

Article

# Didactic Strategies to Promote Competencies in Sustainability

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**Abstract:** Higher education is a principal agent for addressing the sustainable development goals proposed by the 2030 Agenda, because of its key mission of knowledge generation, teaching and social innovation for sustainability. In order to achieve this, higher education needs to integrate transversally the values of sustainability in the way of developing the field of management, as well as research, university life and, of course, teaching. This paper focuses on teaching, and more specifically on the didactic strategies considered most relevant for training in sustainability competencies in college students, according to the guidelines commonly accepted by the international academic community. Through collaborative work among experts from six Spanish universities taking part in the EDINSOST project (education and social innovation for sustainability), funded by the Spanish R&D+i Program, in this paper the role of five active learning strategies (service learning, problem-based learning, project-oriented learning, simulation games and case studies) in education for sustainability are reviewed, and a systematic approach of their implementation in higher education settings is presented. The results provide a synthesis of their objectives, foundations, and stages of application (planning, implementation, and learning assessment), which can be used as valuable guidelines for teachers.

**Keywords:** didactic strategies; sustainability competencies; higher education; service learning; problem-based learning; project-oriented learning; simulation games; case studies

## 1. Introduction

The global challenges facing contemporary society call for an increase in strategies and prompt action [1]. Addressing these wicked problems [2] implies the need to observe the system's perspective and complexity [3] as represented in the sustainable development goals (SDGs) approved by the United Nations in 2016 to be achieved in 2030. Thus, less than two key decades are left to facilitate education frameworks for citizenship participation and awareness, and for developing new ways of knowledge production and decision-making with respect to sustainability. Efforts have been made by

universities to commit to, integrate and implement the education for sustainable development (ESD) into policies, institutions and curricula to achieve the SDGs [4–7], which contribute to the development of skills for problem solving such as systemic and anticipatory thinking, critical and creative thinking, capacity for strategy and action, and the collaborative skills of graduates as agents of change for sustainability [8,9].

EDINSOST (education and social innovation for sustainability) training is a Spanish R&D+i funded project aiming to facilitate the training of engineering and education graduates as agents of change through the integration of sustainability curricula in the Spanish University System. This involves fifty-five researchers from ten universities. The project is organized around four specific objectives, namely: (1) to define the sustainability competency map of the participating degrees and establish a framework for incorporating the map into the degree in a holistic way; (2) to validate different didactic strategies for addressing sustainability from a constructivist and community pedagogical approach; (3) to diagnose the status of the sustainability training needs of the teachers of each degree, as well as to develop and test training proposals, and (4) to diagnose the sustainability competency level of current university students and to develop and test training proposals.

Studies show that students achieve better cognitive learning as more community-oriented and constructive-learning pedagogies are applied [10]. Multi-methodological experiential active learning education increases cognitive learning with respect to sustainability, where the interaction with stakeholders increases the effect of the community approach, facilitating the introduction of transdisciplinarity and the endeavour of systemic and critical thinking [10–15].

Pedagogical strategies have been approached in some peer-reviewed articles, emphasizing the relevance of some pedagogical approaches for better delivering ESD in university subjects at both the national and international level [16–23]. A few papers have even looked into the pedagogical approaches and their effects on sustainability competencies [15,24,25], however this research is still considered limited [24]. On the other hand, different competence frameworks for ESD have been compiled, relating to formal and informal learning settings [26]. Frisk and Larson [25] postulate the need to introduce alternative forms of knowledge, i.e., procedural, effective, and social knowledge [15], in order to effectively educate with respect to sustainability, and focused on four competencies, being: systems thinking and an understanding of interconnectedness; long-term, foresighted reasoning and strategizing; stakeholder engagement and group collaboration, and action-orientation and change-agent skills. On their side, Lambrechts et al. [9], provided a list of educational approaches believed to be appropriate for higher education for sustainable development (HESD) and competencies for SD, being: (1) interactive and participative methods (e.g., Socratic method); (2) action-oriented methods; (3) research methods. Later, in a follow up paper of his seminal work on key competencies for sustainable development (systemic, critical, strategic, normative or anticipatory thinking), Wiek et al. [27] presented detailed operationalization approaches for these competencies. In a follow up study, Lambrechts et al. [28], further elucidated the role and importance of research competency and method in acquiring sustainability competencies; as well as more recently [29], the importance of critical and interpretational competencies in relation to sustainability education in the post-truth era is reflected upon.

Finally, Ploum et al. [30] recently presented a validated competence framework for sustainable entrepreneurship, based on the work of Wiek et al [27]. Nevertheless, the challenge remains of defining some guidelines and interdisciplinary general methodologies which are capable of promoting the principles pursued for sustainability, yet flexible enough to adapt to the particularities of each discipline [18], as a starting point or foundation for faculty interested in integrating sustainability into their teaching practice.

Since there is no previous work explaining how to apply pedagogies in the Spanish context of ESD in a systematic way, this work represents an effort in this sense, presenting the EDINSOST project endeavour regarding the most appropriate didactic strategies for sustainability training, analyzed and tested based on the competency map previously defined in the project's first objective.

### 1.1. Education for Sustainability in Spanish Universities

During the decade of education for sustainable development (DESD), between the years 2005 and 2014, some Spanish universities highlighted the need to integrate education for sustainable development as a fundamental aspect for improving the quality of higher education [31]. In this line, it is worth mentioning that reorienting education and learning towards sustainability had the potential to impact the way people think, helping to create a more sustainable future [6], and to deal with problems that affect the community and the natural environment. It should also be noted how the accelerated scientific-technological development requires a change in the educational paradigm, since this development requires more training to engage citizens who can actively participate in public affairs [32]. That is why “the university must be linked to its immediate social environment, and not be an island in the broad and diverse social ocean. It has to insist more on the dynamics of integration in its environment and become one of its driving forces” [16] (p. 65).

In the Spanish higher education system, the first initiatives related to sustainability took place in the mid-90s, focusing mainly on sustainability campus management, specific areas included: waste management and green areas, energy savings and efficiency, and the promotion of sustainable mobility [31].

It was not until 2002 with the creation of the sustainability working group of the Conference of Rectors of the Spanish Universities (CRUE-Sustainability), that the need for curricular sustainability at the national level began to be recognized. The CRUE-Sustainability group produced the document “Guidelines for the introduction of Sustainability in the Curriculum”. It recommends some specific measures, which must be promoted by the competent authorities in the modification of official degrees, to guarantee an education that includes the following sustainability aspects [33]:

- Having an integrated approach to knowledge, procedures, attitudes and values in teaching.
- Promoting work in multidisciplinary and transdisciplinary teams.
- Stimulating creativity and critical thinking.
- Encouraging reflection and self-learning.
- Reinforcing systemic thinking and a holistic approach.
- Training participatory and pro-active people who are capable of making responsible decisions.
- Acquiring awareness of the challenges posed by globalization.
- Promoting respect for diversity and the culture of peace.

Moreover, the aforementioned guidelines specify general criteria for curricular sustainability, such as the competencies that today’s professionals must master, the aspects that must be reviewed in educational processes in order to allow for true curricular sustainability, as well as the characteristics of the institutional commitment from university boards.

Clugston insists on several of these ideas (cited in [34]), stating that the university education of graduates is a fundamental factor in achieving a culture of full sustainability. Also, university students, should acquire a comprehensive understanding of environmental criteria and sustainable values. Therefore, leading higher education towards a culture of sustainability “presupposes a significant change in the current patterns of production, consumption and behaviour, and these changes involve sharing responsibility on a global, community, regional, local and, of course, personal scale” [35] (p. 227).

In addition to the responsibility in the training of professionals with a sustainable vision, as indicated above, the university must be integrated with its immediate environment. Currently there is a disconnection between the university and its immediate environment, mainly due to the fragmentation between teaching, research and outreach functions. Another drawback is the exclusive theoretical framework of student’s training, instead of focusing their training on the application of academic content to real situations of their immediate environment. In the words of Herrero [17], fragmentation prevention and training that addresses problems which are part of the students’ immediate environment can lead to a future problem-solving professional approach. Moreover, this shift in the pedagogical processes’ focus contributes to include the scientific method, through

students' situational analysis of their environment, and an extension of that analysis, based on the attendance of some nearest societal needs, fulfills the objective that students learn to establish, develop and maintain ties with their respective communities.

University social responsibility emerged from the convergence between taking the previous argumentation into account and the fact that universities were involved in research and in the training of the teaching staff in corporate social responsibility, integrating social responsibility into its organizational structure [36]. It refers to the ability of the university to disseminate and put into practice a set of principles and values through the aforementioned functions (Dominguez, 2008, cited in [37]). Through social responsibility, the university is considered part of the community and, from the perspective of social responsibility, a space in which you learn and research, where the solidarity initiatives beginning with the community are a means for students and teachers alike to learn and research [29,38].

With regard to university legislation, the Organic Law 6/2001, of December 21, 2001 (LOU-Ley Orgánica Modificada de Universidades), modified by the Organic Law 4/2007, of April 12, 2007 (LOMLOU- Ley Orgánica Modificada de Universidades), highlight that universities have social service functions, and that due to the link with society and the environment that surrounds them, university education should contribute to the knowledge and development of human rights, democratic principles, and environmental protection, among others [36].

We cannot ignore the "University Strategy 2015" which establishes that universities from the Spanish university system are expected to: (1) search for specialized excellence and a high-value humanistic education in a balanced way; (2) train professional citizens, fostering and developing training in ethical principles and social and solidarity values; in which the parameters of excellence, debate, research and critical judgment are applied to community commitment with the same rigor expected in other spheres of university activity; (3) address the needs of society as a whole and pursue its problems' solution; and 4. train citizens to engage in the activities of their community.

### *1.2. Competencies for Sustainability in the Spanish University System*

The European higher education area introduced into the university system some novelties that were articulated through the Bologna Process. One of the most important, due to the structural changes involved, is to guide the teaching-learning process towards the development of skills [38]. This has been considered as an opportunity for the inclusion of sustainability in the context of Spanish universities [31]. In fact, it is a requirement that frames the Spanish regulation in the new study plans for the process of the European harmonization of higher education [35].

Regarding the competencies for sustainability, there are several definitions [8,25]. The CRUE-Sustainability group defined four transversal competencies [33]:

- SOS 1: Competence in the critical contextualization of knowledge, establishing interrelations between the social, economic and environmental, local and/or global problems.
- SOS 2: Competence in the sustainable use of resources and in the prevention of negative impacts on the natural and social environment.
- SOS 3: Competence in participation in community processes that promote sustainability.
- SOS 4: Competence in the application of ethical principles related to the values of sustainability in personal and professional behaviour.

Undoubtedly, steps have been taken in the Spanish university system to include these competencies in teaching-learning processes, but not enough has been done to teach how to train in these competences [27]. Thus, teaching based on these competencies for sustainability is a new challenge for university teachers, who must move towards a partially unknown scenario.

In the current literature, initiatives on the integration of sustainability in the university curriculum can be found related to environmental management and eco-campuses [39], teaching in the field of engineering [40], and teacher training [41]. In addition, initiatives can be found in concrete experiences,

such as on service learning [42], through interviews and focus groups with students [43], through the use of portfolios [44], or based on real problems [45].

## 2. Methodology

In the first phase, a process of sharing and reflection was carried out, with the purpose of attaining common reference points allowing for the construction and sharing of meanings, and an agreement on terminology given the polysemic nature of the terms used. The process involved a group of ten researchers, seven of them from an education background and three from an engineering background. It was run by means of virtual meetings and two face-to-face workshops conducted during the first year of the EDINSOST project (project implementation period from November 2016 to June 2019). In this phase the authors agreed on using the socio-critical methodology, which assumes a critical realistic ontology and a transforming dialogical methodology, to frame the pedagogical approach. In this sense, all the Edinsost project researchers were rebuilding and reconstructing their knowledge through planning-action-observation-reflection processes in their natural classroom settings, thus investigating their own practices with the intention of understanding and improving them. From this approach, researchers critically analyzed reality, and assumed a cyclical process of dialogue and negotiation through successive encounters (both face-to-face and virtual), until they reached agreement on a consensual proposal for the systematization of teaching strategies that they estimated to promote competencies in sustainability [46–48]. Within this framework, pedagogical strategies for sustainability were referred to as the set of procedures that are negotiated and used in a reflexive and flexible way to promote and evaluate teaching and learning processes. Based on the authors' experience and expertise in their application, five pedagogical strategies were selected for validation, namely: service learning, problem-based learning, project-based learning, simulation, and case studies.

In the second phase, the authors headed a group of experts in each pedagogical strategy through an iterative process, whereby the main features representing each pedagogical strategy were defined (see Table 2. General features, Section 4.1) and categorised as follows:

- Justification of the pedagogical strategy for sustainability
- Challenges for the students
- Modality of work
- Teacher's role (tutor or facilitator)
- Didactic planning phases:
  1. Preparation phase
  2. Execution phase
  3. Evaluation phase

The third and final phase involved the definition of the steps required to reach a clear and precise didactic planning of the pedagogical strategy. A workshop was held for each pedagogical strategy, where the information to be collected by the faculty community was gathered and structured in a comparable and useful way, such that it served as the basis for further work on the definition of the pedagogical strategies' execution phases, which are presented in Table 1.

**Table 1.** Information required for defining the didactic planning phases of the pedagogical strategies.

Didactic Planning Phases	Pedagogical Strategies		
	Teaching Strategies	Learning Strategies	Assessment Strategies
Phase 1: Definition and Planning	Presentation, definition and delimitation of the strategy		
Phase 2: Monitoring and Execution	Process presentation, monitoring and justification. Action on the proposal. Report presentation		
Phase 3: Assessment	Evaluation of deliverables and competencies. Closing activities		

The required information was later refined and defined in an iterative process until the completion of Tables A1–A5.

Further steps will involve performing two pilots for each strategy in the different contexts (education, engineering, environmental and economic sciences), where the proposed methodological framework will be applied through the different pedagogical approaches and assessed by means of pre-post questionnaires and focus groups.

### 3. Description of Pedagogical Strategies for Sustainability Education

In this section we describe the main characteristic of five active learning pedagogical strategies and how those can improve sustainability education.

#### 3.1. Problem Based Learning

##### 3.1.1. Definition

Problem based learning (PBL) is a teaching and learning strategy in which students in small groups and under the supervision of a tutor, learn to search and analyse the information necessary to solve a problem through determining the most adequate solutions. This problematic situation allows the students to develop explanatory hypotheses, and to identify learning needs to better understand the problem and to reach the established learning aims [49].

The PBL is understood as a philosophy, as a way of understanding education, and as a learning style. As Engel [50] states, 21st century students will be active professionals in the coming decades, where they will have to adapt to a complex and changing society, and to develop specific lifelong learning and self-directed learning skills. In PBL the resolution of the problem is not the priority learning aim [51]. Instead, two key aims are emphasized, namely students need to be able to critically analyse the information and data obtained from diverse sources and resources, and to learn how to learn from the challenges emerged in the resolution process. In this context, the tutor acts as a learning facilitator [52].

PBL activates the exercise and development of a set of cognitive, interpersonal and instrumental skills clearly geared towards working on a real situation close to professional practice [53]. In summary, the main mission of PBL should be to provide the future professional with a training that enacts mastery in intellectual problem-solving tools and skills.

The distinctive features of PBL are: (1) emphasis on students' responsibility for their own learning, (2) transdisciplinary or multidisciplinary nature of problems, (3) theory and practice are inseparable, (4) focus on the process rather than in the products obtained, (4) the teacher moves from being an instructor to become a facilitator of learning, (5) focus in self-evaluation and peer evaluation processes rather than in the learning outcomes outlined by the teacher and (6) emphasis on learning interpersonal and communication skills [54].

##### 3.1.2. Theoretical Basis

PBL is based on the constructivist theory, in which knowledge is the result of the learning process in which the student participates actively. PBL integrates two educational theories: the Piagetian theory [55], which emphasizes the conceptual change and psychological processes involved in intellectual learning and development, and the Vygotskian theory, which focuses on the social relations and the role of the education in the process of knowledge generation [56].

##### 3.1.3. Goals

The main goals of PBL are to: (1) give relevance (social, professional, academic) to learning situations, (2) involve and strengthen the student's role in their own learning, (3) increase autonomy in learning, (4) create situations in which a socio-constructivist approach is required, (5) facilitate

the self-confidence of the student in learning from complex problems, (6) develop competencies for autonomous learning, and (7) develop strategies and tools for inquiry and critical thinking processes.

#### 3.1.4. Phases

The PBL process is based on presenting, defining and delimiting the problem through consensus; identifying the learning needs (the students make a diagnosis about what they must understand in order to solve the problem); developing an explanatory hypotheses; planning the solving process; searching for and analysing the information, and proposing adequate solutions to the problem. Students must prepare a work plan and a final report, which will be presented to the rest of the students.

#### 3.1.5. Examples

Several experiences of PBL in higher education focus on students investigating real sustainability problems, considering their different dimensions such as environmental, social, economic, as well as diverse political, international and cultural perspectives. PBL is used with engineering students to solve socio-environmental problems applied to their discipline and their future professional practice [57]. In social sciences, business management and economics students work in collaboration with companies and local entities to improve the sustainability of organizations, including waste management, renewable energies, and the formulation of action plans [58]. In transdisciplinary university projects based on PBL, students work together in the sustainability of the campus and the university community, for example to improve the environmental behaviour of students, the energy efficiency of university buildings, waste management, or the promotion of organic products and healthy habits amongst the community [59,60].

### 3.2. Project Oriented Learning

#### 3.2.1. Definition

Project-oriented learning (POL) (also known as project-based learning) is a teaching and learning method, the predecessors of which are the fathers of constructivism: Vygotsky, Bruner and Piaget. Starting from constructivism, where learning is built as an interaction between personal experiences and structures, students can develop an entire network of mental structures, allowing them to establish rational and meaningful relationships with the environment and the society. In other words, project-oriented learning is an essential tool for the integrated and dynamic implementation of knowledge, as well as for the development of students through the search for solutions to real and current problems. Students are placed at the center and they are the protagonists of their own learning, which allows a great empowerment.

#### 3.2.2. Theoretical Basis

The project method is a genuine product of the progressive education movement in the US. It was described in detail and definitively delimited for the first time by William Heard Kilpatrick in his essay "The Project Method" (1918). This author had already argued that theoretical learning needed a practical part to be based on, insisting that the important thing is not so much the result, but the process and the acquisition of skills and abilities [61]. In line with this idea, as [19] summarized, the European Higher Education Area (EHEA) –created 18 years ago–also opted for the change from an educational system based solely on instructional teaching to a system based on active learning, placing the student at the center of the educational process. This change in the student's role was developed from the recognition that traditional instruction did not prepare students to deal with today's changing nature of work and society [62,63]. In order to assume this paradigm shift, the central idea of this learning strategy is to link theory with practice, solving real-life problems related to students' future professional contexts [64]. Students are encouraged to take responsibility for their own learning experience and to make the leap from passive learning patterns to more active ones [65].

### 3.2.3. Goals

Through this active teaching-learning methodology, the following general objectives are pursued: (1) structure the knowledge to apply it to real contexts, (2) develop effective reasoning processes, (3) develop self-directed learning skills, (3) encourage self-learning, (4) develop the ability to work in groups and collaborative learning, (5) develop the ability to communicate orally, (6) foster a community (teachers and students) of practice, and (7) use ICT, the Internet and Web 2.0 tools actively.

### 3.2.4. Phases

POL places the student at the center of the learning process, using an approach that must be motivating to them and that encourages the exchange of ideas, creativity and collaboration, which consists of three phases:

1. Definition/Planning/Research
2. Implementation/Production
3. Evaluation/Self-evaluation

This methodology revolves around the dialogue that needs to be established throughout its implementation, and it is encouraged as follows:

- In the definition, planning and research phase, once the subject has been selected, the students have to explain what they know about the issue, what they should know and how they are going to achieve that knowledge (learning objectives). Likewise, during this phase, tasks with deadlines must be assigned to the different members of the group.
- In the second phase, implementation and production, the students must share their progress, reflect on it and modify, eliminate or add whatever they consider fit after collaborating with other students. Thus, all together, they will decide on the design and final form of the product to be prepared and on when, who and how it will be tested.
- Finally, at the evaluation and self-evaluation, students present the final product resulting from the development of their project. Teachers evaluate it, but the students also perform a self-evaluation exercise in which they reflect on their achievement (or lack thereof) of the objectives initially set.

### 3.2.5. Examples

There are many examples within the literature that describe the use of this methodology in the framework of higher education, and its cross-curricular integration is observed in many different degrees. A course developed for the teaching of computer science within the Faculty of Exact Sciences at the Universidad Nacional del Centro de Buenos Aires, based entirely on the development of projects that respond to real problems of business training [66], is one of the examples highlighted. The work developed by Leal et al. [19] is also relevant, as it shows the role of this methodology in working on sustainability within the University framework in an integrated way. Likewise, it seems to be a successful methodology in the preparation of final projects for Masters degree programs. Some Universities have even created a center for project oriented/based learning, where guidance and information are provided for the implementation of this methodology at any level within higher education [67].

## 3.3. Service-Learning

### 3.3.1. Definition

Service-learning (S-L) is an experiential teaching and learning strategy that allows learning and demonstrating competencies in action through the planning and implementation of projects that respond to real needs of the context. Learning is linked to the service that, in turn, favours academic development through social action. Its implementation implies the active participation of students and

coordination between collaborating institutions, with the aim of integrating learning objectives and service objectives that favour the academic, social and personal development of students who learn to take action for the benefit of the community [68].

S-L, also referred to as “community-based learning”, is an innovative pedagogical approach that integrates meaningful community service or engagement with the curriculum, and offers students academic credit for learning that stems from active engagement in the community, and provides the community with an opportunity to address real problems. The strategies of reflection and experiential learning sustain the learning process, and the service is linked to the academic discipline [69] (p. 5).

There are five conditions that make it possible to identify a S-L practice: (1) addressing genuine community needs, that are integrated into the curricular objectives that favour critical understanding and the development of moral reasoning in students; (2) interpersonal relationships among students, wherein the community entities and professionals with whom they interact are characterized by recognition, mutual respect and symmetry; (3) tasks have a collaborative character and allow time for individual reflection; (4) an analysis of the values and counter values of the institutional context in which they are developed is required; and (5) all participants take part in the evaluation [70,71].

### 3.3.2. Theoretical Basis

S-L is nourished by various educational, cognitive and moral development theories. Among them we can highlight experiential education [72], the theory of cognitive development [73], Bruner’s discovery learning theory [74], the pedagogy of hope by Freire [75], Kohlberg’s theory of moral development [76], the influence of sociocultural learning for the development of the individual [56] and the theory of multiple intelligences [77]. As a pedagogical movement, it is also close to collaborative learning and situated learning.

### 3.3.3. Goals

There are basically three goals: (1) to improve the quality of the learning defined in the curriculum by allowing the transfer of knowledge to solve real and complex problems with a social justice approach, and to fulfill other learning goals that are difficult to achieve within the classroom; (2) to engage on community service taking action, especially towards the most disadvantaged people and groups, by responding to a real need that is perceived as such by them; and (3) to train students in values and transversal competencies such as participation, social responsibility, entrepreneurship, ethical sense and solidarity [78].

As a didactic strategy, it not only improves the quality of education, but also engages students in social action with a focus on social justice, while representing a response from the university to the challenges facing the world [79]. The objectives of sustainable development remind us that these challenges are related to poverty, hunger, health and well being, education, gender equality, water, climate, ecosystems and peace [80].

### 3.3.4. Phases

S-L projects follow a systematic methodological process [81] that is similar to that of any project: planning, implementation and evaluation [81–83]. These three nuclear processes include preparing the project with the specific group of students based on the group’s motivation, identifying the social need, defining the service to the community and the link with the curriculum, establishing links with other entities, considering the impact of the project on the student and on the community, disseminating the project and celebrating.

### 3.3.5. Examples

S-L experiences are varied, since reality is also diverse. Two examples are described as follows: (a) mining and energy engineering students developed a project to collaborate with young people at risk of exclusion in a professional qualification program, by which they performed electrical inspections

in old apartment buildings to improve energy efficiency and prevent possible electrical risks; (b) agricultural engineering students in the S-L project “Horticultural Crops” produced vegetables to cover the needs of a soup kitchen and distributed bags of food to people in need.

### 3.4. Case Study

#### 3.4.1. Definition

The case study is a strategy which presents a situation that contains one or several problem areas about which the subject must discuss, analyse, propose solutions, answer some questions, etc.

This strategy facilitates, according to [84], the key to the formative process of a student, which lies in the fact that the learning process is carried out prioritizing fundamentally the autonomous study and work of the subject himself. The case study can be considered as an individual and/or collective activity, producing different learning opportunities.

The case study is designed based on a real situation that is significant to the student’s education, from a personal and/or professional perspective. It intends to make him consider and devise an action plan, the resolution of a problem, a multifactorial analysis, positioning and implication.

Its approach can be very simple, such as a problem’s description, and it can be complemented by extension and deepening documentation and the possibility that the participant inquire into other sources of information.

Note that case studies such as simulation games can be combined with other strategies or methods, such as problem-based learning or project-oriented learning, as part of an alternative methodological approach, focused on self-learning [85]. In turn, the case study characterizes what we identify as cooperative learning [86], whereby an implementation is sought out in a structured way from the learning of a group of students.

There are different aspects that define a case study practice: (1) real socio-environmental conflicts are addressed; (2) the existing interrelations between factors, contexts, processes, subjects, institutions and entities are deepened; (3) there is a problem’s analysis; (4) disciplinary and meta-disciplinary contents are brought into play; and (5) critical reflection is promoted.

#### 3.4.2. Theoretical basis

Constructivism and meaningful learning taken from the perspective of their predecessors, as the case of Piaget, Ausbel, Bruner or Vygotsky, [85] serve as psychological and pedagogical support for this strategy. Thus, the students are the protagonists, as they participate in the construction of knowledge from the cognitive, procedural and attitudinal dimensions set in motion when facing a case study.

#### 3.4.3. Goals

The goals are basically the following: (1) learn to solve situations by putting knowledge into practice; (2) encourage critical and complex thinking; (3) involve participants from an ethical perspective; (4) serve as tool towards awareness or evaluation of the work done.

#### 3.4.4. Phases

Firstly, the case study is designed, adapted or raised based on a thematic or significant problem, then presented in the classroom in the form of a file, documentary, etc. Subsequently, questions are raised about the situation or about the outcome of the situation, always aiming for both the student’s deliberation and knowledge application. Thereafter, the questions are addressed either by the entire class or in groups. Finally, the group-class shares all considerations, alternative itineraries to address the case study and contributions that can enrich different students’ approaches.

### 3.4.5. Examples

The range of possibilities is vast. Case studies can be used to work through the socio-emotional aspects of mediation and the resolution of conflicts between people, to approach the awareness and possible resolution of a conflict, or simply to delve into a topic.

## 3.5. Simulation

### 3.5.1. Definition

The simulation (role-playing games or simulation games) is a didactic strategy that facilitates an experiential learning, given that the protagonists attempt to reproduce the context as close to reality as possible, characterizing the spatial elements and the subjects. The simulation can be understood from the concept of dramatization, as an expression of feelings and representation of events, but above all it has an important component of reflection on the subjects themselves. This learning, which occurs in first person and is shared with the group, develops communication skills, group work, cognition and metacognition related to the chosen theme. It develops in the classroom, but other settings that provide a greater sense of realism can be used, so that the reproduction of reality has a creative dimension that facilitates the contribution of each individual or group.

Simulation is very useful for analyzing socio-environmental conflicts in all their dimensions, including both historical and procedural and the institutions and subjects' roles. As a common denominator, it provides a general knowledge about the context, and can serve as a relevant resource for social and educational deepening into the problem. Additionally, the simulation games can even serve to prepare people to respond to similar situations to those being simulated.

According to López Torres et al. [20], "students have in general, more difficulty approaching sustainability from its holistic and transversal dimension in which the other dimensions interact: social, environmental, economic, political, educational and cultural". The simulation, being a didactic strategy in which all the dimensions interact, serves as an example of the learning process of integrated knowledge.

It is extremely difficult to analyze a system in its organization and operation, taking into account the number of factors that interact in daily life. Teaching resources to undertake this endeavour are scarce on a real scale, with a complexity level beyond that which can be covered by the group class, but the simulation offers us this opportunity [21].

Aspects characterizing a simulation practice are: (1) real socio-environmental conflicts are addressed; (2) the interrelations between factors, contexts, processes, subjects, institutions and entities are examined in depth; (3) there is an analysis of the problem, which spans from the identification of the underlying conflicts, the role of the subjects, the situations of violence (direct and indirect), to the construction of alternative solutions; (4) disciplinary and meta-disciplinary contents are put into play; and (5) there is no room for leaving participants indifferent, promoting a critical awareness.

### 3.5.2. Theoretical Basis

Simulation as a game and as a didactic strategy is supported by previous research [87–89] investigating the historical genesis of the simulation game, as well as Ortega [90] who considered the game as a laboratory where participants reconstruct the world in which they live to understand it. In this same sense, Wildlöcher [91] revealed the importance of the game as an element of connection of the child, adolescent, or young person with the real world. In the field of education, we have the substantial contributions of Sureda [92], Ballenilla [21] and Ruiz-Morales [20,93], which deepen into the simulation game as a didactic strategy to apply in the field of environmental education and sustainability.

### 3.5.3. Goals

The goals of the simulation game are as follows: (1) learn from the simulation of a socio-environmental reality through action; (2) promote critical and complex thinking, based on the analysis of what is experienced in the classroom; (3) involve the participants from an ethical perspective; (4) serve as awareness or evaluation of the work done or a starting point to examine a topic; (5) develop capacities for critically appropriate action.

### 3.5.4. Phases

Professionals who use and design the published simulation strategies agree to give importance to the first moment of the presentation of the problem, plot or starting situation, as well as to the role played by the facilitator with regard to dynamics. The characterization of the protagonists is carried out when preparing the staging, and, if possible, the context where the simulation takes place. Once the simulation is developed, an evaluation that provides for a closure of the reflection process is fundamental. In addition, some sophisticated dynamics introduce video recordings, photography and the “observers” figure, to deepen the evaluation process. Furthermore, the subjects’ role can be analysed when addressing the role of each person in the group and the way in which they organize themselves to face conflicts.

### 3.5.5. Examples

There is a wide range of examples, as in working socio-emotional aspects for the mediation and resolution of conflicts between people, as an approach for the understanding of a conflict such as the breakage of the Aznalcollar dam (accident that affected the Doñana National Park in 1996), the north-south relations, the neighbourhood movement in the construction of Miraflores Park (socio-historical process of citizen participation 1986–2016), and the elaboration of an integral community action program in “Su Eminencia” (disadvantaged area in the city of Seville ) [94].

## 4. Results. Methodological Proposal to Apply Pedagogical Approaches for Sustainability Education

This section, a table containing the explanation of the basic general characteristics representing each of the five pedagogical strategies is presented, addressed in an iterative process. Further, each strategy is further described by the information about each execution phases Appendix A.

### 4.1. General Features

The following table (Table 2) summarises the characteristics that the didactic strategies must address to catalyze the acquisition of competencies in sustainability. For each strategy, the following items are proposed: justification; challenge for students; work mode; role of the teacher, and didactic planning phases (preparation, execution, evaluation).

### 4.2. Execution Phases of the Five Learning Strategies

Specific tables are presented in the Appendix A, for each of the three considered execution phases (i.e., Phase 1: Definition and Planning; Phase 2: Monitoring and Execution; Phase 3: Assessment), presenting a compilation of teaching, learning and assessment strategies that can be applied in their respective learning settings, namely problem-based learning (Table A1); project-based learning (Table A2); service learning (Table A3); case studies (Table A4); and simulation (Table A5).

**Table 2.** Main characteristics representing the five selected pedagogical strategies, mentioning: Justification of the pedagogical strategy for sustainability; Challenge for the students; Modality of work; Teachers' role; Preparation phase; Execution phase; Evaluation phase.

Didactic Strategies	Problem-Based Learning	Service Learning	Simulation	Case Studies	Project-Oriented Learning
<b>Justification</b>	Learning process, research and reflection carried out by the students to solve a real or fictitious problem posed by the teacher. It focuses on the practical application of content and the research of solutions	Engages students in learning through a service to the community with a focus on justice and social and/or environmental responsibility, which produces a reciprocal benefit	Exposes participants to the resolution analysis of socio-environmental conflicts connected with real contexts by means of designing, investigating, reflecting, acting and evaluating	Analyses socio-environmental realities providing different points of view, from a subjective and intersubjective perspective, to develop decision-making processes that lead to the construction of transformative action proposals	Development of learning based projects; complex tasks, based on a question, problem or challenge engaging students in the design and planning of resolution strategies. Implies decision-making and development of investigative activities. Gives students the opportunity to work relatively independently for long periods of time. Concludes with a presentation of the solution or final product
<b>Challenge for students</b>	Confronts students with the challenge of self-directed learning to solve problems related to sustainability	Engages students with service to improve the understanding of academic concepts through applied learning, and promotes sustainable development and social justice as a social and political reform instrument	Involves students in the representation of roles of socio-environmental conflict situations, bringing them closer to the necessary knowledge and measures, from a personal and professional point of view	Makes students analyze one or several situations and respond to different questions in the field of sustainability	Requires students to plan, create and evaluate a project that responds to the needs raised in a certain situation, preferably real (in this case, related to sustainability)
<b>Modality of Work</b>	Individual and collaborative	Active, participatory and reflective through collaboration in a project, with some individual tasks	Fundamentally collaborative dynamics, except for the individual or group report that can be online	Individual and collaborative	Mainly collaborative, with some individual tasks
<b>Teacher's Role</b>	Tutor, facilitator	Tutor, facilitator	Tutor, facilitator	Tutor, facilitator	Tutor, facilitator
<b>Preparation phase</b>	1.1. Introduction of the problem to the students 1.2. Definition and delimitation of the problem in a consensual manner	1.1. Sketch of the idea 1.2. Relationship with entities 1.3. Project planning	1.1. Choice of the topic and socio-environmental problems by the classroom community (teacher/students) 1.2. Search and choice or construction/Simulation Game adaptation	1.1. Choice of the topic and socio-environmental problems 1.2. Search and choice or construction/Case Study adaptation	1.1. Analysis of the state of art 1.2. Definition and delimitation of the initial project proposal by consensus 1.3. Analysis of initial proposals: detection of difficulties and information needs
<b>Execution phase</b>	2.1. Follow-up of the resolution process 2.2. Presentation and justification of possible solutions 2.3. Choice of the optimal solution 2.4. Preparation and presentation of the final report	2.1. Perform the service 2.2. Relate to the people and entities of the environment 2.3. Register, communicate, and disseminate the project 2.4. Reflect on the learning of the intervention.	2.1. Analysis of ideas and conceptions about the chosen problem 2.2. Text composition of the educational and historical reality, context, etc. 2.3. Distribution of roles including observers appointed by the teacher, without knowledge by the rest of the class group 2.5. Development of the Activity	2.1. Working document with questions about the problem 2.2. Answers of the questions individually 2.3. Sharing in small groups, with possibility of intergroup interaction	2.1. Preparation of the project proposal 2.2. Follow-up contrast and debate of the ideas included in the project 2.3. Preparation and presentation of the project report
<b>Evaluation phase</b>	Process of hetero-evaluation of sustainability competencies	Ensemble evaluation	Hetero-evaluation dynamics	Hetero-evaluation dynamics (individual and group)	Process of hetero-evaluation of sustainability competences

## 5. Discussion and Conclusions

The initial result of the EDINSOST project was the sustainability competency map for higher education and engineering degrees [95]. From this starting point, to enable the development of these competences, course coordinators would profit from assistance with the implementation of the pedagogical strategies in the classroom. In this sense, future graduates' qualifications in sustainability will not be restricted to a simplistic communication of the planetary problems society faces. Rather, they will include the ability to design and manage new frameworks in which they find real-life problems intended to be solved. This calls for a diverse array of approaches in order to prepare students to deal with the complexity and uncertainty of sustainability issues [29] under transdisciplinary and multi-methodological active learning perspectives, which have been found to increase cognitive learning with respect to sustainability [29,96].

University teachers may find it challenging to teach their courses based on these competencies for sustainability, when it means to moving towards a partially unknown scenario, with few methodological proposals for the inclusion of sustainability in the university field [97], and even more so when the home institution incentives are not aligned with the pursuit of innovative pedagogies [27].

Additionally, in the process of developing key competencies for sustainability, various and multifaceted contexts have to be created in formal settings (while informal learning offers these per se) [26]. Therefore, the coordination and alignment of subjects across the curriculum becomes central [27] and pedagogical strategies within them, in this sense, the design of courses to promote sustainability competencies, is not necessarily more difficult to create, but necessarily implies some constraints associated with the problem-based, solution-oriented and transdisciplinary work that has to be done [27].

With the aim of facilitating and improving the way that didactic strategies are used, this paper provides guidelines for applying five pedagogical strategies within the Spanish higher education system, methodologically going beyond the application of a concrete strategy, towards an organization both in the way of working with the contents, as in the work completed in the classroom, the role of students, and of the teacher. A comprehensive framework has been developed to apply problem-based learning, project-oriented learning, service learning, simulation and case study didactic strategies to the different areas of education, engineering, environmental sciences and economic sciences.

Previous research has called for an agenda with respect to competence acquisition, investigating among other topics the effectiveness of the learning processes, course design and the implementation and returns of the competencies of sustainability on current learning approaches [24,25], recognizing the need for a continuous review of the application, evaluation, and adaptation of the competence frameworks to assure a sustainable vision [25]. In this sense, further work within the framework of the EDINSOST project will look into the different pedagogical approaches, in order to acquire the competencies in the EDINSOST framework. Specifically, two pilots for each strategy will be performed in the different contexts of education, engineering, environmental sciences and economic sciences, where the proposed methodological framework will be applied through different pedagogical approaches and assessed afterwards.

The outcomes from the application of the framework across the different programmes [27], universities and fields of knowledge, would certainly help to generate insights on how to better support faculty in the delivery of sustainability competencies. Universities will also hopefully learn together how to support teachers in this essential task.

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## Appendix A

Table A1. Execution Phases of the Problem-Based Learning Strategy.

Execution Phases of the Problem-Based Learning Strategy	Teaching Strategies	Learning Strategies	Assessment Strategies		
	Techniques/Individual or Group Activities	Learning Activities	Individual Competence Evidences	Group Competence Evidences	Assessment Instruments
Phase 1: Definition and Planning 1.1 Problem Presentation 1.2 Definition and delimitation in a consensual way	<ol style="list-style-type: none"> <li>1) Questionnaire of previous ideas</li> <li>2) Individual readings</li> <li>3) Brainstorm on the problem and debate</li> <li>4) Presentation of proposals</li> <li>5) Work in groups for the definition and delimitation of the problem</li> <li>6) Identify learning needs</li> </ol>	<ol style="list-style-type: none"> <li>1) Brainstorming</li> <li>2) New ideas characterization and contrast</li> <li>3) Group proposal preparation</li> <li>4) Criticism and reflection to detect knowledge needs</li> <li>5) Development of the situational diagnosis</li> <li>6) Systematic list of problem analyses</li> </ol>	<ol style="list-style-type: none"> <li>1) Questionnaire</li> <li>2) Reflection script</li> <li>3) Group participation</li> <li>4) Problem delimitation (conceptual map)</li> </ol>	<ol style="list-style-type: none"> <li>1) Initial work proposal</li> <li>2) Group proposal</li> <li>3) Situational diagnostic</li> <li>4) Systematic list of problem analyses</li> </ol>	<ol style="list-style-type: none"> <li>1) Observation script</li> <li>2) Rubric for proposals</li> <li>3) Situational diagnosis (conceptual map)</li> <li>4) Hypothesis proposal</li> <li>5) Systematic list of problem analyses</li> </ol>
Phase 2: Monitoring and Execution 2.1. Process monitoring 2.2. Presentation and justification 2.3. Solutions choice 2.4. Final report	<ol style="list-style-type: none"> <li>1) Search and learn information</li> <li>2) Read and analyse of documentation</li> <li>3) Information contrast</li> <li>4) Reports preparation</li> <li>5) Practical workshops</li> <li>6) Group discussions and feedback</li> </ol>	<ol style="list-style-type: none"> <li>1) Searching new information</li> <li>2) Analysis, organization and synthesis of new information</li> <li>3) Establishment of the working plan</li> <li>4) Final report preparation</li> <li>5) Generation of possible solutions</li> <li>6) Group information debate</li> </ol>	<ol style="list-style-type: none"> <li>1) Students participation in class and in tutorials.</li> </ol>	<ol style="list-style-type: none"> <li>1) Working plan</li> <li>2) Researching report</li> <li>3) Decision making matrix</li> <li>4) Solutions report</li> </ol>	<ol style="list-style-type: none"> <li>1) Working plan</li> <li>2) Researching report</li> <li>3) Solutions report</li> <li>4) Assessment rubrics</li> <li>5) Reflexive diary</li> </ol>
Phase 3: Assessment 3.1. Hetero-evaluation of competencies 3.2. Closure	<ol style="list-style-type: none"> <li>1) Self-assessment activities</li> <li>2) Co-evaluation and aggregate assessment</li> <li>3) Final report presentation</li> </ol>	<ol style="list-style-type: none"> <li>1) Criticism and reflection on the problem solving process</li> <li>2) Writing and presentation of final report and results</li> <li>3) Organization, synthesis and solution proposals presentation</li> <li>4) Final report preparation</li> </ol>	<ol style="list-style-type: none"> <li>1) Self-assessment</li> <li>2) Reflective diaries</li> <li>3) Portfolio</li> <li>4) Oral presentation</li> <li>5) Practical exam (application to other similar problems)</li> </ol>	<ol style="list-style-type: none"> <li>1) Written report</li> <li>2) Co-assessment</li> <li>3) Peer assessment</li> <li>4) Final report</li> </ol>	<ol style="list-style-type: none"> <li>1) Final presentation with solution proposals</li> <li>2) Self-assessment rubric</li> <li>3) Reflexive diary</li> <li>4) Peer assessment rubric</li> <li>5) Oral presentation rubric and final product presentation rubric</li> <li>6) Tutor assessment</li> </ol>

**Table A2.** Execution Phases of Project-Oriented Learning Strategy.

Execution Phases of the Project-Oriented Learning Strategy	Teaching Strategies	Learning Strategies	Assessment Strategies		
	Techniques/Individual or Group Activities	Learning Activities	Individual Competence Evidences	Group Competence Evidences	Assessment Instruments
Phase 1: Definition and Planning 1.1 Initial project proposal development 1.2 Initial proposals analysis	1) Previous ideas questionnaire 2) Individual readings 3) Discussion on the first ideas expressed 4) Proposals presentation 5) Feedback on the proposals	1) Retrospect of ideas and organization of knowledge 2) Characterize new ideas 3) Contrast expressed ideas 4) Prepare group proposal 5) Reflect critically to detect knowledge needs	1) Questionnaire 2) Reflection guide 3) Participation	1) Proposals analyses 2) Formulation of improvement needs	1) Observation guide 2) Rubric for proposals
Phase 2: Execution 2.1. Final proposal elaboration 2.2. Contrast and discussion of the final reports	1) Initial knowledge questionnaire 2) Documents reading 3) Information contrast 4) Develop concept maps 5) Practical workshops 6) Prepare final reports 7) Presentation closure (teacher) 8) Feedback and contrast between the initial proposals and the new ones	1) Memory of ideas and knowledge organization 2) Access new information 3) Analyse, organize and synthesize new information 4) Review original proposal and prepare final report 5) Reflect critically on the changes introduced	1) Participation in class and in tutorials 2) Initial knowledge data (from the initial questionnaire)	1) Conceptual Maps 2) Reports 3) Improvement proposals	1) Observation guide 2) Rubric for Conceptual Maps 3) Rubric for Reports
Phase 3: Assessment 3.1. Project presentation	1) Final project presentation 2) Assess the impact of the project's strengths and weaknesses	1) Organization, synthesis and evidence of the knowledge elaborated	1) Class participation	1) Final proposal	1) Assessment rubric 2) Final product presentation

**Table A3.** Execution Phases of Service-Learning Strategy.

Execution Phases of the Service Learning Strategy	Teaching Strategies	Learning Strategies		Assessment Strategies	
	Techniques/Individual or Group Activities	Learning Activities	Individual Competence Evidences	Group Competence Evidences	Assessment Instruments
Phase 1: Diagnosis and Planning 1.1 Draft elaboration 1.2 Relationship with entities 1.3 Joint project planning	<ol style="list-style-type: none"> <li>1) Investigate social needs, context and beneficiaries</li> <li>2) Define Social challenge</li> <li>3) Establish academic learning goals</li> <li>4) Identify partners for the project</li> <li>5) Establish agreements</li> <li>6) Define pedagogical aspects</li> <li>7) Define organizational aspects</li> </ol>	<ol style="list-style-type: none"> <li>1) Investigate the social needs and of the characteristics of the situation, context and beneficiaries</li> <li>2) Communication with entities and social agents</li> <li>3) Apply the knowledge to satisfy the detected needs</li> </ol>	<ol style="list-style-type: none"> <li>1) Competency pre-test questionnaires results</li> <li>2) Diagnostic results (initial evaluation)</li> <li>3) Students participation level in the preparation phase tasks</li> <li>4) Annotations and individual reflection field diaries</li> <li>5) Learning contents collected in the personal portfolio contents</li> </ol>	<ol style="list-style-type: none"> <li>1) Results of the focus groups and the collective reflection on the compliance degree with the expectations and the proposed goals</li> <li>2) Materials generated for the project</li> <li>3) Materials generated for the project dissemination</li> <li>4) Service assessment and social objectives achievement</li> <li>5) Academic learning assessment</li> </ol>	<ol style="list-style-type: none"> <li>1) Field diary (initial diagnostic observation guideline)</li> <li>2) Competency Pre-test questionnaire</li> <li>3) Experience report with answers to questions</li> <li>4) Portfolio (Rubric of pedagogical and organizational aspects)</li> <li>5) Directed debates</li> </ol>
Phase 2: Execution 2.1 Preparation 2.2 Execution 2.3 Closure	<ol style="list-style-type: none"> <li>1) Preparation with the group of students analysing motivation, expectative, prior knowledge and possible prejudices</li> <li>2) Service execution with the environment collaboration</li> <li>3) Individual and group reflection on learning</li> <li>4) Service registration and learning</li> <li>5) Final reflection of the project</li> </ol>	<ol style="list-style-type: none"> <li>1) Fulfilment of service to the community</li> <li>2) Reflection tasks about the service performed, values involved, skills developed and acquired learning</li> <li>3) Preparation and execution of project dissemination</li> <li>4) Field diary elaboration</li> </ol>	<ol style="list-style-type: none"> <li>1) Formative assessment by teachers, students and community partners</li> <li>2) Student participation level in the Service Learning project execution tasks</li> <li>3) Annotations and individual reflection in the field diary</li> <li>4) Personal Portfolio content</li> <li>5) Individual contribution to the focus groups</li> </ol>	<ol style="list-style-type: none"> <li>1) Results of the focus groups and the collective reflection on the compliance degree with the expectations and the proposed goals</li> <li>2) Materials generated for the project</li> <li>3) Materials generated for the project dissemination</li> <li>4) Service assessment and social objectives achievement</li> <li>5) Academic learning assessment</li> </ol>	<ol style="list-style-type: none"> <li>1) Field diary</li> <li>2) Assessment questionnaire of the ApS formative experience by teachers, students and community partners</li> <li>3) Portfolio</li> <li>4) Directed debates</li> </ol>
Phase 3: Assessment 3.1. Multifocal assessment from different perspectives	<ol style="list-style-type: none"> <li>1) Evaluation of the participants</li> <li>2) Service assessment</li> <li>3) Learning assessment</li> <li>4) Self-assessment</li> <li>5) Celebration</li> </ol>	<ol style="list-style-type: none"> <li>1) Assessment tasks: Focus group, Interviews, Questionnaire Pre-Post, Discussion</li> </ol>	<ol style="list-style-type: none"> <li>1) Competency post-test questionnaires results</li> <li>2) Results of the final evaluation by teachers, students and community partners</li> <li>3) Students participation level in tasks</li> <li>4) Annotations and reflection in the field diary</li> <li>5) Personal portfolio contents</li> <li>6) Individual perceptions of the compliance degree with the objectives</li> </ol>	<ol style="list-style-type: none"> <li>1) Results of the focus groups and the collective reflection on the compliance degree with the expectations and the proposed goals</li> <li>2) Materials generated for the project</li> <li>3) Materials generated for the project dissemination</li> <li>4) Service assessment and social objectives achievement</li> <li>5) Academic learning assessment</li> </ol>	<ol style="list-style-type: none"> <li>1) Field diary</li> <li>2) Satisfactions questionnaire by teachers, students and community partners</li> <li>3) Competence Post-test</li> <li>4) Experience report with answers to questions</li> <li>5) Portfolio</li> <li>6) Directed debates</li> </ol>

**Table A4.** Execution Phases of Case Study (CS) Strategy.

Execution Phases of the Case Study Strategy	Teaching Strategies		Learning Strategies		Assessment Strategies	
	Techniques/Individual or Group Activities	Learning Activities	Individual Competence Evidences	Group Competence Evidences	Assessment Instruments	
Phase 1: Training	1) Previous ideas questionnaire on strategy and socio-environmental problems 2) Choice by the group of theme and socio-environmental problems 3) Search, choose, adaptat and construct of the CS	1) Identify, analyse and pool emerging socio-environmental issues 2) Choose problem 3) Identify previous ideas and conceptions			1) Initial questionnaire	
Phase 2: Execution	1) Read and gather articles about didactic use of the CS 2) Analyse ideas and concepts based on the ideas raised in the questionnaire 3) Generate an atmosphere of trust and communication 4) Presentation: what is CS and the didactic applications associated? 5) Present problematic questions or analysis plot of the case study 6) Work with the case studies from what it has been done individually	1) Transfer and reconstruct knowledge 2) Group members knowledge 3) Identify problems, describe situations and analyse 4) Share analysis, summarize and propose solutions	1) To connect with personal, professional and existential contradictions 2) To be aware of complexity, interdependence and difficulties 3) Learning for personal and professional life	1) Creation of collective Knowledge 2) Social and communication skills	1) Teacher's field diary	
Phase 3: Assessment	1) Develop a report regarding the issues raised and do a presentation in class	1) Assess and analyse cognitive, procedural and attitudinal processes 2) Apply to other life learning situations	1) Awareness about the complexity and interdependence of socio-environmental realities 2) Provide tools for new learning processes to be developed in others contexts	1) Cooperative and collaborative learning 2) Social and communication skills 3) Awareness about the relevance of the collective in thoughts and actions	1) Teacher's field diary 2) Pooling evaluation by the group 3) Final questionnaire	

**Table A5.** Execution Phases of Simulation Strategy.

Execution Phases of the Simulation Strategy	Teaching Strategies	Learning Strategies	Assessment Strategies		
	Techniques/Individual or Group Activities	Learning Activities	Individual Competence Evidences	Group Competence Evidences	Assessment Instruments
Phase 1: Training	<ol style="list-style-type: none"> <li>1) Previous ideas questionnaire on strategy and socio-environmental problems</li> <li>2) Choice by the group of theme and socio-environmental problems</li> <li>3) Search, choose, adapt and construct the Simulation Game</li> </ol>	<ol style="list-style-type: none"> <li>1) Identify, analyse and pool emerging socio-environmental issues</li> <li>2) Choose problem</li> <li>3) Identify previous ideas and conceptions</li> </ol>	<ol style="list-style-type: none"> <li>1) Learning from doing and connect learning with everyday life</li> <li>2) Learning for personal and professional life</li> </ol>		<ol style="list-style-type: none"> <li>1) Initial questionnaire</li> </ol>
Phase 2: Execution	<ol style="list-style-type: none"> <li>1) Read and pool articles</li> <li>2) Analyse ideas and concepts</li> <li>3) Present the simulation game and its didactics' applications</li> <li>4) Present educational and historical reality, and context</li> <li>5) Distribute roles</li> <li>6) Develop the activity:               <ol style="list-style-type: none"> <li>a) Provide information and build arguments</li> <li>b) Identify the conflict</li> <li>c) Re-argumentation</li> <li>d) Intergroup bargaining</li> <li>e) Search for agreements</li> </ol> </li> </ol>	<ol style="list-style-type: none"> <li>1) Transfer and reconstruct knowledge</li> <li>2) Group members knowledge</li> <li>3) Experiential representation of roles, situations and conflicts</li> <li>4) Conflict steering</li> <li>5) Assess and analyse cognitive, procedural and attitudinal processes</li> </ol>	<ol style="list-style-type: none"> <li>1) To connect with personal, professional and existential contradictions</li> <li>2) To be aware of complexity, interdependence and difficulties</li> </ol>	<ol style="list-style-type: none"> <li>1) Development of strategies to deal with learning in conflict situations</li> <li>2) Knowledge creation collective</li> <li>3) Social and communication skills</li> <li>4) Cooperative and collaborative learning</li> </ol>	<ol style="list-style-type: none"> <li>1) Teacher's field diary</li> <li>2) Observers contributions</li> </ol>
Phase 3: Assessment	<ol style="list-style-type: none"> <li>1) Heteroevaluation mechanisms:               <ol style="list-style-type: none"> <li>a) What have the students observed?</li> <li>b) How have we felt?</li> </ol> </li> <li>c) What other role would you have wanted to play?</li> <li>d) What would it have been like, playing in that other role, and how would you have stand up for it?</li> <li>e) What have we learned from the dynamic?</li> <li>f) How do we assess what we have done?</li> <li>g) What attracts our attention?</li> </ol>	<ol style="list-style-type: none"> <li>1) Disseminate learning</li> <li>2) Cooperative and collaborative learning</li> <li>3) Application to other life learning situations</li> </ol>	<ol style="list-style-type: none"> <li>1) Provide tools for new learning processes to be developed in others contexts</li> </ol>	<ol style="list-style-type: none"> <li>1) Awareness about the relevance of the collective in thoughts and actions</li> </ol>	<ol style="list-style-type: none"> <li>1) Teacher's field diary</li> <li>2) Pooling evaluation by the group</li> <li>3) Delivery of the group report</li> <li>4) Final questionnaire</li> </ol>

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