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Challenge-based education methodology within sustainable development environments: from ocean i³ to EmPACT i³ experience

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This paper discusses the application of challenge-based education (CBE) in sustainability contexts, based on the Ocean i³ and EmPACT i³ projects. Within the framework of the Sustainable Development Goals (SDGs), especially SDG 3, CBE is proposed as a way to develop transversal and sustainability skills. The study describes its implementation in open, multicultural, multilingual, and cross-subject contexts, with the participation of regional agents. It highlights the creation of collaborative communities, redefining the role of the teacher as facilitator and the thoughtful use of log books. The experience shows how to structure active learning with local solutions, offering recommendations for universities seeking a transformational educational experience committed to sustainability.

KEYWORDS

higher education, challenge-based learning, education for sustainable development, SDG 4, environments for innovation

Introduction: background and rationale for the educational activity innovation

The Agenda 2030 (United Nations, 2015) sets the Sustainable Development Goals (SDGs) as a target for 2030, challenging universities to make education for sustainable development (EDS) part of their research, teaching, and administration (Weybrecht, 2017). EDS, crucial to SDG 4.7 (UNESCO, 2014), fosters skills such as critical thought and global citizenship by calling for innovative, action-oriented educational environments (UNESCO, 2017).

Spanish universities have taken on board the Agenda 2030, and the Spanish university rectors' conference (CRUE) opted to make the SDGs one of its priorities (CRUE, 2012). The most significant, visible advances are those centered on the greening of campuses and research initiatives (Sáez de Cámara et al., 2021). Teaching practices, on the other hand, are developing more slowly (Cotton et al., 2009; Sterling and Scott, 2008; Wals, 2009) and require the implementation of cross-subject projects and measures to tackle the social-environmental issues related to degree curricula (Cruz-Iglesias et al., 2022; Rekalde-Rodríguez et al., 2023).

The configuration of the physical learning environment depends largely on the chosen teaching-learning methodology, as it must respond to its specific requirements. Thus, the physical setting is not a secondary element; it shapes participation and the types of tasks carried out in the learning process (Delbury and y Carcamo, 2020). The OECD (2013) report on innovative learning environments highlights a broad consensus that learning is situated and socially embedded. While literature often associates learning environments mainly with ICT-based programs (Zitter and Hoeve, 2012), the OECD conceptualizes them holistically as learning ecosystems that

integrate both the learning processes and the environment in which they occur. In this view, context functions as an organic system essential to contemporary understandings of learning, where diverse combinations of approaches are considered the norm (Dumont et al., 2016).

This paper, therefore, sets out to describe the construction of two open, living EDS environments open to the region: Ocean i³ and EmPACT i³, in order to help the academic community in its task of designing and structuring EDS-linked teaching and learning processes.

Pedagogical framework(s), pedagogical principles, and competencies/standards underlying the educational activity

Learning environments go beyond the traditional classroom, extending into informal spaces such as outdoor training (Rekalde-Rodríguez et al., 2024) or living labs (Prestol, 2020), where knowledge flows freely. The OECD (2013) stresses that context is crucial to situated learning, seen as a dynamic, flexible ecosystem (Dumont et al., 2016). The OECD Handbook for Innovative Learning Environments (2017) proposes seven essential principles to take into account when designing innovative learning environments:

- (1) The learning environments recognize the learners as their core participants, encourage their active engagement, and develop in them an understanding of their own activity as learners.
- (2) The learning environments are founded on the social nature of learning and actively encourage well-organized cooperative learning.
- (3) The learning professionals within the learning environment are highly tuned to the learners' motivations and the key role of emotions in achievement.
- (4) The learning environment is acutely sensitive to the individual differences among the learners in it, including their prior knowledge. It is said: "As the learning becomes more personalized, the active role of the learners themselves" (p. 26).
- (5) The learning environment devises programs that demand hard work and challenge all, without excessive overload. It is said: "No-one should be allowed to coast for any significant time on work that does not stretch them. By the same token, simply increasing pressure to overload does not make for deep and lasting learning" (p. 25).
- (6) The learning environment operates with clarity of expectations and deploys assessment strategies consistent with these expectations; there is a strong emphasis on formative feedback to support learning.
- (7) The learning environment emphasizes horizontal connections across disciplines, the community, and the real world. As stated: "Real-world problems do not fit neatly into subject boundaries, and tackling them makes learning more relevant" (p. 26). It also highlights that partnerships and networks will be essential in the future.

To put these seven principles into practice, the OECD (2017) proposes: (a) innovation in the core educational elements of the learning environment, i.e., students, trainers, content, and learning resources plus the dynamics that put them together; (b) turning

organizations into training spaces; and (c) opening up to alliances with the community, cultural institutions, media, companies, and so on.

Furthermore, the literature points out that scientific progress often comes about in interdisciplinary settings in which the traditional borders between subjects are no longer the initial point of reference (Bernstein, 2015; Correa and Carlachiani, 2021; Evans, 2019; Morin, 2011; Tilbury, 2011).

The complex, global challenges posed by EDS can only be met through a cross-subject approach to education (Barth et al., 2023; Sabbah, 2021), implemented in contexts that represent true learning environments (Oser and Baeriswyl, 2001); stimulus-rich learning environments that encourage an active learning process (Zabalza and Zabalza, 2019). In fact, the literature warns us that skills development is not automatically guaranteed by the method used but depends on the learning environment (Gil-Molina et al., 2024; Membrillo-Hernández et al., 2019).

Innovative environments call for methodologies focused on both process and results (Márquez and Blas, 2022). Challenge-based learning (CBL), an active methodology aligned with EDS (Evans, 2019), was promoted by Apple (2008), though its academic origins date back to 2001 (Gallagher and Savage, 2023). The Enlight consortium defines it as a multidisciplinary approach in which students solve real problems by developing 21st-century skills (2025). Challenge-based education (CBE) aims to not only deepen subject matter expertise but also to develop transferable 21st-century skills, such as creativity, collaboration, and communication, and to better prepare students for challenges they are likely to encounter in their future careers (Enlight, 2025).

CBE focuses on learning by solving complex, real problems (López-Fraile et al., 2021), on the basis of experiential learning (Benítez Erice et al., 2016; Portuguese and Gomez, 2020). While similar to project based learning (PBL), it involves greater flexibility and co-creation within the community (Membrillo-Hernández et al., 2019).

Sukackè et al. (2022) consider CBE in five different dimensions: (1) the learning activities deal with real problems for which a response/solution must be found; (2) the solution type must be real and open; (3) the product—response/solution—leads to one or more specific actions; (4) the process challenges students to analyze, design, develop, and execute the best response/solution to the challenge; and (5) throughout the process, teachers play the part of coach and co-researcher. Outside professionals play an active part in students' skills development (Agüero et al., 2019), and this multiactor collaboration (students, teachers, and outside agents) fosters integration between academia and the world of work (Yang et al., 2018), acting as a methodological bridge between these two spheres (Pinto and Soto, 2021).

The CBE process is divided into three interconnected stages: engagement, investigation, and action (Nichols et al., 2016). Each phase offers opportunities for mini-research cycles and prepares students to move on to the next phase or, if necessary, go back to a previous phase in a continuous process of documentation, reflection, participation, and collaboration.

Gallagher and Savage (2023), after reviewing a total of 100 papers using a qualitative thematic matrix, identified eight features common to CBE approaches: challenge definition, global themes, real-world challenges, collaboration, technology, flexibility, multidisciplinary, and innovation and creativity. Van den Beemt et al. (2023) take into account these features, but incorporate dimensions and indicators to reflect the range of features to be seen in CBE implementation: vision

challenge (link to real problems, global themes, and stakeholders), teaching and learning (T-shaped professionals, guided teaching, self-directed learning, summative assessment training, interdisciplinarity, collaborative learning and use of educational technology), and support (ICT infrastructures and teacher support in designing challenges, change in the teacher's role from expert to facilitator).

The literature stresses the development of transversal skills such as teamwork, communication, leadership, and creativity based on sustainability (Kohn Rådberg et al., 2020; Pérez-Rodríguez et al., 2022; Portuguez and Gomez, 2020; Rodríguez-Chueca et al., 2020), and the purpose of having a social, environmental, economic, and political impact on the region through sustainable solutions (van den Beemt et al., 2023).

In short, CBE is considered a method to transform adult learning and develop 21st-century skills to meet the needs of the world of work (Leijon et al., 2022). Its features of flexibility, adaptability, and connectivity with the region and the community mean that this methodology is clearly oriented toward sustainable development (Kohn Rådberg et al., 2020; Portuguez and Gomez, 2020; Sukackè et al., 2022; van den Beemt et al., 2023). However, this calls for engagement with the bodies and stakeholders in order to ensure that the EDS is rooted in the challenges of the region.

Finally, while CBE is being implemented in higher education in different areas, good practices need to be identified and described; these are as yet lacking because of its incipient nature as a methodology and research area (Gallagher and Savage, 2023; Leijon et al., 2022; Sukackè et al., 2022).

Learning environment (setting, students, faculty), learning objectives, pedagogical format

Ocean i³ (2018–2022) and EmPACT i³ (2024–2026) are international, cross-border inter-university projects within the Basque Country-Nouvelle Aquitaine region, involving the University of the Basque Country (EHU), the University of Bordeaux (UBx), and Euskampus Foundation.

Ocean i³ was funded by the European Regional Development Fund (FEDER), through the Interreg V-A Spain, France, Andorra program (POCTEFA 2014–2020), and EmPACT i³ is funded by Interreg VI-A Spain-France-Andorra (POCTEFA 2021–2027).

The overall aim of these environments is horizontal participation by students, teachers, and stakeholders in the Basque Country and Nouvelle-Aquitaine to develop responses/solutions through projects/ideas with a social, environmental, and educational impact, focused on major challenges in the ecological and social transition in this cross-border region (see Figure 1). Both respond to a positioning with regard to sustainability and the use of oceans, concerning SDG 14 (life below water), 4 (quality education), and 17 (alliances) in Agenda 2030, as recognized by the General Assembly of the United Nations (UN) in September 2015. EmPACT i³ incorporates SDG 7 (renewable energies) and SDG 12 (circular economy).

Both are cross-subject as they involve a range of university subject areas (including Fine Arts, Biology, Criminology, Law, Economics, Nursing, French Philology, Engineering, Teaching, and Psychology). They are also cross-level, as bachelor's, master's, and doctoral degree students take part, as well as multilingual, as Basque, Spanish, French, and English coexist within them. Shared leadership and support in the



FIGURE 1
EmPACT i³ community 2024–2025.

students' training process are shared between lecturers from both universities and bodies in the Basque Country-Nouvelle-Aquitaine region (Rekalde-Rodríguez et al., 2021). This joint work enriches students' educational experience, developing key competencies that provide a new vision and awareness of sustainability (Cruz-Iglesias et al., 2022) and employability (Zinkunegi-Goitia and Rekalde-Rodríguez, 2022).

In general terms, as pointed out by Rodríguez-Chueca et al. (2020), to maximize the ability to put to use the specific skills of each degree and encourage the development of transversal skills to boost students' employability, it is felt to be appropriate, pertinent, and beneficial to include them in the curriculum in the final years of a degree course. Such inclusion varies depending on the university and the degree and may involve subject course work, final dissertations or projects, or practicums (Alba, 2017). It is implemented in the second term (January–June), with the academic community and social agents taking part in three cross-border workshops (or five in the case of Ocean i³) for training, dialog, and collaborative supervision.

These are based on the SBE model that inspired the European universities in Enlight, in which activities are structured in three inter-connected phases: (1) engage, in which students set out from a global idea to define specific challenges; (2) investigate, in which information is compiled from primary and secondary sources and findings documented; and (3) act, in which solutions aligned with the research are developed (Enlight, 2025; Nichols et al., 2016). This methodology is implemented traditionally in academic contexts with the support of outside agents (Nichols et al., 2016; Pinto and Soto, 2021), but the Ocean i³ and EmPACT i³ projects have adapted the model to their complex environments, as shown in Table 1, which specifies the aims, tasks, participants, and spaces involved in each phase of the process.

In each phase, students reflect on their learning in a logbook. The whole process fosters a critical, collaborative response to real challenges based on a cross-subject approach (see Figure 2).

Results to date/assessment (processes and tools; data planned or already gathered)

The challenges are a call to action for the whole community, but above all for the students, as they are called on to investigate and

TABLE 1 Phases along CBE in EmPACT i³.

Objectives	Tasks	Participants	Space
<i>Engage:</i> To transit from a broad, unachievable global idea to a more specific, viable challenge to move the community to action.	1. Formulation of relevant questions in order to approach the big global idea. 2. Selection of the most pertinent questions and initial definition of challenges.	- UPV/EHU and UBx teaching staff - Social agents in the Basque Country and Nouvelle-Aquitaine - Euskampus Foundation technical staff	Cross-border meeting
	3. Presentation of the initial definition of challenges and redefinition thereof. 4. Specifying projects in terms of action.	- UPV/EHU and UBx students - UPV/EHU and UBx teaching staff - Social agents in the Basque Country and Nouvelle-Aquitaine - Euskampus Foundation technical staff	First cross-border workshop
	5. Thinking about learnings. Writing a log.	UPV/EHU and UBx students	Online. Euskampus Digital platform
<i>Investigate:</i> Executing action-oriented projects (group/individual) that yield realistic, viable responses to the challenge.	6. Searching for academic information. 7. Student mobility. Laboratory work, field work, discussion with experts, etc. 8. Dialog and discussion with participants in this cross-subject challenge.	- UPV/EHU and UBx students - UPV/EHU and UBx teaching staff - Social agents in the Basque Country and Nouvelle-Aquitaine - Euskampus Foundation technical staff	Second cross-border workshop Stakeholders in the Basque Country and Nouvelle-Aquitaine Autonomous work by students
	9. Thinking about learnings. Writing a log.	UPV/EHU and UBx students	Online. Euskampus Digital platform
<i>Action:</i> Discuss and disseminate projects aligned with the challenge in the cross-subject, cross-border community.	10. Dialog and discussion about the challenge with the cross-subject, cross-border community. 11. Action in the region. 12. Anticipating the challenges. 13. Disseminating achievements.	- UPV/EHU and UBx students - UPV/EHU and UBx teaching staff - Social agents in the Basque Country and Nouvelle-Aquitaine - Euskampus Foundation technical staff	Third cross-border workshop Basque Country and Nouvelle-Aquitaine region Autonomous work by students
	14. Thinking about learnings. Writing a log.	UPV/EHU and UBx students	Online. Euskampus Digital platform



FIGURE 2
One of the workshops at EmPACT i³.

reflect on the challenge and to devise, prepare, and organize actions. The results include: 11 completed projects, participation of 15 EHU students and 14 UBx students, 18 EHU teachers and 7 UBx teachers,

13 social agents, and 11 disciplines mobilized during the academic year 2024–2025. Table 2 shows the projects that students on the different degree courses at both universities set up to define, focus on, and dimension each of these broad, global challenges. In many cases, each student specified these group projects even further (territory, physical and temporal space, people involved, and so on), making them into their final degree project, doctoral thesis, subject course work, or work placement. Many of the projects were linked to a target to meet the challenge posed more directly, but indirectly, they also had an impact on other challenges. The cross-border and cross-subject projects developed products ranging from communication plans and educational materials to academic analyses, comparative studies, and sustainable prototypes, generating practical solutions and raising awareness of current environmental issues.

Through these projects, students from both universities developed competencies specific to their university studies and transversal competencies. Students become aware of their achievements through a reflective process that they record in their logbook. In the words of a student: “I believe that my participation in EmPACT i³ has fostered the development of my employability skills, as it has allowed me to

TABLE 2 Panoramic view of projects during the 2024–2025 course.

Projects	Degrees	Social agents	Results
Managing microplastic granules in the plant.	Engineering school (Bidart) (UBx)	GUREAK.	Analyzing and redesigning the in-plant process to avoid dumping pellets (microplastics) into the sea. Intervention to raise awareness among personnel.
Sound landscape and exhibition on biodiversity in the Marais d'Orx nature reserve	UPV/EHU Degree in Fine Arts	PARCC/MACS Maison des Rivages	Cross-border creation and exhibition of drawings and paintings.
Control of bathing water quality by analyzing the presence of pathogens and antibiotic-resistant bacteria in the plastisphere.	UPV/EHU Degree in Microbiology	Rivages Pro Tetch SUEZ	Plastisphere analysis in terms of resistance to antibiotics.
Itsasoarekin modu seguruan biziz, erronka kolektiboa.	UPV/EHU Degree in Advertising and Public Relations	Comité Côte Basque MNS SOS & SURF ESKOLA	Creating a communication plan for the organization.
Mots d'océan	UPV/EHU Degree in French	Maison des Rivages SOS & SURF ESKOLA Comité Côte Basque MNS	Creating teaching materials and a glossary associated with lifesaving and the evolution of the coastline.
Escape game	UPV/EHU Degree in Teaching	LibrePlume	Creating and setting up an escape game to foster children's and young people's literature concerning ocean sustainability.
Implementing energy communities in the Basque Country.	UBx Degree in Governance of the Energy Transition	Gaia EVE-Basque energy body Euskampus	Comparative study of policies and governance of energy communities, Basque Country-Nouvelle-Aquitaine.
Processability trials on a new resin for recyclable bio-based composites.	UPV/EHU Faculty of Chemistry PhD & post-doc POLYMAT(UPV/EHU)	Compositadour	Processability trials on a new resin for recyclable bio-based composites.
THE "SEA" OF PLASTIC (1)	UPV/EHU Engineering PhD	RESAK MATER	Collecting, describing, and studying the recyclability of plastic waste from the seabed in the Bay of Biscay.
THE "SEA" OF PLASTIC (2)	ESTIA Engineering School	MATER RESAK	Prototyping products from marine plastic waste.

strengthen abilities such as teamwork, communication with other organizations, problem-solving, and adaptability. I have also acquired practical tools and knowledge that make me feel better prepared to face the challenges of today's work environment, such as how to create a good resume or how to implement an escape room".

With regard to assessment, we must differentiate between two levels in the assessment of students: on the one hand, that is directly linked to the project, and on the other, that is linked to the assessment of the products derived from this participation. At the first level, the assessment aims to make students aware of the learning acquired through their participation in the open eco-learning environment represented by EmPACT i³. To this end, assessment is conceived as a formative process for students, in which the teacher monitors progress through the logbook, using a general rubric that can be adapted to the specific syllabus. The assessment criteria are organization and presentation of information, adequacy of the record of activities and monitoring of the process, personal reflection and critical analysis, appropriate use of language and written expression, creativity and visual presentation, and compliance and consistency with tasks. These criteria guide the teacher's feedback to students, which may be written or oral, when compiling the logbook. The assessment of the logbook is not subject to a numerical grade or a mark on the student's academic record, but rather its purpose is for students to reflect and become aware of their learning beyond the value of the results obtained. Let

us say that this level corresponds more to the personal aspect of the change in attitudes that this participation has brought about, and this is recognized with a certificate issued by the project organization. In contrast, the second level is carried out outside the EmPACT i³ project and involves the evaluation of the products derived from the intervention. These are evaluated using the criteria established in the teaching program for each syllabus and degree; let us say that this corresponds to the technical aspect of each degree program.

Discussion on the practical implications, objectives, and lessons learned

This study shows how CBE, within the Ocean i³ and EmPACT i³ project, aligns with the principles of the SDGs proposed by UNESCO (2017), where active learning in real contexts reinforces the acquisition of key skills. As Van den Beemt et al. (2023) point out, the success of CBE lies in its ability to integrate global challenges with local solutions through a cross-subject approach like that implemented in this project involving collaboration between universities, students, and social agents in the region.

Experience backs up the ideas of Nichols et al. (2016) in their three-phase model (engage, investigate, and act), but adds a

critical component: ongoing reflection using logs, as pointed out by Kolb (1984) in his theory of experiential learning, allows students to turn practical experience into significant knowledge. Furthermore, the results match the proposition by Sterling and Scott (2008) concerning the need to move on from traditional approaches to sustainability, as CBE fosters not only technical skills, but also critical thought and social commitment, aspects that Wiek et al. (2011) identify as essential in training for sustainability.

Moreover, the study backs up the ideas of Tilbury (2011) and Barth et al. (2023) about how innovative learning environments must be open and flexible, fostering cooperation between a range of figures, as achieved in the Ocean i³ and EmPACT i³ projects with the participation of local stakeholders. It is also shown that, as argued by Sukackè et al. (2022), the role of the teacher in CBE evolves toward that of a learning facilitator, guiding students to cope with complex challenges without imposing predetermined solutions.

In conclusion, this study validates the potential of CBE as a key methodology for EDS in higher education, in line with the arguments of Leijon et al. (2022) and Gallagher and Savage (2023); but stresses the importance of: (1) structuring systematic processes of reflection, (2) fostering solid alliances in the region, and (3) adapting existing theoretical frameworks to specific contexts. Future research should further explore the long-term impact of these experiences on students' employability and on socio-environmental change in the regions, in line with the recommendation by Evans (2019) concerning the assessment of sustainability skills.

This study describes the process followed to put into practice the CBE methodology in the Ocean i³ and EmPACT i³ learning environments for sustainable development. Environments that go beyond the walls of the university take place in open, living, and permeable spaces, in contact and dialog with the social, economic, and cultural fabric of the region. The steps described and the examples given make it possible to conclude that to construct and put into practice CBE, the following is required:

Participation

By all groups (students, teachers, and social agents) in the spaces generated for dialog, exchange, and face-to-face discussion, from when the challenges are defined to when the results are disseminated. This participation involves attendance and work at cross-border workshops where

- The challenges and their impact are defined.
- Work on the challenge is monitored.
- A shared overview of the impact of the work is built.
- The value of the results obtained is maximized.
- Future lines of action are proposed.

Engagement

Constructing and developing CBE in an EDS environment seeks the interest of those who take part in the community; interest in knowing about and understanding the situation, acting in an informed, structured manner, reflecting on practices and changing/regulating one's own behavior in relation to the issue, situation, etc.

This engagement is reinforced by students spending a week with a body in the Basque Country/Nouvelle-Aquitaine region linked to the challenge on which they are working.

Commitment

To the challenge and all the tasks arising from it, encouragement is given to a responsible attitude to the work on the challenge over time, between one workshop and another, through autonomous and collaborative work in the digital space (*Euskampus* online platform). Also involved is the direct responsibility taken by students for individual work, such as the final degree project, master's dissertation, voluntary practicums, subject course work, and so on, all of which have an impact on the challenge.

Reflection

The CBE process in an EDS environment aims to make students change their perspective on the situation through the critical thought generated by the experience. This involves a restructuring of the way students see the challenge and contribute with their responses (solutions, actions, and so on), above and beyond acquiring knowledge. It is the questioned narrative students build up during their training path in CBE that gives rise to this realization of what they are doing, why they are doing it, why they are doing it, and what sense it makes. A narrative set down in a logbook, which specifies the impact of their participation in this environment on the development of their employability skills.

All this aims to assist the academic educational community in the task of designing and structuring CBE-based teaching and learning processes.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

Ethics statement

Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

IR-R: Writing – review & editing, Project administration, Writing – original draft, Methodology, Conceptualization, Supervision. PG-M: Investigation, Resources, Visualization, Conceptualization, Methodology, Writing – review & editing. EC-I: Writing – original draft, Conceptualization, Resources, Methodology, Project administration. OZ-G: Visualization, Methodology, Writing – review & editing, Conceptualization. AM-U: Visualization, Resources, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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