Fire Ecology

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Service-learning to improve training, knowledge transfer, and awareness in forest fire management

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Abstract

Background Forest fires represent a severe threat to Mediterranean ecosystems and are considered one of the major environmental and socioeconomic problems of the region. The project *Plantando cara al fuego* (PCF, Spain) is designed to transfer knowledge and to improve the training of new generations in forest fire management. The project is based on the application of service-learning (S-L), an educational methodology that combines learning and community service. Conceived as a compendium of S-L initiatives, the PCF project is composed of several S-L projects with the objective of reducing the problem of forest fires. The individual projects are developed at the regional/local level, each one involving different social agents such as researchers, students (from different disciplines), schools, multidisciplinary professionals, NGOs, or the administration.

Results Participants received an initial training in S-L to design projects focused on different aspects of forest fires (environmental awareness, outreach/communication, fire prevention or post-fire restoration). These applied projects are formally integrated in the learning process via curriculum, which serve to teach and reinforce transversal skills and allow students to get involved and work to solve real problems. In general, the response of the participants was highly favorable, since the projects served to create an atmosphere that facilitates learning, interaction between participants, the application of theoretical class contents, knowledge transfer, or the exchange of good teaching practices.

Conclusions The summary of the PCF project presented in this work serves as a practical guide describing the activities, participants, and the necessary steps involved in the design, development, and evaluation of S-L projects to address environmental problems. In this case, the S-L was adapted to a specific context (i.e., the problem of forest fires) to which it had never been previously applied, but this methodology is versatile and can be applied to different environmental issues.

Keywords Student training, Educational innovation, Service-learning, Knowledge transfer, Fire-fighting, Peer tutors, Forest conservation, Social engagement, Environmental awareness

Resumen

Antecedentes Los incendios forestales representan una severa amenaza para los ecosistemas mediterráneos, y son considerados como uno de los mayores problemas ambientales y socioeconómicos de la región. El Proyecto "Plantando Cara al Fuego" (PCF, España), ha sido diseñado para transferir conocimientos y mejorar el entrenamiento de nuevas generaciones en el manejo de incendios forestales. El Proyecto está basado en la aplicación del Servicio de Aprendizaje (*Service-learning*, o S-L), una metodología que combina el aprendizaje con el servicio comunitario. Concebido como un compendio de iniciativas S-L, el Proyecto PCF está compuesto de varios proyectos S-L con el objetivo de reducir los problemas de los incendios forestales. Los proyectos individuales están desarrollados a niveles regionales/locales, cada uno de ellos implicando diferentes actores sociales como investigadores, estudiantes (de diferentes disciplinas), escuelas, profesionales de diversas disciplinas, e instituciones no gubernamentales (ONGs) o de administración.

Resultados Los participantes reciben un entrenamiento inicial en S-L para diseñar proyectos enfocados en diferentes aspectos de los incendios forestales (concientización ambiental, comunicación y difusión, prevención de incendios, y restauración post-fuego). Estos proyectos aplicados son integrados formalmente en el proceso de aprendizaje a través de una currícula, que sirve para enseñar y reforzar las habilidades transversales y permite a los estudiantes implicarse y trabajar para resolver problemas reales. En general, la respuesta de los participantes es altamente favorable, dado que los proyectos sirven para crear una atmósfera que facilita el aprendizaje, la interacción entre participantes, la aplicación de contenidos teóricos brindados en clase, la transferencia de conocimientos, o el intercambio de buenas prácticas de enseñanza.

Conclusiones El resumen de los proyectos PCF presentados en este trabajo sirven como una guía práctica que describe las actividades, participantes, y los pasos necesarios implicados en el diseño, desarrollo, y evaluación de proyectos S-L para para encarar problemas ambientales. En este caso, el S-L fue adaptado a un contexto específico (i.e., el problema de los incendios forestales), al cual nunca antes había sido previamente aplicado, mostrando que esta metodología es versátil y puede ser aplicada a diferentes cuestiones ambientales.

Introduction

Fire represents a major force for environmental change and habitat degradation worldwide, especially in non-adapted ecosystems. Wildfire generally requires the confluence of at least four factors before it can occur: ignition, continuous fuel availability, drought, and favorable weather conditions (wind, high temperatures and low humidity) (Pausas and Keeley 2021). Fire regimes are complex and intrinsically related to socioeconomic and environmental factors, such as deforestation, agriculture, invasive species, landscape fragmentation, drought, fire management, forestry plantations, and climate change (Mandle et al. 2011; Pausas and Fernández-Muñoz 2012; Alencar et al. 2015; Fernandes et al. 2019). In addition to the environmental risks, wildfires are more prevalent in inhabited, fragmented areas, especially at the wildland urban interface (WUI), and the consequent loss of material goods also focuses attention on socio-economic aspects (Chas-Amil et al. 2013). In this respect, wildfire threatens rural populations and places firefighters at risk, while also affecting the livelihood of local inhabitants, rural development, and different sectors of the economy (Doerr and Santín 2016).

Fire management requires a good understanding of ecological and technical aspects; however, social and educational aspects such as training and social awareness (Nunes et al. 2019; Tedim et al. 2015), which are much less well explored and discussed, are also important. Considering that human behavior is the ultimate cause of wildfires (intentional or not), greater efforts must be made to transmit technical knowledge about fire prevention to forest owners and the general population (Molina-Terrén et al. 2016). Also, the consideration of fire as a natural ecosystem process requires a more integrated framework, a coordinated vision that recognize links between humans and their natural environments in land-use planning or risk management (Moritz et al. 2014). Due to the complexity of the problem and the multiple factors involved, scientific-technical proposals must be integrated with educational and awareness programs that are capable of generating social awareness (at social, economic, and environmental levels) and of influencing people to favor environmentally responsible attitudes.

In the present paper, we draw on a national program in Spain that aims to improve wildfire awareness, prevention, and training in an interdisciplinary manner. After a brief contextualization, we provide a detailed description of our experience in applying an educational approach based on service-learning (S-L). The educational program was carried out through collaboration between public

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administrations, universities, and educational institutions (primary and secondary schools). The program was adapted to different and specific contexts, and the learning process was evaluated at the end of the project. The results of the evaluation, the conclusions reached, and future prospects are presented and discussed.

Geographical context and regional problem

The *Plantando cara al Fuego (PCF)* initiative emerged in Galicia (NW Spain), a region included in the Atlantic-Mediterranean climatic transition zone and which covers 6% of the total area of Spain. The incidence of forest fires is particularly high in Galicia, and the 8000 fires year⁻¹ that occurred in the period 2001–2010 (Fernández and Vega 2016) represented 30% of fires in the whole national territory. The number of large forest fires (> 500 ha) during the period 2006–2015 was also the highest in the country (Spanish Government 2019). These events contribute to the place the region (including North-Central Portugal) as one of the areas of highest incidence of fire and burned area in the Mediterranean basin (San Miguel-Ayanz et al. 2019).

The problem is complex and is affected by both environmental and socioeconomic factors, including rural depopulation, land abandonment, habitat fragmentation, landscape homogenization, and the presence of exotic tree monocultures that increase fuel continuity and the probability of fire (Chas-Amil et al. 2015). As a consequence of the combination of human and environmental factors, different areas are affected by fires every year (Fig. 1). Data from Copernicus (EFFIS 2022) and the Ministry of Ecological Transition (MITECO 2022) indicate that 2022 can be considered the most devastating year of the twenty-first century and the worst season in terms of area burned in the last 3 decades in Spain. Furthermore, the problem will foreseeably be magnified further in the coming years due to climate change and other factors such as depopulation and changes in land use (Turco et al. 2018; Maes et al. 2020). All of these factors pose a serious risk to environment, social, and economic development, making forest fires one of the main environmental problems facing Spanish society and, by extension, southern Europe.

Educational needs and origin of the PCF initiative

There is currently growing concern about the climate crisis and greater recognition of the value of natural capital, the domination of forest cover by monoculture plantations, and the high annual incidence of wildfires. There is also increasing social concern about the consequences

Fig. 1 Pictures of different wildfires that occurred recently in Spain between 2020 and 2022. **a** Burned landscape after the Ribas de Sil wildfire (Lugo province). **b** Firefighters at the Carballeda de Valdeorras wildfire (Ourense province), image courtesy of the BRIF Laza. **c** Extinguishing services acting in the Sierra de la Culebra wildfire (Zamora Province), picture by Alvcnss (CC BY-SA 4.0). **d** Burning hills during the Navalacruz wildfire (Ávila province), image courtesy of Bomberos de Ávila

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of fire. In recent years, we have also become increasingly aware of the importance of multidisciplinary approaches in understanding forest fires. At the educational level, the number of forest fire management studies included in undergraduate (Forestry Engineering and Biology) and postgraduate (Forestry Engineering) university studies and training cycles has increased at the national level, also including professional training. Aspects related to environmental education in general are also taught in undergraduate (Pedagogy and Teacher Training) and postgraduate courses such as master's degree and PhD programs. However, education on certain aspects of forest fires remains limited.

Considering the current situation, reinforcement of training capacities is needed to overcome the technical, social, and economic limitations of fire management. Even in fire-prone regions, the scarcity of specialized technical and human resources affects the capacity to provide adequate training in forest fire management. Despite the huge environmental problem, there are no consolidated, recognized studies addressing Forest Fire Dissemination and Communication in which research centers, universities, and secondary education centers participate jointly (Santiago 2016) nor any joint training programs for researchers, educators, and social actors.

Beyond academic/professional training, the perception of fire as both an environmental and a social problem is increasing, and many sectors of society are willing to participate in environmental actions, which range from grassroot movements to formal measures (Quiroga et al. 2017). In Spain, regional plans generally include public dissemination and awareness-raising campaigns regarding fire prevention. Regional administrations, associations, and NGOs also organize awareness-raising activities, but society somehow remains separated from environmental problems (including wildfires). Nevertheless, it is essential to take advantage of this work that brings environmental values closer to civil society, and education and communication are key aspects to consider in this respect. In fact, citizen involvement reduces the occurrence of fires and the damage caused and therefore also reduces budget required for fire extinction (Monroe et al. 2016). Conservation values and nature protection are also enhanced by citizen involvement (Schuttler et al. 2018).

For the above reasons, education must become a fundamental part of the process, by engaging students (and others) in the conversation to reflect on how to protect, care for, and manage the environment sustainably, while also providing training in the necessary actions. In this respect, project-based learning using participatory methodologies or platforms that facilitate access to scientific information are of special interest for transmitting information about environmental issues to society (Niemiller et al. 2021). Development of an appropriate educational approach requires broadening the scope of action and creation of dialogue about how to construct the sustainability of the territory, both between local/popular and scientific learning, and at the intergenerational level (García-Romero and Martínez-Lozano 2022). It is thus essential to include initiatives that help to improve education, training, and environmental awareness about forest fires that can be extended to other regions. From a scientific point of view, such initiatives contribute to reducing fire incidence through the active participation of society.

The *Plantando cara o lume* (PCL, in Galician) initiative emerged in 2016 as a local, participative project aimed to educate the Galician population about the problem of forest fires and to enhance social participation in the response. Thus, this regional project served as the starting point of the project *Plantando cara al Fuego* (PCF, in Spanish; Facing the fire, in English), expanding the initiative nationwide to include institutions from another 3 regions in addition to Galicia (Madrid, Andalucía, and Castilla-La Mancha), which greatly amplified the topics included, the interaction between participants, and also the representativeness of the results obtained. With the general objective of improving education and increasing awareness about wildfires, both the regional and the national initiative are based on the Service-learning methodology.

A brief description of the service-learning methodology

Service-learning (S-L) is an educational methodology that combines learning and community service in a single project with a civic and academic basis, in which students become involved in an organized service activity that meets community needs (Sotelino et al. 2016). Multiple activities related to nature conservation and awareness focus on education but are conducted outside the educational system. However, S-L integrates community service within the curriculum by providing academic credits for active participation in real world problems (Grönlund et al. 2014; Cayuela et al. 2020). The inclusion of different social agents in the training process represents a fundamental part of S-L projects and gives the methodology a multidisciplinary character. Their perceptions and experience are unique and differ from those of researchers, teachers, and practitioners, as it is essential to design locally adapted and effective activities in S-L projects. The inclusion of this type of knowledge "outside" academia, known as local ecological knowledge (LEK) or traditional ecological knowledge (TEK), is a fundamental value to be considered in disciplines such as ecological restoration (Gann et al. 2019).

S-L projects improve training skills by combining three powerful educational tools (Santos Rego and Lorenzo Moledo 2018; Uruñuela 2018): (a) learning through experimentation and cooperation among peers, which helps students to construct their own knowledge; (b) benefit to the community through the application of the projects; and (c) collaboration-based training with social agents (administration, landowners, and forest agents). These aspects define a context of reciprocity between the educational institution and community, where both benefit. The educational activity provides students an environment where they can overcome educational alienation and learn within a relevant collective activity focused on human relationships (García-Romero and Lalueza-Sazatornil 2019).

Setting a clear objective for the PCF project

The PCF initiative was developed by taking into account the aforementioned needs, context, and capacities, and its main goal was to improve student training by using an experience-based educational approach, i.e., S-L. The project enables students, tutors, and citizens to learn about the environmental problem of forest fires, thus developing scientific-technical knowledge and civic values with the young population through the application of educational projects.

S-L has its origin in social sciences and has therefore mainly been applied in this field. The lack of examples of its use in the field of environmental science represented a challenge regarding the design and development of the initiative. It should also be noted that the PCF project has a large number of participants in different areas. Therefore, the objective of this paper is to provide a description of the different steps required to adapt the S-L methodology for student training, knowledge transfer, and raising awareness on issues related to fire ecology, fire prevention, post-fire management, and forest restoration.

## Methods

Project organization and participants

A brief introduction to the PCF project in the wildfire context

Based on previous experience (5 years, NW Spain) and the knowledge of the working group in implementing S-L in different educational areas (Santos Rego and Lorenzo Moledo 2018), the PCF project created a collaborative environment between higher education institutions (HEIs) (i.e., universities, vocational centers), research and educational centers, and social agents (companies, administration, forest owners, and NGOs) at all stages of the S-L projects. These actors designed and carried out individual S-L projects, taking into consideration environmental needs as well as cultural, social, and economic aspects of wildfire management in each area. Thus, the PCF project can be considered a series of individual and interconnected S-L projects.

Initially, and once the problems/needs were clearly identified, tutors from the educational centers interacted and identified the main training needs, providing different knowledge and skills and designing materials and activities. The social actors then provided resources, thus enhancing the educational and training strength of the project.

Target audiences and organization of the PCF project

Considering that the S-L methodology involves the inclusion of different social agents, the potential audience is wide, with a broad age range, social profile, and academic level and involving different work disciplines (Fig. 2). Different roles were assigned according to individual
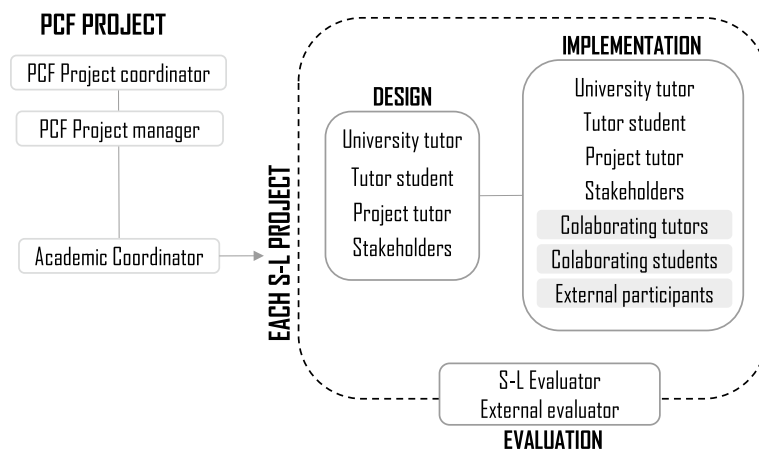
Fig. 2 Scheme of the different roles of the PCF project participants, also including the roles of each contributor in the different stages (design, implementation, and evaluation) of the S-L projects

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involvement in the project, to optimize participation. In addition to coordination roles, we identified two types of university and school students depending on the role and implication: *students who acted as tutors*, i.e., peer tutors, and collaborating students; *researchers and university professors* participating as *tutors* or *collaborating tutors*; and *staff from different organizations* (primary and secondary school, forest administration, forest companies, associations, NGOs) who can be considered as *stakeholders*. In conjunction, the PCF project brings together different actors from different institutions in Spain (Table 1).

– *HEI students (university and vocational students).* Although students from environmental sciences and forestry played a central role in forest management tasks, the inclusion of students from other disciplines, such as education, communication sciences, economics, audiovisual sciences, or journalism, was essential to generate real working groups and provided an opportunity to broaden the range of action of the S-L projects. The interactions between different disciplines enabled students to apply innovative forestry management techniques, which enhanced training in a field that requires skilled workers. S-L projects also provide an opportunity to develop transversal skills (Santos Rego et al. 2022), and in the case of the PCF project, they provided students with an opportunity to develop valuable communication skills, as well as contact with potential employers.

– *Researchers and HEI teachers.* Collaboration between different agents increases the research impact on society, providing an opportunity to develop communication and transfer skills. Likewise, the involvement of educators helps to improve educational materials, methods, and strategies. Collaboration with different agents also provides a platform for the exchange of perspectives in natural and social phenomena essential for the democratization of science (García-Romero and Herba 2022).

– *Stakeholders.* These partners are essential for S-L projects, contributing to key aspects (local knowledge, historical, or social context) to define the environmental problem and providing the means (material or economic) for the development of activities. This group includes a wide diversity of participants such as primary and secondary schools, land/forest owners, members of NGOs, companies, environmental associations, and public administrations. Different stakeholders——individuals or communities——possess broad, detailed knowledge that serves to integrate social perspectives in fire management, increasing community engagement in environmental protection. They often have materials

that increase the scope of the different educational, awareness-raising, and/or volunteer activities that they normally carry out. Through collaboration with researchers, S-L projects reinforce and recognize their activities. Within the different stakeholders, the main service of the S-L projects to the community is provided through schools:

a) *Primary and secondary school students*: The project encourages students' interest in science and their participation in addressing the problem of forest fires. Developing S-L projects with academics and researchers may also motivate students to study STEM disciplines (science, technology, engineering and maths) and follow scientific careers. In addition, the introduction of scientific knowledge from early stages of education has a significant effect on students' attitude towards the environment, and this influence extends to the family environment.

b) *Primary and secondary school teachers*: Collaboration with researchers and participation in PCF will help teachers to renew educational materials, strategies, and tools to reinforce activities and motivate their students, as well as being part of a common endeavor that entails the development of civic responsibility (García-Romero and Lalueza-Sazatornil 2019).

Project methodology
Phases of the PCF project
The national project was organized in three interdependent phases in order to adapt the S-L methodology to the environmental problem of wildfires:

– Phase 1. Teacher training (teachers from universities, vocational centers, peer tutors, key stakeholders), and exchange of good educational practices
– Phase 2. Design and implementation of S-L projects, where peer tutors (from universities and educational centers) learn while they act on specific needs of their local environments
– Phase 3. Dissemination and multiplier effect through (a) exchange of good practice for training and education on forest fires, through virtual resources and forums, and (b) launch of the training and education network on forest fires (FUEGORED)

Phase 1——training This phase included different activities in which the aforementioned trainers learned S-L principles and methodology:

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Table 1 People from different institutions and organizations participating in the design and implementation of S-L projects

Entity	Location	Type of entity	People involved
Companies			
AGRESTA	Madrid	Forestry services company	1
VIVEROS ELSEMBRADOR	Albacete	Forest Management Company	1
Montevivo	Andalucía	Forest Management Company	1
Forestación Quinxo SL	Ourense	Forest Management Company	1
Local/Forestry communities			
Forestry community of Río Caldo (Lobios)	Ourense	Community of Forest Owners	5
Grupo Local de Pronto Auxilio Urbanización Siete Fincas	Córdoba	Community of Forest Owners	9
Educational centers			
Colegio Cervantes -Maristas	Córdoba	Secondary school	3
IES do Castro de Vigo	Vigo	Secondary school	2
IES El Escorial	Madrid	Secondary school	3
IES Lucus Augusti	Lugo	Secondary school	3
IES Terras do Xallas	A Coruña	Secondary school	1
IES Tomás Navarro Tomás	Albacete	Secondary school	2
CEIP Plurilingüe do Xurés	Ourense	Primary school	1
CIFP Aguas Nuevas	Albacete	Vocational/professional training center	2
Universities and researching centers			
University of Castilla La Mancha (UCLM)	Albacete	University	9
University of Córdoba (UCO)	Córdoba	University	5
University of Santiago de Compostela (USC)	Santiago	University	37
Polytechnic University of Madrid (UPM)	Madrid	University	2
National Inst. for Agricult. Research (INIA)	Madrid	Researching center	3
NGOs			
Lirio do Xurés	Ourense	Regional NGO	1
Miraxurés	Ourense	Regional NGO	1
Plataforma Baixa Limia (PLABALI)	Ourense	Regional NGO	1
Sociedad Cultural y Deportiva Fontefría	Ourense	Regional NGO	2
Amigos da Terra	Vigo	Regional NGO	2
Pau Costa Foundation	Barcelona	International NGO	2
WWF/Adena	Madrid	International NGO	2
Administrations			
Municipality of Córdoba	Córdoba	Local administration	1
Municipality of Muiños	Ourense	Local administration	1
Junta de Comunidades de la Castilla-La Mancha	Castilla- La Mancha	Regional Administration	2
Xunta de Galicia	Galicia	Regional Administration	6
GEACAM (Public Company for Environmental Management of Castilla-La Mancha)	Castilla- La Mancha	Regional Administration	2
INFOCA-Junta de Andalucía	Andalucía	Regional Administration	3
TOTAL			**126**

– *HEI tutors*: We initially carried out training and exchange of good practices in fire education and created a working group on wildfire education and training, conducted by S-L specialists. In addition to basic and advanced notions of S-L, tutored practical work on how to design collaborative and adaptable S-L projects within the framework of forest fires was carried out. A virtual environment for communication was also created. To increase the scope, interest, and interaction between participants, an international session on education and training necessities to fight wildfires was held online. More than 100 researchers, fire specialists, and stakeholders from various countries affected by wildfires participated in the session,

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including Spain, Argentina, USA, Mexico, Brazil, Bolivia, Panama, Paraguay, Chile, Portugal, UK, Italy, Republic of Congo, Greece, Lithuania, South Africa, Russia, and Australia. Fire specialists with a background in education also presented an overview of activities related to training and education in different countries.

- *HEI students*: this step was conceived as a blended learning program, combining fieldwork with tutors in the respective regions (USC-Galicia, INIA-Madrid, UCLM-Albacete, UCO-Andalucía) and online training with all students and tutors.

Phase 2——design and implementation of the S-L projects This can be considered the essential phase of the project. Each region/community included several activities, such as design and implementation of the S-L projects with the educational centers and reporting on experiences (Fig. 3). While the design of the projects mainly involved teacher tutors, peer tutors, and key stakeholders, other students and collaborators were also involved in the implementation of the S-L projects. Project design is a particularly sensitive stage, and it was, in all cases, supervised by the education and S-L experts. In general, the projects can be divided into four different categories: (1) environmental awareness, (2) outreach and communication, (3) fire prevention, and (4) post-fire restoration (Table 2).

- *Environmental awareness*: The main objective of these projects was to create *technical* products, e.g., a mobile phone application for learning about fires, a university survey, or different innovative audiovisual products.
- *Outreach and communication*: Although these projects included only social educational tasks, such as making a documentary and holding a summer campaign, communication plays a central role in PCF and can be considered a common element in all S-L projects.
- *Fire prevention*: This category included S-L projects in which the participation of the local and regional administrations, together with the forestry and fire fighting services, was important. The projects included actions focused on prevention through biomass removal or prescribed fires, as well as the identification of fire-prone species and the amelioration of silvicultural models to reduce fire incidence.
- *Post-fire restoration*: These projects highlighted the importance of certain ecosystem values and how they are affected by fire. In general, they emphasized the key role of soil and biodiversity and the importance of analyzing soil status and recovery. Other projects focused on the protection, recovery and growing of endangered native plant species.

These 4 categories were not defined a priori, and, therefore, some projects might be included in one or more categories, e.g., some projects in the fire prevention category
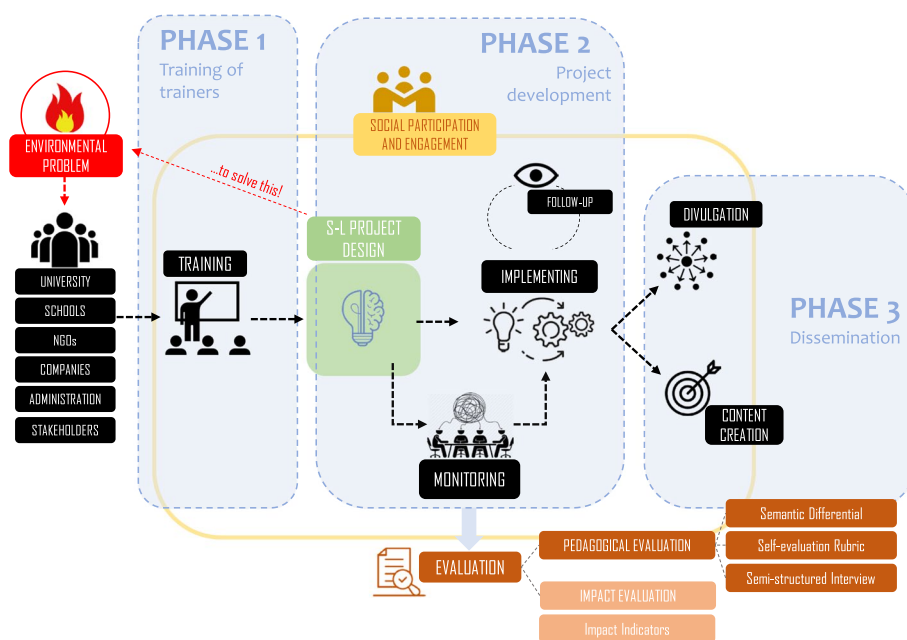
Fig. 3 A schematic representation of the different stages in the development of S-L projects. From left to right, blue boxes represent how the progressive phases of the PCF project contribute to the development of stages in individual S-L projects

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Table 2 List of individual S-L projects organized into four categories: Environmental awareness, outreach and communication, fire prevention, and post-fire restoration

Category	Title	Place	Disciplines involved	Participants	Tutor Students	Degree/ Master project	Objectives and brief summary of the S-L project
Environmental awareness	*Interactive Fire Platform*	A Coruña	Computer Engineering Degree	USC, Secondary school IES Terra do Xallas (A Coruña)	1	yes	Design of a mobile application (Android and IOS) that will allow high school students and non-specialized public to know different aspects about the problem of forest fires through questionnaires
	University survey: How much do you know about forest fires?	Lugo, Santiago	Forestry Engineering	All faculties of USC, Regional Forestry Administration	1	yes	Questionnaire intended to identify the degree of knowledge of the university population on aspects related to forest fires. Almost 700 participants
	Naturarte	Santiago	Communication Sciences	USC, Students of Design and Animation	1	no	Students developed animation using forest fires and the conservation on natural values as main topics. Those works with higher technical quality/originality were used in the social networks of the PCF project.
	Living memories of forest fires in the Xurés I. Educational activities	O Xurés (Ourense)	Education in nature, Forestry engineering, Communication Sciences	USC, NGOs, Forest owners, Neighbors.	3	yes	Students prepared a report summarizing all S-L projects carried out in the Xurés Natural Park, discussing education strategies to use in educational centers.
Outreach and Communication	*Living memories of forest fires II. Documentary*	O Xurés (Ourense)	Communication Sciences, Master in management of educational activities in nature.	USC, NGO, Forest owners, Neighbors	4	yes	The students carried out a documentary project framed within the S-L projects carried out in the Xurés NP. The documentary collects the personal vision of people affected by fires, collecting testimonies in the form of experiences, ideas, memories, and feelings.

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Table 2 (continued)

Category	Title	Place	Disciplines involved	Participants	Tutor Students	Degree/ Master project	Objectives and brief summary of the S-L project
	Now more than ever, face the fire	Santiago	Communication Sciences, Forest Engineering	USC, Regional Forestry Administration	2	yes	Exploring the potential of new forms of digital communication as an informative tool. Create a new identity and brand image for the national project. Students designed and implemented a social awareness campaign. The information published in different social networks and newsletter collects data and spread information, promoting social behavior to reduce fire incidence.
Fire prevention	*Fire prevention through the use of friendly (prescribed) fire*	Albacete	Forestry Engineering	UCLM, NGOs, 2 educational centers, forestry companies and Administration with forestry management.	1	no	Student tutors and the forest service focus on prevention, highlighting the need for management tools appropriate to each type of habitat and situation. Restoration techniques were promoted in affected areas, through impact zoning (burn severity and vulnerability) and the application of emergency actions for soil conservation.
	Fire prevention in the Wildland-urban interface (WUI) of Sierra Morena	Córdoba	Forestry Engineering	UCO, Local administration, 1 secondary school, forest management administration	1	no	Simple approach to technical aspects of fire management: identification of plant species in (periurban) fire-prone areas that favor fires and forest fuels assessment; exemplification of prevention and extinction activities by the forestry administration.
	Making development and conservation compatible	O Xurés (Ourense)	Forestry (Technical grade Secondary school)	USC, Local Administration, Regional Administration with forest management, 3 NGOs, Forest owners.	2	yes	Develop a silvicultural model to increase forest heterogeneity and reducing fuel load. Students planned and executed a reforestation (2 ha) in collaboration with school students, neighbors, NGO members and the Regional forestry service.

Table 2 (continued)

Category	Title	Place	Disciplines involved	Participants	Tutor Students	Degree/Master project	Objectives and brief summary of the S-L project
Post-fire restoration	*Soil protection tools for damage mitigation*	Albacete	Forestry Engineering	UCO, NGOs, 2 educational centers, forestry companies and Administration with forestry management	1	no	Student learned (remotely) and then explained how to assess postfire soil damage using laboratory and field techniques. Practical application was carried out in an experimental area of the ECOFOR group. Technically, the project consisted in a previous evaluation (severity) and a post-fire restoration of a burned area
	Restoration and fire prevention in the Northern Sierra of Madrid	Madrid	Forestry Engineering and INIA students	UPM, INIA, NGOs, a training center, Administration with forestry management and a neighborhood community	1	no	Integral project combining the management of recently burned forest areas and awareness activities for the population. The S-L project focused the training of higher education students to increase social awareness, interactive forest activities (diminishing soil erosion and soil protection) and prevention workshops to reduce the introduction of pyrophytic species
Post-fire restoration (cont.)	*Burning a forest, you burn part of yourself*	O Xurés (Ourense)	Forestry engineering, Education and Communication Sciences	Primary school, regional forestry and local administration, forest management companies, NGOs and forest owners.	1	no	Training on post-fire soil protection techniques (mulching, barricades construction, etc). Designing and implementation of awareness-raising activities for young students and families. Demonstrations of actions carried out by the forestry services. Workshops to differentiate postfire severity degrees and application of soil protection techniques. Discussion on the need to support post-fire soil protection actions.

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Table 2 (continued)

Category	Title	Place	Disciplines involved	Participants	Tutor Students	Degree/Master project	Objectives and brief summary of the S-L project
	Guarding treasures of nature	O Xurés (Ourense)	Master of Forestry	USC, Regional Forestry Administration	1	yes	Conservation and recovery of the endangered *Prunus lusitanica*. Students recognized the natural value of the environment, focusing on threatened species, identifying key soil and climatic conditions, and discussing silvicultural work and conservational strategies. Generating maps, cartography and a series of recommendations. The student tutor organized visits to the protected area.
	S-L project in the forest community of Teis	Vigo	Forestry and Natural Environment	USC, Forestry community of owners, Secondary School.	1	no	Capture the attention of young people and bring the population -with a more urban profile- to become aware of forest and nature values and the services they provide. Create a local (school) nursery with native species intended for restoration activities. Elimination of invasives species. Restoration activities were carried out by neighbors and local schoolchildren through a permanent school-workshop,

Abbreviations: *USC* University of Santiago de Compostela, *UCLM* University of Castilla La Mancha, *UCO* University of Córdoba, *UPM* Polytechnic University of Madrid, *INIA* Instituto Nacional de Investigaciones Agrarias (National Institute for Agricultural Research), *Xurés NP* Natural Park of Xurés

also included educational or dissemination activities, and restoration projects also included fire prevention activities. In all cases, projects were carried out during 2020 and 2021. Further details about the project design and development can be consulted in the official webpage (https://www.plantandocaraalfuego.org/proyectos-desar rollados/, in Spanish). Through the design and implementation of activities adapted to local realities, S-L projects allowed future managers, ecologists, practitioners, and students from different disciplines (e.g., environmental, forestry, education, economics, communication) to learn about different topics on the basis of real experiences.

Phase 3——dissemination   The main ideas, methodology, and findings of the individual S-L projects——and the PCF project in general——were disseminated via different platforms and media. Other than the official website, the international meeting, and various international conferences, different examples in which the working group was promoted are listed as follows:

- At the SERE2020, the Society for Ecological Restoration promoted the creation of the working group YOUNG#ER - Education and Training of young professionals towards socio-ecological restoration, and the opening of a forum on communication in education.
- The project was also presented to diverse forums, working groups, congresses, and societies, as in the mentioned FUEGORED and the Society for Ecological restoration (SERE) but also in the European COST Action Firelinks (https://www.cost.eu/actio ns/CA18135/), at the 1st International Congress on Fire in the Earth System, and to ENCIGA (the regional association of science teachers to improve STEM quality in non-university educational levels).

Communication and dissemination plan   Considering that the ultimate cause of forest fires is human behavior, a communication and dissemination plan (CDP) was designed in the form of an individual S-L project (see Table 1) to increase the project visibility among young people and to favor environmentally friendly attitudes, especially those aimed at preventing forest fires. The campaign was designed to focus on the months during which fire risk is highest. The communication plan was designed by 2 peer tutors, lecturers from the Faculty of Communication Sciences (USC), and >50 students in collaboration with forest managers. Different technologies and online platforms were used (newsletter, social

networks) to fit the priority age profile, i.e., the younger generation. Although the main objective was fire prevention and raising social awareness by exploring the potential of new forms of digital communication, other goals intended to consolidate a communication strategy were considered: actively involving individuals in forest fire prevention, putting into practice the recommendations promoted in the different platforms, increasing the active presence in social networks, and presenting information regarding environmental events from a more relevant and more optimistic point of view.

To achieve these objectives, the CDP was divided in different steps: (a) creation of a theoretical framework to define strategy, key communication points, and social advertising (distinguishing social publicity and commercial advertisement); (b) definition of communication needs of the project through meeting with the PCF team and analysis of current activity; (c) development of the CDP (including planning, production, and publication of content); and (d) analysis and drafting of conclusions. In general, the CDP increased the audience, the number of visits, and the attention of the traditional media. At the same time, the PCF project (and the individual S-L projects) gained visibility through the dissemination of the message across different social networks (Facebook, Instagram, Twitter, TikTok), with special emphasis on the peak fire risk in the summer season (CDP) but also describing the daily work and providing monthly news. Thus, technical information was adapted and made more accessible. In addition, the international session of education and training held during the training phase, which brought together more than 100 researchers, fire specialists, and stakeholders from almost 20 countries in a single online event, also served to disseminate the initiative.

Main results and evaluation
The implementation of innovative methods requires evaluation to determine any benefits produced. In the case of service-learning, the impacts on both learning and the community are assessed (García-Romero et al. 2021). In the particular case of the PCF project, 2 evaluations were conducted:

- Evaluation of the impact of the S-L projects involving citizens in wildfire-related problems (the "Evaluating the impact of the S-L projects in society" section)
- Evaluation of the methodology as a pedagogical and training tool (the "Evaluating the methodology as a pedagogical and training tool" section)

Evaluating the impact of the S-L projects in society

One direct indicator used to evaluate the involvement of society in the problems related to forest fires was the number of all organizations and participants involved in the design and implementation of the S-L projects (Table 1). This information can be also classified according to the type of entity and gender of participants (Table 3). The analysis showed that the project led to the involvement of different actors related to forest fires, such as public administrations, companies, landowners, NGOs, educators, and researchers. Two clear clustering trends were observed. On the one hand, the university brought together a large proportion of the participants (42%). On the other hand, gender results indicated that women were widely represented as teachers in training schools (71%), research centers (66%), HEIs (56%), primary schools (60%), secondary schools (50%), and NGOs (54%). However, female presence was low in regional forestry administrations (23%) and forest management companies (25%), and it was completely non-existent in administrations and forest owner communities (0% in both cases), which is consistent with the tendency to consider forestry a distinctly male profession (FAO 2016). In Spain, the lack of visibility of women in rural areas is addressed in the Plan for the Promotion of Rural Women (Spanish Ministry of Health, Social Services and Equality 2015). Women leadership of S-L projects (Table 4) was important (71%), reflecting the current participation of women in university studies. Likewise, the large number of female participants, many of them tutors involved in the mentoring of S-L projects (72%), can be highlighted. These figures are interesting as STEM studies are generally less popular among women (Beede et al. 2011).

Table 3 Participants by gender from each type of entity and organization associated with the design and implementation of S-L projects

Entities	Participants	Women participation
Local administrations	2	0
Regional forest management administrations	13	3
Professional training schools	7	5
Researching centers	3	2
Primary schools	5	3
Secondary schools	14	7
Community of forest owners	14	0
Forest management companies	4	1
NGOs	11	6
Universities	53	30
Total	**126**	**57**

Table 4 Roles of people involved in the design and implementation of S-L projects

Participant role	Participants	Women participation
PCF project coordinator	4	0
Academic coordinator of the PCF project	1	1
Collaborating students in S-L projects	30	4
Tutor students in S-L projects	21	15
S-L project evaluators	5	1
External evaluators	3	2
Project mentor teacher trainer	6	1
Trainer of ICT applied to S-L projects	2	2
PCF project managers	2	1
S-L project collaborating tutors	34	5
S-L project tutors	18	13
Total	**126**	**45**

While it is important to highlight the number of peer tutors and collaborators participating in the projects, it is essential to emphasize the participation of primary and secondary school students in the different activities programed (Table 5). Thus, between 2020 and 2021, more than 300 students from primary and secondary schools participated in the PCF project activities. This figure, together with the number of family members who may have been indirectly involved during and after the activities, far exceeds our initial estimates and met the objective of reaching out to the young population.

Evaluating the methodology as a pedagogical and training tool

The evaluation incorporated diverse methodological parameters, and a mixed or combined approach was used. Quantitative and qualitative techniques were used for data collection and subsequent analysis. After

Table 5 Number of students interacting with tutor students (university and professional training) participating in activities in the S-L projects

Educational center	Students involved
Primary school Plurilingüe do Xurés (Galicia)	50
Training center Aguas Nuevas (Castilla La Mancha)	30
Primary/secondary school Cervantes - Maristas Córdoba (Andalucía)	30
Secondary school Cidade Antioquía (Galicia)	30
Secondary school O Castro (Galicia)	60
Secondary school El Escorial (Madrid)	50
Secondary school Lucus Augusti (Galicia)	15
Secondary school Tomás Navarro Tomás (Castilla La Mancha)	50
Total	**315**

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implementation of the projects, previously designed and validated instruments (Santos Rego and Lorenzo Moledo 2018) were adapted to each part of the project and used to evaluate the results (ex post facto evaluation). The following instruments were used:

– Semantic differential (Oswood Scale): 31 questionnaires were administered to peer tutors and student collaborators (51% of the participants in this profile).
– Self-evaluation rubric: 10 questionnaires were administered to S-L project tutors (55% of the participants in this profile).
– Semi-structured interview: n total, 19 representatives belonging to collaborating entities (43% of the participants in this profile) participated in the interviews.

Semantic differential

This instrument was used to ask students about several dimensions of the PCF:

a) *General opinion of the project*: 77% of the total responders found the project very motivational and 87% would strongly recommend it.
b) *Activities they performed in relation to others in their courses*: participants found these activities "most interesting" (>90%) and "very useful" for learning (>80%) and also "strongly related" (74%) or "sufficiently related" (19%) to their university courses.
c) *Service developed*: participants found the service developed "very useful" (71%), "very satisfactory" (74%), and "good" or "very good" (100%).
d) *Learning as students*: the great majority of students found the learning "very useful" (84%, the other 16% classified the experience as "useful"), "very satisfactory" (81%, with the remaining 19% classifying the experience as "useful"), or "strongly applicable" to real life needs (74%).
e) *Teacher implication and socio-community implication*: students consistently found them "very approachable" (81% for teachers, 93% for socio-community), "active" (81% for teachers, 91% for socio-community), "easy to understand" (81% for teachers, 91% for socio-community), and "motivational" (81% for teachers, 93% for socio-community).
f) *Student implication in the project*: a high proportion of the students described their own involvement as "enthusiastic" (70%) or "satisfactory (81%).

These data show that students found their participation both motivational (according to the usefulness they find in their service) and related to the discipline involved and with a sense of real-life learning.

Self-evaluation rubric of the project

This rubric served to ask teachers about the different learning dimensions, based on a Likert scale with 4 levels. Teachers evaluated the program with positive values in all cases, especially in those aspects related to the skills developed by students (3.87 ± 0.35), focus on learning and the professional field (3.625 ± 0.74, for both aspects), followed by the guidance provided by the entity and the impact on social projection (3.375 ± 0.74 in both cases). The level of student participation, the available resources, and the transdisciplinary nature of the program were also highly rated (3.25 ± 0.46, in all cases). On the other hand, academic recognition (2.625 ± 1.19) and visibility (2.25 ± 0.707) scored the lowest values.

Semi-structured interview to participating entities

Beyond the quantitative data, qualitative information provides greater accuracy and meaning to the responses, according to the typology of the participating entities. This report addresses the following dimensions of assessment: comments on student participation (interest, involvement, and learning), assessment of the project impact, project highlights, and proposed improvements.

The responses emphasized the high level of involvement of the students in terms of interest, attention, and willingness to work in the practical execution of the projects. The responses also stressed the importance of student implication related to motivation and meaningful learning. A high proportion of participants from secondary schools mentioned the content regarding sustainability, land protection, and fire management (prevention or post-fire treatments). They indicated existing interest, since sensitization activities had already been carried out, so that these students already recognized these problems as their owns. Vocational training or university students highlighted learning communication skills and teamwork, as well as social skills developed in contact with the professional world.

Regarding the impact of S-L projects, the responses indicated that activities increased awareness and served to disseminate information among young people about fire prevention and post-fire management. Environmental associations and forestry managers valued help in accessing the young population as "*the intergenerational relay in preventive action is complex but motivating*". Teachers from secondary schools pointed out that S-L projects enhanced educational innovation in the centers. They also indicated that results were very positive, with statements such as "a much better result than expected," "students were able to design a project that was executed from start to finish," and "in the dissemination phase they overcame their limitations and their communication barriers." Importantly, when asked about the degree

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of satisfaction, all respondents answered positively, with ratings ranging from "high" (2 respondents) to "full" (all other respondents).

Asked about the most outstanding points, respondents made special reference to the increase in the awareness about wildfire-related problems in young people. Different aspects of the experience were positively valued, regarding both the purpose and the learning process. The project was considered an opportunity for students from different disciplines to interact and make contact with professionals and businesses that served to provide experience in various skills and real-life situations. Considering the proposed improvements, all were related to further extension of the project. There was also a clear demand for continuity to enable the long-term results to be evaluated. The educational centers also suggested increased dissemination and more interactions with other centers.

Discussion

To carry out a constructive analysis of S-L projects, some aspects can be highlighted and discussed because of their positive value or complexity. At the same time, these aspects should be considered as the main lines of conclusion of these projects.

The potential of S-L projects to be used in the teaching of fire ecology

As we have been indicating throughout the text, the need to improve learning and training in environmental disciplines, including ecology, is fundamental to understand and reduce the problem of forest fires. In this sense, Cooke et al. (2021) indicated that we have an urgent need to recruit and train future generations of ecologists, those considered ecologists per se, but also those involved in related areas as geology, biology, or environmental sciences. These authors highlighted some limitations also identified in the PCF project such as the society-nature disconnection or the necessity for better technical approaches for student training. In fact, their diagnosis of future needs for ecology learning——including fire ecology——considers recommendations that can be achieved by the use of S-L projects. Thus, the increase of experiential and field-based learning, the need to improve students' communication skills, or, more importantly, the introduction of ecology-related learning in the curriculum, considerations emphasized in the PCF project, were indicated as fundamental aspects to improve teaching and learning in ecology worldwide.

Knowledge embedded in the curriculum

One of the most outstanding aspects of the inclusion of S-L in fire management is that the approach included formal training into the academic curriculum and is thus integrated into the training and the degrees awarded. In the period 2020–2021, students involved in the project have written up and defended theses as part of their BSc (5) or MSc (3) theses. One of the BSc theses reported the results of a questionnaire distributed to staff and students at the University of Santiago de Compostela. Considering the high level of participation (700 questionnaires completed), the survey yielded some rather worrying results. Although the target audience represents a part of society (allegedly) well-informed about environmental issues, the respondents showed intermediate to poor knowledge about wildfires, forest characteristics, and land management. The responses clearly indicate that there is still much work to do in terms of dissemination and education.

The importance of learning versus results

The positive response shown by the students and, above all, by the teachers must be emphasized. This project served to create an atmosphere of reciprocity that facilitated the exchange of good teaching practices. In terms of education, it is also essential to recognize the importance of the continuous learning process and not only focus on results. Thus, although the development of individual S-L projects aimed to address real world problems, participants considered that the actual impact had more to do with the process itself (awareness and training in fire prevention) than the environmental outcome (S-L project activities). The experience itself, rather than the environmental objective proposed, was the most important factor. However, the inclusion of the learning process in environmental service contributes to giving meaning to environmental endeavor and values. In S-L, learning is not always viewed as an end itself, but as subsidiary to being able to contribute to a common good, in this case wildfire prevention (García-Romero and Martínez-Lozano 2022). In this case, the broad scope of the project may have contributed to the fact that many students focused on environmental issues and land protection.

Economically feasible activities

The development of S-L projects provides benefits for individuals, different groups, agencies, and organizations, at little or no cost to participants. Most of the S-L projects were carried out with small budgets or no economic support. In some cases, mobility was supported by travel allowances, but the community work, collaboration between associations and agents, and hours of dedication of the students (later reflected in the completion of degree or master's theses) implied a reduction in costs that make application of such projects feasible and adaptable to numerous situations.

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Multidisciplinary and transversal skills

Because of the multidisciplinary nature of S-L projects, the impact extends beyond the limits of the environmental topic addressed and has the potential to transcend disciplines. The atmosphere of reciprocity mentioned above for teachers can be also extended to students. Additionally, some S-L projects involve rural or urban-rural interface areas, generally with small populations and low economic activity. These projects serve to reinforce students' transversal skills with a view to their incorporation in the job market and even place future workers in contact with local employers in peri-urban or rural areas. Contact between different agents is also fundamental for the recognition of local needs that can serve to identify new job niches. As the S-L projects focused on wildfire fighting and by extension, environmental protection, they contribute to reversing the pathway of degradation pointed out by Blignaut et al. (2014) by increasing social change as a necessary strategy towards a more sustainable society.

Increasing the diversity of participants

Although S-L projects have a strong component of scientific knowledge, the participation of different stakeholders is expected to increase in coming years. It is important to involve more participants, as a greater diversity of stakeholders will increase the representativeness of S-L projects and the scope of knowledge. Expectations in this respect are high because the PCF project has been included by the WWF, in their report entitled Fires Forest and the Future (2021), as an innovative initiative that can serve as a mirror for other regions affected by wildfires. However, to increase the attractiveness for potential participants, we must highlight the positive aspects of becoming involved in S-L projects (beyond the direct economic return) and its potential for systemic change and constructing mutuality between different social agents (McMillan et al. 2016). Dialogue and mutuality are important, as local populations have often been excluded instead of being actively involved in environmental and land protection. Therefore, S-L provides a framework for dialogue and for building participatory and more realistic territorial management by protecting mutual trust between stakeholders, social agents, and scientists, with the special participation of the students.

Limited time continuity

As in many other situations, it is difficult to create a trusting environment and adequate working conditions within a limited time frame. Temporal continuity, which allows follow-up of the work and results to be collected over time, has been indicated by the participants as a limitation of S-L projects. The first edition of the PCF included institutions and participants from 4 autonomous regions in Spain. Fortunately, the second edition (to be held in 2022–2023) will enable the continuity of some projects, and it will also extend S-L activities to all national regions, significantly increasing the number of participants. Considering future sustainability and integration at the national level, it is essential to stabilize the working group, as an association or foundation. The first steps have already been taken in this direction, and the Iberian working group on education and training in forest fires will soon be presented.

Participant limitations

For greater impact on learning, participants asked for more on-site and face-to-face activities. This is perfectly understandable considering the social context due to the health crisis (COVID pandemic) experienced during the early stages of the project. After a period of reduced outdoor activities, the demand for this type of activity is now increasing. However, this process requires a more flexible curriculum, together with greater participation, interaction, and creativity of the teachers involved. The time that students spend on fieldwork can only be justified when the experience is considered valuable. Participatory and experience-based activities should be the core of learning rather than being considered extracurricular (Dewey 1958), so that the values actively constructed are linked to present and future prospects (personal and professional) of the students.

Conclusions

Although it may initially seem complex, our approach can serve as a preliminary guide to applying S-L projects to different types of environmental problems, especially to problems related to forest fires. It may be some time before S-L projects integrates in the learning process on a regular basis, but adopting this approach to solving certain environmental problems, such as forest fires, has many advantages. Thus, the ability to integrate practical knowledge into the curriculum, the multidisciplinary nature of the projects, the collaborations between agents from different sectors, and the inclusion of responsibility and civic sense within the discipline are valuable aspects of S-L projects that encourage the application of this approach with the aim of improving student training and education.

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Authors' contributions

AM, JCRG, UOU, OR conceived the original idea of the paper. AS, DGR, MLM developed technical material for evaluation. PSA, BO, JCRG, JM, OR, DM, JRM, FRS, AM designed the S-L projects, developed the activities and collected data. PSA, BO, AS, DGR, AM analyzed the data. PSA and AM developed the structure and prepared a first version of the manuscript. All authors contributed to manuscript revision, read and approved the submitted version.

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Availability of data and materials

Part of the data collected data as well as evaluating materials will be available soon at the webpage of the PCF project.

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The authors declare no competing interests.

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