneous mixtures.

Table 4
Items related to sustainability awareness (common to the pre-test and post-test).

Knowledge
No.17. Conserving plant diversity is necessary for sustainable development.
No.18. In order to achieve sustainable development, the population must become more aware of the natural wealth of their environment.
Attitudes
No.19. I believe that using more natural resources than we need poses a threat to the well-being and health of future generations.
No.20. I believe that traditional knowledge about plants can be used to take action against problems related to climate change.
Behavior
No.21. I use plants from the countryside to make creams, meals, etc.
No.22. I like to observe plants and learn more about them.
Values
No.23. It is better to live in a city even if there is more pollution.
No.24. Knowledge about plants is only useful for those who work in the field or study them.

Table 5
Items in the pre-test and post-test relating to the emotions raised by the intervention.

pre-test	post-test
No.25. Thinking that I have to learn concepts about matter generates …	No.25. Learning concepts about the subject has generated …
No.26. Learning about aromatic plants and essential oils gives me …	No.26. Learning about aromatic plants and essential oils has given me …
No.27. Before the study of homogeneous and heterogeneous mixtures, I feel …	No.27. Before the study of homogeneous and heterogeneous mixtures, I felt …
No.28. The study of the states of matter (solid, liquid, gas) and their changes of state (evaporation, solidification …) produces in me …	No.28. The study of the states of matter (solid, liquid, gas) and their changes of state (evaporation, solidification …) has produced in me …
No.29. When I am told that I have to study the chemical changes (reactions) of matter, I feel …	No.29. When I have had to study the chemical changes (reactions) of matter, I have felt …
No.30. When they tell me that I have to study dissolutions, I feel …	No.30. When I have had to study dissolutions, I have felt …

attitudes and behavior (items 20, 21, and 22). When compared with the results obtained by Marcos-Merino et al. [31], who also had future teachers as participants, there was a similarity in terms of very positive attitudes toward sustainability but a difference in that no significant levels of sustainable behavior were recorded.

The results obtained in this work allowed for global reflection on ethnobotany as a didactic tool. The positive evaluation obtained reveals that this is a versatile method, accessible and easy to use for any teacher, without the need to be an experienced physicist, chemist, or botanist. It could be said that the use of plants and traditional knowledge can be, in this sense, interesting and effective for a "science of proximity" given that the contents and materials related to daily life are closer than other resources that may be more abstract [36].

The use of nearby, accessible, and low-polluting materials and resources contributes to the promotion of a sustainable economy and integral development [37], especially the use of plants that are native to the area, as opposed to the usual chemical products used in experimental science laboratory experiences. In addition, this approach allows the development of all the competences worked on in line with the teaching plan [26] (Table 1).

4.1.1. Analysis by gender

It would be valuable to analyze independently the answers given in the pre-test and post-test by women and men in order to establish whether there were differences in the impact produced by the intervention on the basis of gender. Similar to those carried out with global data, as described in the previous section, a statistical comparison was made between the values obtained for each questionnaire, this time distinguishing them by gender (Table 6).

Significant changes were obtained for 14 of the 24 items. With the exception of items 2 and 15, with values of $p < 0.05$ and *ns* (not significant) in the case of women, all the others in which a statistically significant variation was obtained coincided global data, for women. Moreover, as was the case with the overall data (G), if we observe the mean values, the trend of the responses in which a statistically significant variation occurred, given by women and men separately, coincided with the desired one. It can also be seen that both at a general level and taking each of the blocks as a reference, the changes reached greater significance in the female gender.

Focusing on those items in which the variations were not significant in the case of men but significant for women and at the global level (items 6, 9, 11, 13, 14, 20, and 21), it can be seen that women value much more positively the usefulness of what they have learned for their professional future (item 6), as well as the usefulness of ethnobotany for the promotion of curiosity and educational improvement (items 9 and 11). Likewise, their assessment of the methodology was also more positive, regarding the process of distillation of aromatic plants as the most appropriate activity to address contents on mixtures and changes of state (items 13 and 14).

In terms of sustainability awareness, studies conducted on university populations do not show significant differences based on gender in terms of perception, attitudes, and values toward sustainable development [36]. This is extrapolated to the general population, although with a certain tendency toward greater awareness on the part of women [38]. Education plays a very important role in increasing the level of environmental awareness among university students [39]. However, it is noteworthy that in this study, the greatest impact occurred among women, since only women showed a significant increase in relation to the importance they gave to traditional uses as a resource against the problems arising from climate change (item 20), and they were more interested in the use of

Table 6
Items whose answers were statistically significantly different, those differences being interpreted as achievement of the didactic objectives (Mann-Whitney U, *p < 0.05, **p < 0.001, ns = not significant), and the mean values in each test, differentiating between Global (G), female (F) and male (M) answers.

Block	*Item (abbreviated content)*	*pre-test*			*post-test*			*p*		
		G	*F*	*M*	*G*	*F*	*M*	*G*	*F*	*M*
Attitudes	No.1. I am going to like the activity and/or I liked it a lot.	4.207 ±0.561	4.237 ±0.667	4.152 ±0.383	4.761 ±0.206	4.780 ±0.209	4.727 ±0.205	**	**	**
	No.2. Contents about matter in the laboratory can facilitate teaching-learning.	4.478 ±0.428	4.407 ±0.452	4.606 ±0.371	4.620 ±0.370	4.644 ±0.406	4.576 ±0.314	*ns*	*	*ns*
	No.6. What I have learned from this activity will be useful in my work.	3.739 ±1.096	3.678 ±1.188	3.848 ±0.945	4.196 ±0.928	4.254 ±1.124	4.091 ±0.585	*	*	*ns*
	No.7. I consider myself prepared to teach science.	2.935 ±1.029	2.831 ±1.074	3.121 ±0.922	4.196 ±0.687	4.153 ±0.718	4.273 ±0.642	**	**	**
	No.8. I would like to apply ethnobotany-based methodologies in my classes.	3.315 ±1.405	3.339 ±1.538	3.273 ±1.205	4.043 ±0.877	4.136 ±0.809	3.879 ±0.985	**	**	*
	No.9. Using ethnobotany as a didactic tool to promote curiosity.	3.902 ±0.990	3.932 ±1.133	3.848 ±0.758	4.326 ±0.574	4.390 ±0.449	4.212 ±0.797	*	*	*ns*
	No.11. Promoting the culture of traditional knowledge is useful for educational improvement.	4.152 ±0.812	4.136 ±0.809	4.182 ±0.841	4.413 ±0.641	4.407 ±0.797	4.424 ±0.377	*	*	*ns*
Methodology	No.12. Sifting and distilling vegetables to learn concepts such as “heterogeneous mixtures and separation of components.”	3.957 ±0.833	3.932 ±0.857	4.000 ±0.813	4.413 ±0.421	4.373 ±0.445	4.485 ±0.383	**	*	*
	No.13. Distillation of essential oils to address “homogeneous mixtures and separation of their components.”	4.076 ±0.642	4.000 ±0.690	4.212 ±0.547	4.304 ±0.610	4.305 ±0.492	4.303 ±0.843	*	*	*ns*
	No.14. Distilling essential oils to address “states of matter” and “changes of state.”	4.120 ±0.590	4.085 ±0.631	4.182 ±0.528	4.402 ±0.551	4.407 ±0.556	4.394 ±0.559	*	*	*ns*
	No.15. Making soap to work on chemical transformations.	4.424 ±0.664	4.559 ±0.596	4.182 ±0.716	4.685 ±0.306	4.678 ±0.326	4.697 ±0.280	*	*ns*	*
Sustainable consciousness	No.20. Traditional plant knowledge can be used to take action against climate change.	4.109 ±0.801	4.119 ±0.865	4.091 ±0.710	4.337 ±0.951	4.424 ±0.766	4.182 ±1.278	*	*	*ns*
	No.21. I use plants from the field to make creams, meals …	2.772 ±2.156	2.780 ±2.140	2.758 ±2.252	3.304 ±2.170	3.407 ±2.039	3.121 ±2.422	*	*	*ns*
	No.22. I like to observe plants and learn more about them.	2.957 ±1.537	3.153 ±1.752	2.606 ±0.996	3.522 ±1.681	3.695 ±1.733	3.212 ±1.485	*	*	*

wild plants in their daily lives (item 21), suggesting a possible influence derived from the methodology used.

4.2. Motivation (affective and emotional dimensions) of students toward learning physics and chemistry

Considering the total number of marked options for each of the emotions in the pre-test and post-test, data processing was conducted on the basis of the response count. The statistically significant results are shown in Table 7. In addition, the mean values obtained are represented graphically in order to facilitate their interpretation (Fig. 1).

A first descriptive and systematic analysis of the data as a whole revealed an increase in positive emotions versus a decrease in negative ones (Table 7 and Fig. 1). It is known that the implementation in the classroom of didactic experiences based on active methodologies causes an increase in the intensity of positive emotions and a decrease in negative ones. However, unlike the results obtained by Retana-Alvarado et al. [40], in this study, these variations were mathematically significant, which translates into a more marked incidence, which may be due to the implementation of ethnobotany as novel content.

4.2.1. Analysis by gender

Again, we propose to analyze statistically the possible variations produced in the answers given in each questionnaire by women and men separately (Table 7), in order to determine possible changes in the results based on gender.

It can be seen that, in the case of men, the variations were not significant except for two emotions, “Fun” and “Nervousness.” However, the variations were very marked in the case of the female gender, meaning a greater impact from the didactic proposal on women. Therefore, it can be said that the overall increase in positive emotions was mainly due to the responses provided by women.

In addition, the calculation of the mean values obtained for each item reveals that women experienced an increase in all positive emotions, in particular with regard to Confidence, Curiosity, Calmness, and Enthusiasm, reaching figures that were close to and even exceeded the corresponding mean figures for men, who started from a higher initial assessment of these emotions but who, after the intervention, showed no significant variations. With regard to negative emotions, a reduction occurred for both genders. This change was only significant for all emotions in the case of women, but they continued to express higher levels of Worry, Boredom, Rejection, Nervousness, and Anxiety than did men, in whom there were hardly any changes. These changes are graphically depicted in Fig. 1.

The fact that women showed a lower percentage of responses than men for positive emotions and higher one for negative emotions, much more marked in the first questionnaire, could be due to the existence of a gender stereotype that conditions women to have a worse perception of their ability to learn chemistry or physics contents than men do [41], a cliché that continues to exist despite the fact that in recent years the number of female scientists has increased [42].

A study carried out by Hernández-Barco and Corbacho-Cuello [43] concluded that women feel or express a greater amount of negative emotions than men toward physics and chemistry, a situation that is difficult to reverse since this emotional bias is produced from studies prior to university education [10]. In this work, this difference was greatly reduced.

Table 8 shows the variations resulting from comparing the answers given by women and men in each questionnaire in order to determine the level of impact of the didactic intervention on each of the two genders.

At the start of the intervention, there were no variations in relation to Fun and Enthusiasm; however, there was a bias in the other positive emotions, with higher values in the case of men (Table 8). This difference disappeared in the post-test, producing a leveling of the data (significance disappears).

Table 7
Emotions whose responses were statistically significantly different (Mann-Whitney U, *p < 0.05, **p < 0.001, ns = not significant), and mean values in each test, differentiating between Global (G), female (F) and male (M) responses.

Emotion	*pre-test*			*post-test*			*P*		
	G	*F*	*M*	*G*	*F*	*M*	*G*	*F*	*M*
Confidence	0.076 ±0.070	0.054 ±0.051	0.116 ±0.103	0.159 ±0.134	0.161 ±0.135	0.157 ±0.133	**	**	*ns*
Fun	0.141 ±0.122	0.144 ±0.124	0.136 ±0.118	0.362 ±0.231	0.350 ±0.228	0.384 ±0.238	**	**	**
Curiosity	0.495 ±0.250	0.449 ±0.248	0.576 ±0.246	0.585 ±0.243	0.610 ±0.239	0.540 ±0.250	*	**	*ns*
Tranquility	0.082 ±0.075	0.054 ±0.051	0.131 ±0.115	0.125 ±0.110	0.119 ±0.105	0.136 ±0.118	*	*	*ns*
Enthusiasm	0.141 ±0.122	0.141 ±0.122	0.141 ±0.122	0.223 ±0.173	0.237 ±0.181	0.197 ±0.159	**	*	*ns*
Worry	0.210 ±0.166	0.288 ±0.206	0.071 ±0.066	0.071 ±0.066	0.093 ±0.085	0.030 ±0.030	**	**	*ns*
Boredom	0.130 ±0.114	0.153 ±0.130	0.091 ±0.083	0.067 ±0.063	0.076 ±0.071	0.051 ±0.048	**	*	*ns*
Rejection	0.105 ±0.094	0.147 ±0.126	0.030 ±0.030	0.043 ±0.042	0.059 ±0.056	0.015 ±0.015	**	**	*ns*
Nervousness	0.163 ±0.137	0.203 ±0.162	0.091 ±0.083	0.076 ±0.070	0.113 ±0.101	0.010 ±0.010	**	**	**
Anxiety	0.114 ±0.101	0.155 ±0.132	0.040 ±0.039	0.054 ±0.051	0.079 ±0.073	0.010 ±0.010	**	*	*ns*

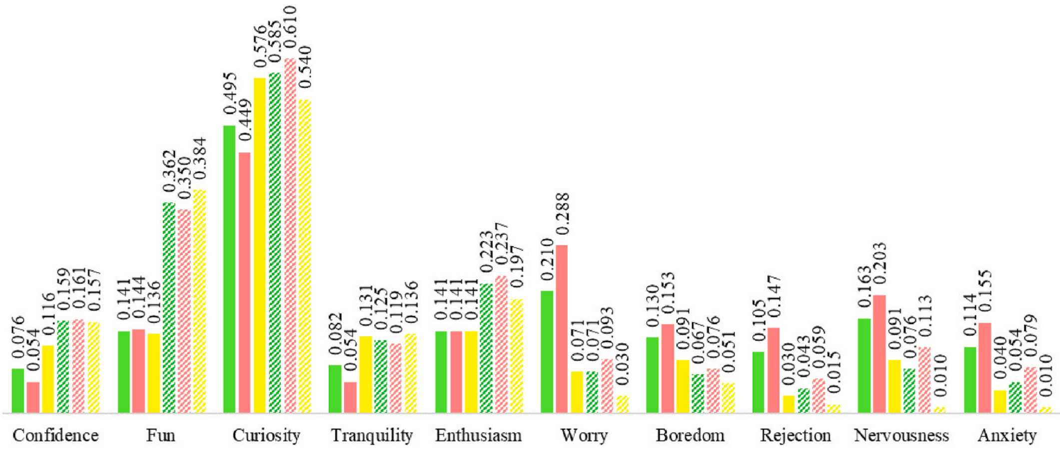

Fig. 1. Comparison of mean values obtained for each of the emotions in pre-test (solid fill) and post-test (raster fill) in global (green), for female (pink) and for male (yellow).

Table 8
Mean values obtained for the responses given for each emotion by female (F) and male (M) respondents and differences detected in each case for each of the tests (Mann-Whitney U, *p < 0.05, **p < 0.001, ns = not significant).

Emotion	pre-test			post-test		
	F	M	p	F	M	p
Confidence	0.054 ±0.051	0.116 ±0.103	*	0.161 ±0.135	0.157 ±0.133	*ns*
Fun	0.144 ±0.124	0.136 ±0.118	*ns*	0.350 ±0.228	0.384 ±0.238	*ns*
Curiosity	0.449 ±0.248	0.576 ±0.246	*	0.610 ±0.239	0.540 ±0.250	*ns*
Tranquility	0.054 ±0.051	0.131 ±0.115	*	0.119 ±0.105	0.136 ±0.118	*ns*
Enthusiasm	0.141 ±0.122	0.141 ±0.122	*ns*	0.237 ±0.181	0.197 ±0.159	*ns*
Worry	0.288 ±0.206	0.071 ±0.066	**	0.093 ±0.085	0.030 ±0.030	*
Boredom	0.153 ±0.130	0.091 ±0.083	*	0.076 ±0.071	0.051 ±0.048	*ns*
Rejection	0.147 ±0.126	0.030 ±0.030	**	0.059 ±0.056	0.015 ±0.015	*
Nervousness	0.203 ±0.162	0.091 ±0.083	**	0.113 ±0.101	0.010 ±0.010	**
Anxiety	0.155 ±0.132	0.040 ±0.039	**	0.079 ±0.073	0.010 ±0.010	**

In relation to the negative emotions, Boredom was reduced and balanced between the genders. Otherwise, although the negative view of the methodology used was reduced, there was still a significant difference between the emotions expressed by male and female participants, with a tendency toward higher values for the females.

This can be interpreted as signifying a change in women's perception of science, less marked in men, which saw a large increase in positive emotions to levels similar to those expressed by men and a reduction in negative emotions in general, but without breaking gender differences.

Finally, in order to reveal whether there was a predilection for content, the percentages of the responses for each emotion from women and men were plotted separately, showing the breakdown for the emotions as marked in the post-test in items 25–30 (Figs. 2 and 3).

There did not appear to be a marked predilection toward some contents or others, either as a group or on the basis of gender (Figs. 2 and 3), despite the use of ethnobotany. This fact is even more noteworthy given that all the students except one came from branches other than the health sciences, and that one might expect a certain level of rejection of subject matter related to plants, which are far from their interests [17,18].

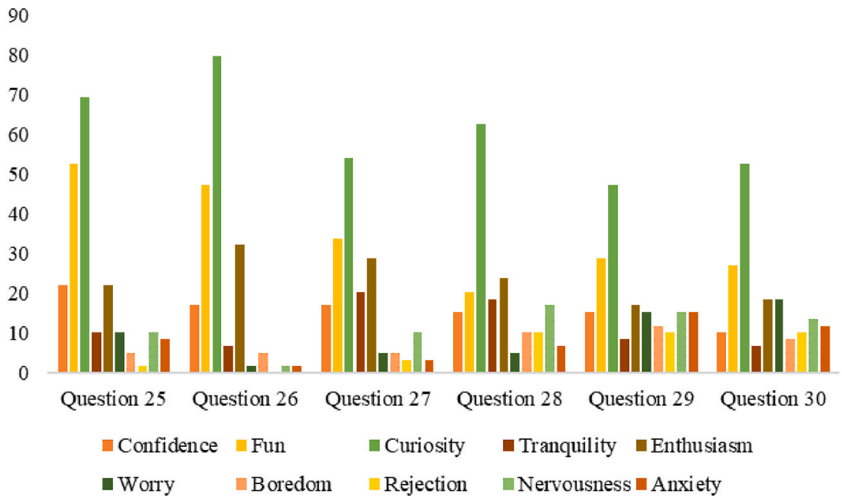

Fig. 2. Comparison of the percentage of emotions expressed in the post-test for all female participants (items 25–30).

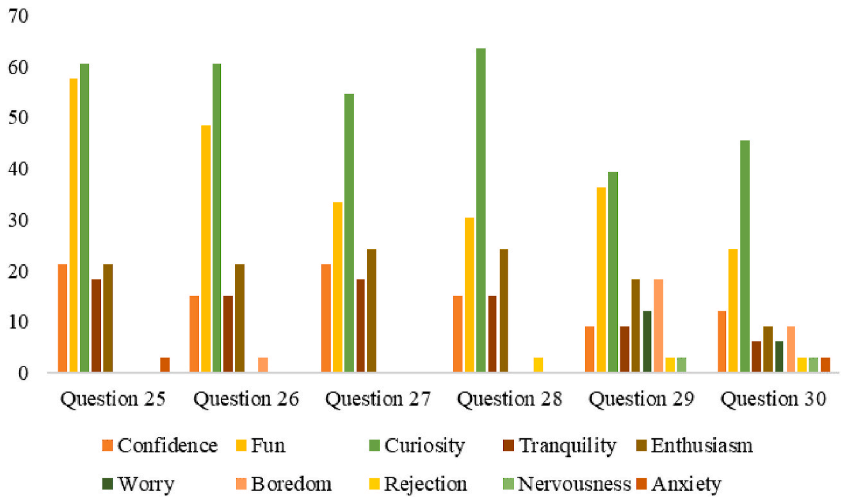

Fig. 3. Comparison of the percentage of emotions expressed in the post-test for all male participants (items 25–30).

5. Conclusions

Designing and using alternative tools based on sustainable education that seek to promote the emotional and direct involvement of the student in order to achieve meaningful learning helps reduce the negative attitudes that often exist in relation to the study of scientific subjects.

The results obtained in this work, in which ethnobotany was used to address physics and chemistry subjects, indicate that traditional knowledge associated with plants is a potentially effective didactic resource to improve the science education of future teachers, without influencing their previous studies or preconceived interests.

The students rated the didactic proposal very positively. An increase in self-efficacy and improvement in attitudes toward the subject were achieved, with a greater impact on the female gender, achieving a positive step toward breaking the existing gender gap in terms of the preconceptions that women tend to have of their own ability to learn and, therefore, teach science content.

The use of knowledge based on the immediate environment also influences knowledge of sustainability and the sustainability of the method itself, since it not only facilitates access to materials that are more familiar and recognizable to teachers and students but also creates awareness of the possibility of using cleaner materials, reducing the environmental impact generated by products of chemical origin, which are common in many laboratories. This, combined with the use of active methodologies, helps improve the motivation of teachers in training toward the study of experimental sciences, increasing their positive emotions and drastically reducing their negative emotions while also having an important impact in terms of eliminating gender stereotypes and the societal idea that women are less qualified for the study and learning of science.

The results obtained in this work indicate that the use of ethnobotany as a transversal didactic tool integrated into physics and chemistry topics causes an increase in self-motivation, improves the self-efficacy of teachers in training, and increases their sustainability awareness while permitting the acquisition of the didactic competences established in the teaching plan, increasing interest in the study and teaching of complex scientific subjects, reducing gender differences in the teaching-learning of science, and contributing to the energizing of a great variety of theoretical contents, opening the way to the possible adaptation of this tool for use in other scientific subjects.

The current work presents a clear limitation in the assessment of other different aspects of the educational process, such as the cognitive or psychomotor dimensions. These could be included in further pieces of research, since the efficacy and feasibility of involving ethnobotany in science education is checked out. In this sense, there are still some dimensions of the learning process that are not considered or evaluated and should be taken into account in future studies (E.g., the cognitive performance for students, measured through summative assessment).

Further research into the development of methodological strategies that allow ethnobotany to be introduced in the classroom in a simple way, not only in eminently practical activities of a one-off nature, but in a transversal way in traditional theoretical classes and during a complete thematic block, could be of great interest.

Data availability statement

The participants of this study did not give written consent for their data to be shared publicly, so due to the sensitive nature of the research supporting data is not available.

CRediT authorship contribution statement

Lorena Gutiérrez-García: Writing – review & editing, Writing – original draft, Software, Resources, Methodology, Investigation. **Jesús Sánchez-Martín:** Software, Resources, Methodology. **José Blanco-Salas:** Supervision, Software, Resources, Methodology, Investigation. **Trinidad Ruiz-Téllez:** Supervision, Methodology. **Isaac Corbacho-Cuello:** Writing – review & editing, Writing – original draft, Methodology.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: LORENA GUTIERREZ GARCIA reports financial support was provided by Spain Ministry of Science and Innovation. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This work is partially supported by Junta de Extremadura and “ERDF A way of making Europe”, through the Project GR21047, as well as by the Spanish Ministry of Science and Innovation and the State Research Agency through grant PID2020-115214RB-I00 funded by MCIN/AEI/10.13039/501100011033. Ms. Gutiérrez García would also thank Fundación ONCE for its economical support throught PhD Programme Grant.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e35301.

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